

Research Problem Review 78-13

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# TANK GUNNERY ANALYSIS FOR DEVELOPING A TANK CREW TRAINING DATA BASE

William K. Earl,  
Operations Research Associates

FORT HOOD FIELD UNIT

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Field Assessment

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(6) TANK GUNNERY ANALYSIS FOR DEVELOPING  
A TANK CREW TRAINING DATA BASE

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ARI FIELD UNIT AT FORT HOOD, TEXAS

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(11) August 1978

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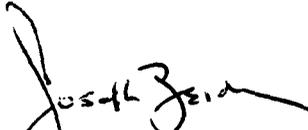
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FOREWORD

This report was prepared by the Fort Hood Field Unit of the U.S. Army Research Institute for the Behavioral and Social Sciences (ARI) in response to a request through the Training Developments Branch of the Operations and Plans Division, HQ TRADOC Combined Arms Test Activity (TCATA). Some of the research was accomplished by Operations Research Associates, under Contract DAHC 19-75-C-0017. The purpose was to provide a detailed tank crew training data base to be used in the Department of Defense net assessment study of U.S. and Soviet tank crew training. This report was incorporated as Chapter 9 of Annex A of the report "Net Assessment of U.S. and Soviet Tank Crew Training." The findings were immediately utilized by TRADOC to revise and improve the Army's Tank Gunnery Qualification Test.

  
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## TANK GUNNERY ANALYSIS FOR DEVELOPING A TANK CREW TRAINING DATA BASE

### BRIEF

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#### Requirement:

This report was prepared in response to a request by the Training Developments Branch of the Operations and Plans Division, HQ MASSTER, Fort Hood, Texas. The research was designed to fulfill a requirement for the collection, analysis, and reporting of tank crew gunnery score data. The research was required as input for a Department of Defense net assessment study of U. S. and Soviet tank crew training. The objectives were: (1) to provide a tank crew training data base consisting of data from at least ten tank battalions and, (2) an analysis of this data base which would permit the identification of some of the variables affecting gunnery performance.

#### Procedure:

Table VIII gunnery data were collected from fifteen tank battalions in the U. S. Army: eight from USAREUR and seven from CONUS. Main gunnery scores were analyzed for both day and night firings measuring number of hits and firing times required.

#### Principal Findings:

- o Table VIII data from the sample USAREUR battalions appears to be more valid and reliable than data from CONUS battalions.
- o Both USAREUR and CONUS tank crews fire more accurately at middle ranges of from approximately 1000-1800 meters. First round accuracy at the short ranges from 600-1000 meters is relatively poor.
- o There was no practical difference in main gun accuracy performance between Table VIII A (day) and Table VIII B (night).
- o There is no difference in first round accuracy between precision and battlesight engagement methods in the battlesight range band (600-1800 meters).
- o There is little difference in first round accuracy and firing time when engaging either stationary or moving targets.
- o There is not a strong linear correlation between first round accuracy and firing time.

**Utilization of Findings:**

This report has been incorporated by TRADOC, as a entity, into the report "Net Assessment of U. S. and Soviet Tank Crew Training" for use by the Director of Net Assessment, Department of Defense. The findings are being used by TRADOC to revise and improve the Army's Tank Gunnery Qualification Test. The aim is to increase cost effectiveness by improving gunnery proficiency and reducing operating costs and ammunition expenditures.

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\*This report was included as Chapter 9 of Annex A of the TRADOC report, Net Assessment of U.S. and Soviet Tank Crew Training. Sections, figures, tables and pages were, therefore, numbered as they would appear in this report.

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## TANK GUNNERY ANALYSIS

### \*9-1. Introduction.

a. Data from the Table VIII gunnery qualification score cards were used for analyzing gunnery performance. The analysis was limited to main gun performance using two performance measures; first round accuracy scores (called hit probabilities) and first round firing times. Hit probabilities are Hit-Miss scores for each round transformed into a proportion or percentage assigning 1 (or 100) to a hit and zero to a miss. Firing times are measures of elapsed time, in seconds, from when the tank crew examiner (TCE) or assistant instructor (AI) started each trial to when the first round was fired.

b. The sample is comprised of data collected from 15 tank battalions; eight battalions from USAREUR and seven from CONUS. The various battalions fired from four to six main gun engagements on both Table VIII A and B. The total number of first rounds in the sample amounted to approximately 6,000; 3,000 for the USAREUR battalions, and 3,000 for the CONUS battalions.

c. Chapter Organization. This chapter is organized into three main sections. The first section presents a general description of the gunnery performance of the USAREUR and CONUS battalions when treated as two different groups. Data from the individual battalions were pooled together to create the two larger groups. The second section consists of three parts. The first part presents separate analyses of each of the fifteen battalions. The second part integrates the results from the individual battalions. The third part provides a longitudinal study of the gunnery performance of one battalion over one year's time. The third section presents an analysis of differences in gunnery performance between battalions serving in the same division. The analysis included comparisons of battalions assigned to three different divisions.

### 9-2. General Description of USAREUR and CONUS Tank Crews Performance.

a. In organizing the data for a general analysis, it was found that the target engagement conditions under which the battalions were tested differed mainly in terms of whether they were located in USAREUR or in CONUS. The engagement conditions of USAREUR battalions were quite similar among themselves, but differed in several respects from the engagement condition of CONUS battalions. The same relation was true for the CONUS battalions. In addition, it was found that the accuracy measures of the two groups differed considerably. Since the measures of the two groups were quite different, it was decided to keep them separate in all analyses because merging the measures would tend to obscure the real differences and produce statistics which would

\*This report was prepared to be incorporated as Chapter 9 of Annex A of the TRADOC report Net Assessment of U.S. and Soviet Tank Crew Training. Therefore, pages, tables and figures were numbered as they would appear in the TRADOC report, e.g., the first section (Introduction) of this report was designated as 9-1 instead of 1.

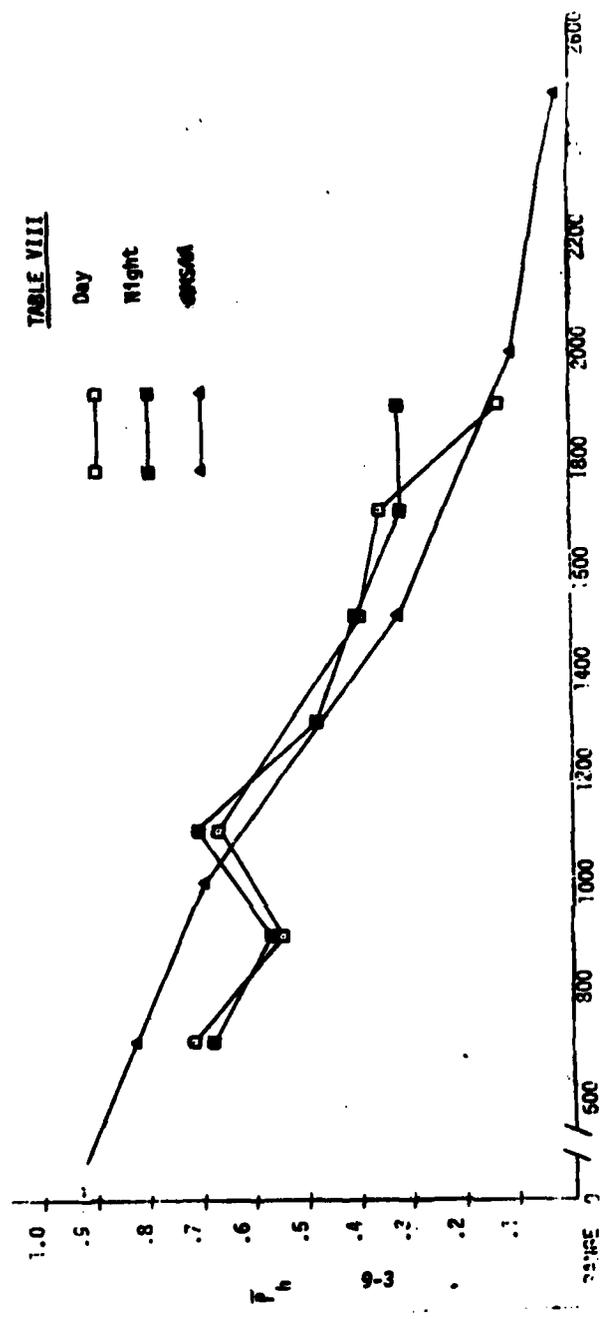
present a misleading interpretation of the underlying dichotomy. Furthermore, the general analysis was restricted to include data from engagements using high velocity tank killing ammunition; HEAT, TP-T, APDS, and TPDS-T. Because of the different ballistic characteristics of HEP ammo and because the primary interest is in tank killing capability, data from HEP engagements were not included.

b. Overall Description. The overall description consists of two graphs of mean hit probabilities presented in figures 9-1 and 9-2. The data from which the means were calculated, the means themselves, and the standard error of the means (SEM) are listed in the accompanying tables, tables 9-1 and 9-2. An overall description of firing time data is not included because it is not influenced by the range factor in the same way as accuracy is. The mean values computed for all ranges were calculated by dividing range into 200 meter intervals; 0-199, 200-399, etc. The data from all engagements with ranges that fell within an interval were pooled and summed. Statistics were calculated from the pooled data for that interval. The statistical value was then plotted at the midpoint of the range interval; at 700 for the 600-799 interval, 900 for the 800-999 interval, etc. Included in figures 9-1 and 9-2 is one of the AMSAA curves. It provides a well known general frame of reference for judging the relative performance levels of the gunnery qualification curves.

(1) Figure 9-1 presents overall mean hit probability performance of the USAREUR tank crews on all types of engagements as a function of target range. The curves show the following relations. One, there is no difference in mean hit probability ( $\bar{P}_h$ ) performance between Tables VIII A (Day) and B (Night). Table 9-1 specifies that the overall  $\bar{P}_h$  for Tables VIII A and B were .50 and .51, respectively. Two, in the range from 1000 to 2000 meters, the performance curves closely follow the AMSAA curve at values that are somewhat higher than the AMSAA values. A z-test for significance of a proportion was run on the data from Tables VIII A and B to test for differences between the USAREUR and AMSAA  $\bar{P}_h$  values. The results, presented in table 9-3, indicate that the day and night  $\bar{P}_h$  values for the 600-799 and 800-999 range intervals were significantly less than the AMSAA values; z-day (600-799)=2.54,  $p < .05$ , z-night (600-799)=2.33,  $p < .05$ , and z-day (800-899)=8.94,  $p < .001$ , and z-night (800-999)=8.25,  $p < .001$ . The day  $\bar{P}_h$  values for the 1000-1199, 1400-1599 and 1600-1799 range intervals were found to be significantly greater than the AMSAA values, while there was no statistically significant difference in  $\bar{P}_h$  values at the 1800-1999 meter interval. The night  $\bar{P}_h$  values for the 1000-1199, 1600-1799, and 1800-1999 meter intervals were significantly greater than the AMSAA values, while there was no significant difference in  $\bar{P}_h$  values at the 1200-1399 and 1400-1599 meter intervals. Generally speaking, the results indicate that the combined day and night accuracy performance for USAREUR tank crews was less, by about 15 percent, than the AMSAA curve at the short ranges from 600-1000 meters, and somewhat better than the AMSAA curve at ranges from 1000-1800 meters, by about 5 to 10 percent.

**TABLE VIII**

Day  
Night  
Overall



**Figure 9-1 Overall First Round Mean Hit Probabilities ( $P_h$ ) of USAREUR Tank Crews on Table VIII & 9-3**

TABLE 9-1

Overall First Round Mean Hit Probability ( $\bar{P}_h$ ) Performance of USMCUR Tank Crews Firing TPDS, HEAT, and TPT Ammunition on Moving and Stationary Targets using Precision and Battlesight Engagement Methods.

TARGET RANGE BAND	TABLE VIII A (Day)				TABLE VIII B (Night)			
	No. Hits	No. Misses	Total Rounds	$\bar{P}_h$ S.E.M.	No. Hits	No. Misses	Total Rounds	S.E.M.
600-799	44	17	61	.72 .09	23	11	34	.12
800-999	185	162	347	.53 .04	259	194	453	.03
1000-1199	218	112	330	.66 .04	148	61	209	.05
1200-1399					38	42	80	.08
1400-1599	82	125	207	.40 .05	35	48	83	.08
1600-1799	51	91	142	.36 .06	88	199	287	.04
1800-1999	13	86	99	.13 .06	10	21	31	.12
TOTAL	593	593	1186	.50 .02	601	576	1177	.02

TABLE VIII:

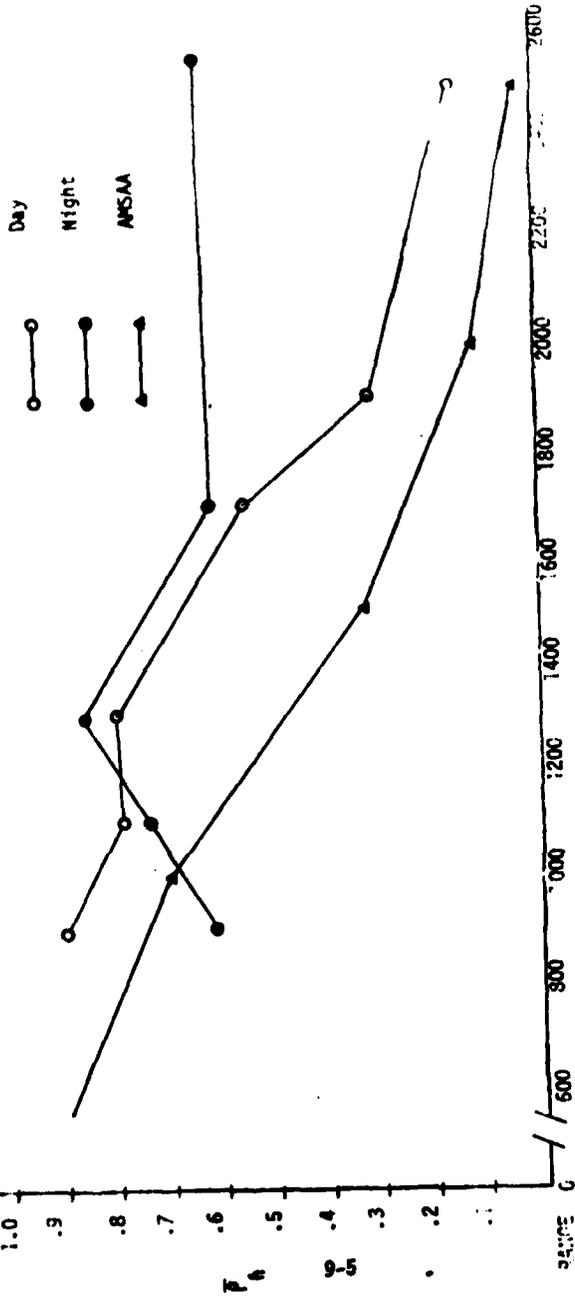


Figure 9-2 Overall First Round Mean Hit Probabilities ( $P_h$ ) of CONUS Tank Crews on Table VIII A etc.

TABLE 9-2

Overall Mean Hit Probability ( $\bar{P}_h$ ) performance of COMUS Tank Crews Firing TPDS, HEAT, and IPT Ammunition on Moving and Stationary Targets Using Precision and Battlesight Engagement Methods.

TARGET RANGE BAND	Table VIII A (Day)				Table VIII B (Night)			
	No. Hits	No. Misses	Total Rounds	$\bar{P}_h$ S.E.M.	No. Hits	No. Misses	Total Rounds	S.E.M.
600-799	45	5	50	.90 .06	119	75	194	.05
800-999	118	32	150	.79 .05	145	52	197	.05
1000-1199	121	30	151	.80 .05	131	22	153	.05
1200-1399								
1400-1599								
1600-1799	223	180	403	.55 .04	217	137	354	.04
1800-1999	32	67	99	.32 .07				
2500	25	128	153	.16 .05	98	55	153	.06
TOTAL	544	442	1006	.54 .02	710	341	1051	.02

TABLE 9-3

## Z TEST FOR SIGNIFICANCE OF A PROPORTION

	Range Interval Midpoint						
	700	900	1100	1300	1500	1700	1900
ANSAA $\bar{P}_h$	.83	.74	.61	.47	.33	.24	.14
USAREUR $\bar{P}_h$							
Table VIII A	.72	.53	.66	—	.40	.36	.13
Total Hits	44	185	218	—	82	51	13
Total Rounds	61	347	330	—	207	142	99
Z Score	2.54	8.94	1.99	—	2.14	3.34	0.29
p	<.05	<.001	<.05	—	<.05	<.01	N.S.
USAREUR $\bar{P}_h$							
Table VIII B	.68	.57	.71	.48	.42	.31	.32
Total Hits	23	259	148	38	35	88	10
Total Rounds	34	453	209	80	83	287	31
Z Score	2.33	8.25	2.96	0.18	1.88	2.78	2.89
p	<.05	<.001	<.01	N.S.	N.S.	<.01	<.01

(2) Figure 9-2 presents overall  $\bar{P}_h$  performance of the CONUS tank crews on all types of engagements as a function of target range. The curves show the following relations. One, both curves present  $\bar{P}_h$  values across almost all ranges that are much higher than the AMSAA curve. Two, the Table VIII B (night) curve presents a  $\bar{P}_h$  value of .64 at the 2500 meter range (see table 9-2) which can only be considered as unrealistically high and which calls into doubt the reliability and validity of CONUS target sensing and scoring standards. Three, the difference in  $\bar{P}_h$  performance between the Table VIII A and B curves appear at the extremes. Day performance seems to be better than night performance at the 800-999 meter interval while night performance is superior to day performance at 2500 meters. There is no practical difference between  $\bar{P}_h$  values at the ranges from 1000 to 1800 meters. Four, both curves show optimum performance at the 1200-1399, and 1600-1799 meter range intervals indicating that the CONUS tank crews probably do their best shooting at the middle ranges from 1200 to 1800 meters.

c. The Effects of Engagement Variables on Accuracy and Firing Time. This section presents a description of how combinations of different engagement variables influenced the gunnery performance of the sample tank crews. The description of their effects on accuracy performance will be presented first, followed by the description of their effects on firing time.

(1) The Effects of Engagement Variables on First Round Accuracy. Before the descriptions are presented, it must be noted that the engagement conditions of the USAREUR and CONUS battalions differed in their specifics for many of the engagements. These differences are due, presumably, to differences in range facilities, ammo availability, and emphasis on different types of engagements. There were two engagement conditions that were similar. They involved precision and battlesight engagements firing HEAT ammo at stationary targets. The other engagement conditions varied on one factor or another.

(a) Precision Versus Battlesight Engagement Methods. Figure 9-3 and figure 9-4 presents the USAREUR and CONUS  $\bar{P}_h$  curves for precision and battlesight engagements firing HEAT ammo at stationary targets on Table VIII A (Day). Comparing the precision and battlesight curves with one another on both graphs shows no practical difference in first round mean hit probability performance between engagement methods. The battlesight method is as accurate as the precision method over the ranges for the battlesight engagements, 600 to 1800 meters. Figures 9-5 and 9-6 present the same engagement conditions for Table VIII B (night). Figure 9-5, which appears to describe the more valid functions shows that first round mean hit performance is almost identical at the 1000 to 1199 meter range interval; .71 for precision and .70 for battlesight (see table 9-6), and substantially better for battlesight at the 1200 to 1300 meter interval. Again there are no consistent differences in first round mean hit probabilities between engagement methods.

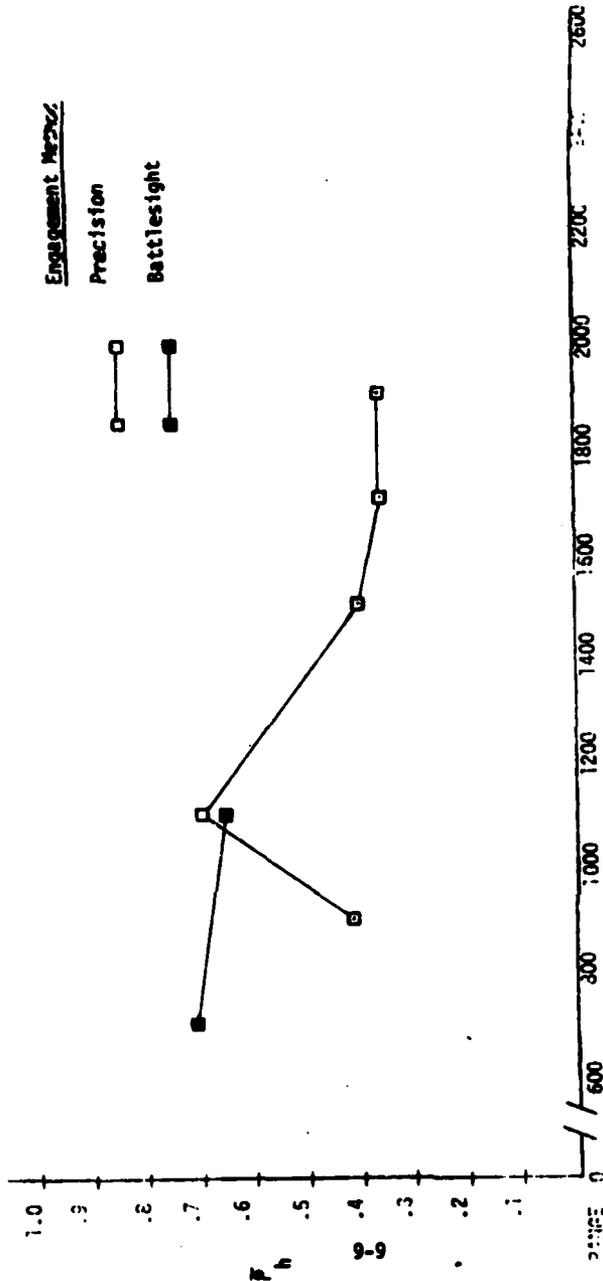


Figure 9-3 First Round Mean Hit Probabilities ( $P_h$ ) of ISAREUR Tank Crews on Table VIII A (Day). Engagement Method: Precision and Battlesight; Target Motion: Stationary; Ammo: HEAT

TABLE 9-4  
 First Round  $\bar{P}_h$  Measures  
 USABEIR Tank Crews  
 TABLE VIII A (Day)

TARGET RANGE BAND	Precision Engagement, HEAT Ammo Stationary Targets					Battlesight Engagement, HEAT Ammo Stationary Targets				
	No.		Total Rounds	$\bar{P}_h$	S.E.M.	No.		Total Rounds	$\bar{P}_h$	S.E.M.
	Hits	Misses				Hits	Misses			
600-799	41	57	98	.42	.07	44	17	61	.72	.09
800-999	90	38	128	.70	.06	99	52	151	.65	.06
1000-1199	82	125	207	.40	.05					
1200-1399	51	91	142	.36	.06					
1400-1599	13	86	99	.36	.07					
1600-1799										
1800-1999										
TOTAL										

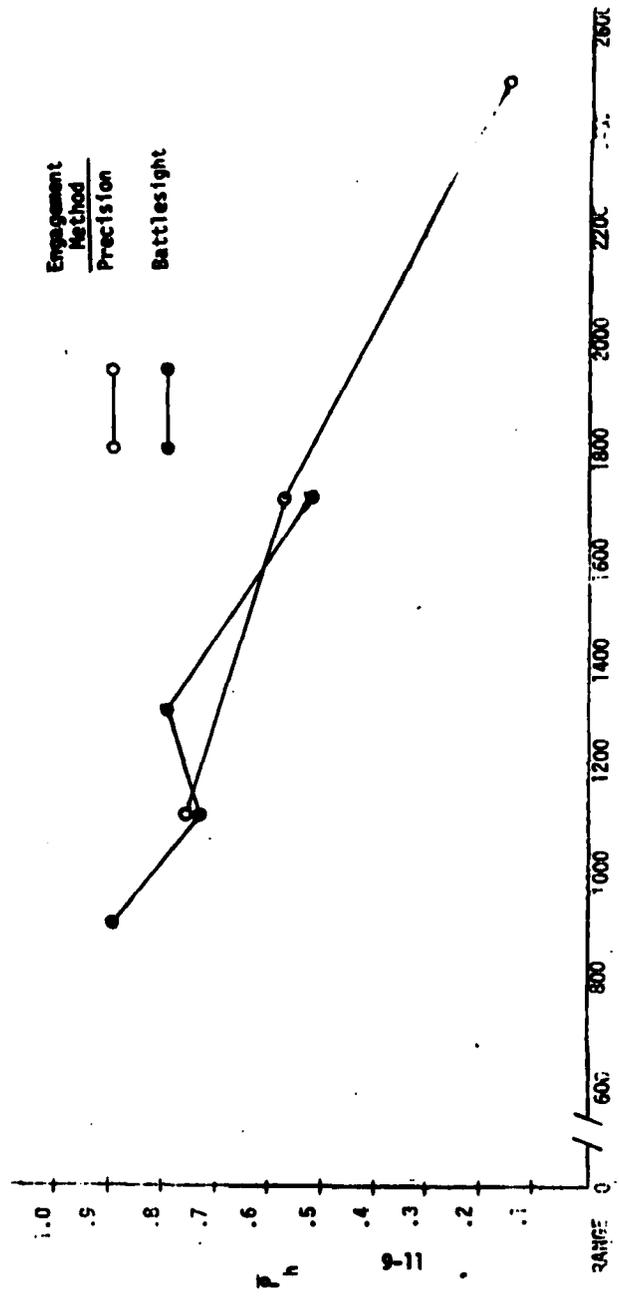


Figure 9-4 First Round Mean Hit Probabilities ( $P_h$ ) of CONUS Tank Crews on Table VIII A (Day). Engagement Method: Precision and Battlesight; Target Motion: Stationary; Ammo: HEAT

TABLE 9-5

First Round  $P_h$  Measures  
COMUS Tank Crews  
TABLE VIII A (Day)

TARGET RANGE BAND	Precision Engagement, HEAT Ammo				Battlesight Engagement, HEAT Ammo					
	Stationary Targets		Total		Stationary Targets		Total			
	No. Hits	No. Misses	Total Rounds	$P_h$	S.E.M.	No. Hits	No. Misses	Total Rounds	$P_h$	S.E.M.
600-799						45	5	50	.30	.08
800-999						37	13	50	.74	.09
1000-1199	38	12	50	.76	.09	121	30	151	.30	.05
1200-1399										
1400-1599										
1600-1799	85	65	150	.57	.06	27	24	51	.33	.10
1800-1999										
2500	25	128	153	.16	.05					
TOTAL										

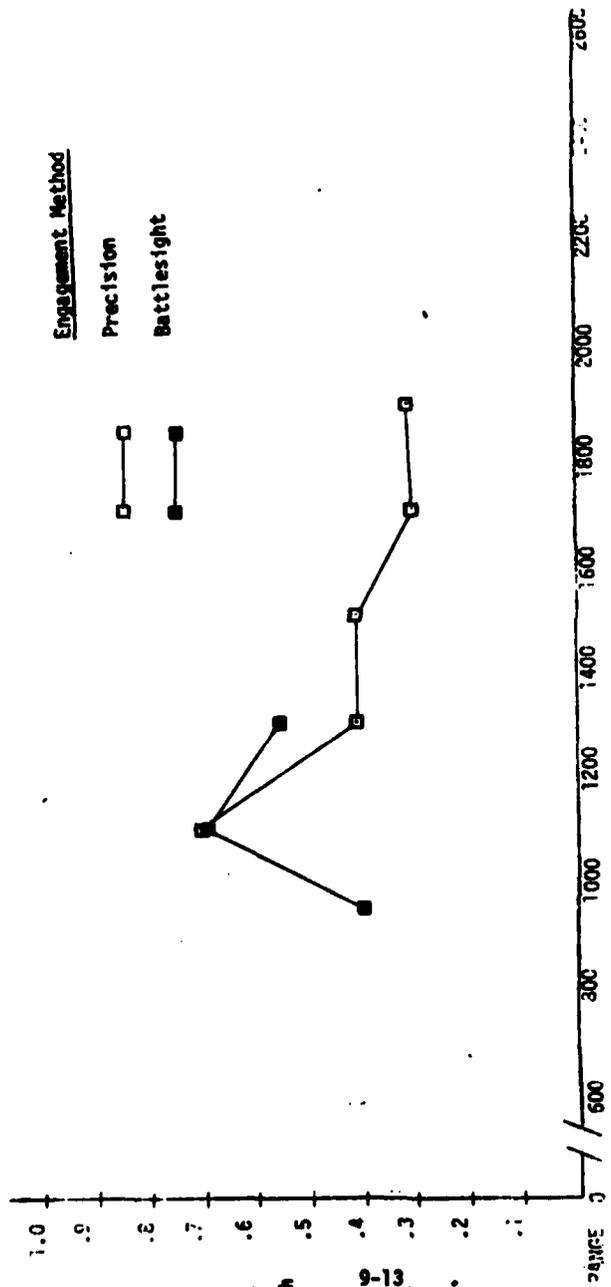


Figure 9-5 First Round Mean Hit Probabilities ( $P_h$ ) of USAREUR Tank Crews on Table VIII 8 (right). Engagement Method: Precision and Battlesight; Target Motion: Stationary; Ammo: HEAT



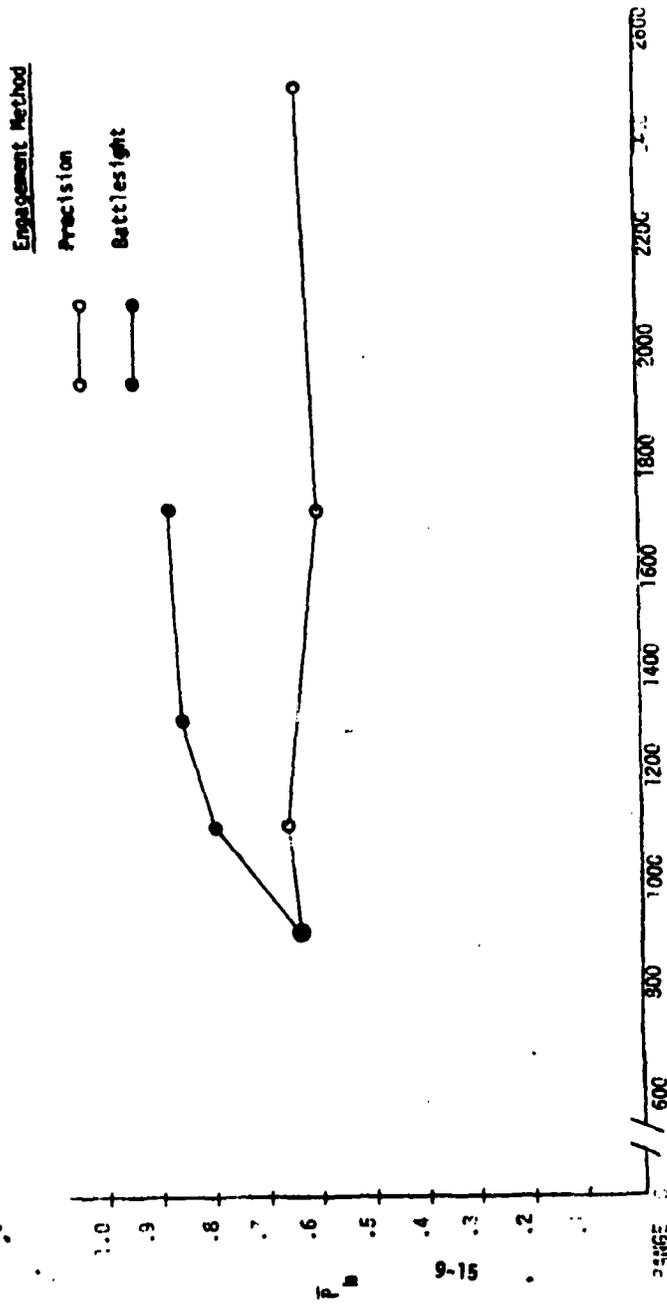


Figure 9-6 First Round Mean Hit Probabilities ( $P_h$ ) of COMUS Tank Crews on Table VIII B (Mfight). Engagement Method: Precision and Battlesight; Target Motion: Stationary; Ammo: HEAT

TABLE 9-7  
 First Round  $\bar{P}_h$  Measures  
 COMUS Tank Crews  
 TABLE VIII B (Night)

TARGET RANGE BAND	Precision Engagement, HEAT Ammo Stationary Targets				Battlesight Engagement, HEAT Ammo Stationary Targets			
	No. Hits	No. Misses	Total Rounds	$\bar{P}_h$ S.E.M.	No. Hits	No. Misses	Total Rounds	$\bar{P}_h$ S.E.M.
	600-799	30	17	47	.64 .10	62	35	97
800-999	33	17	50	.66 .10	40	10	50	.80 .09
1000-1199					131	22	153	.86 .05
1200-1399								
1400-1599								
1600-1799	60	40	100	.60 .07	45	6	51	.88 .08
1800-1999								
2500	98	55	153	.64 .06				
TOTAL								

(b) Figure 9-6 is interesting in that it describes flat slopes for the  $\bar{P}_h$  functions across range, indicating that  $\bar{P}_h$  is independent of the influence of range. It is difficult to believe that these curves describe the true performance parameters of CONUS battalions on Table VIII B.

(c) Moving Versus Stationary Targets. Figures 9-7 and 9-8 present the CONUS  $\bar{P}_h$  curves for engaging stationary and moving targets on Table VIII A (Day) and B (Night), respectively. The results are similar to the previous comparisons. The plots show no consistent difference in first round mean hit probability between precision engagements against stationary and moving targets. Figure 9-9 presents the plots of USAREUR tank crews engaging moving targets with battlesights and firing TPDS-T ammo. During the day, their  $\bar{P}_h$  values at the 600-799 and 800-999 meter range intervals were .58 and .57 respectively (see table 9-10). The closest comparison that can be made is to compare the above values with those in figure 9-3, table 9-4, where stationary targets were engaged with the battlesight method and HEAT was the ammo. The  $\bar{P}_h$  values for these conditions were .72 for the 600-799 meter interval and .65 for the 1000-1199 meter interval. These results indicate that performance against the stationary targets was considerably better, but there is no way to determine what effect the different types of ammo contributed to the difference. Comparing the Table VIII B scores in figure 9-9, table 9-10, with the battlesight curve in figure 9-5, suffers from the same problem in that the ammo is different. On the one range interval shared by both curves, the 800-999 meter interval  $\bar{P}_h$  on the moving target was .69 (see table 9-10), while the value for the stationary target was .41 (see table 9-6), a reversal from the previous Table VIII A comparison. It suffices to say that these comparisons are confounded, inconsistent, and show no definite trends. Taken as a whole, the CONUS and USAREUR data indicate that target motion had negligible effect on first round mean accuracy performance.

(2) The Effects of Engagement Variables on First Round Firing Time. The firing time statistics presented in this section consist of means and standard deviations presented in tables which accompany the figures. The statistics were derived in the same manner as the previous  $\bar{P}_h$  values were; by pooling the data within the 200 meter range intervals and calculating the statistics from the pooled data. The figures in this section present plots of the first round mean firing times over range, although it will be found that range has only minimum influence on firing time. Nevertheless, some understanding of functional relationships can be derived from plots of the means that describe the general nature of the relation between firing time and various engagement factors. Graphs of these functions are presented in the following paragraphs.

a. The Effects of Target Range, Time of Day, and Engagement Method. Figures 9-10 and 9-11 present plots of mean firing time for precision and battlesight engagements on Table VIII A (Day) and B (Night) for USAREUR and CONUS tank crews, respectively. Examination of the plots reveal that if

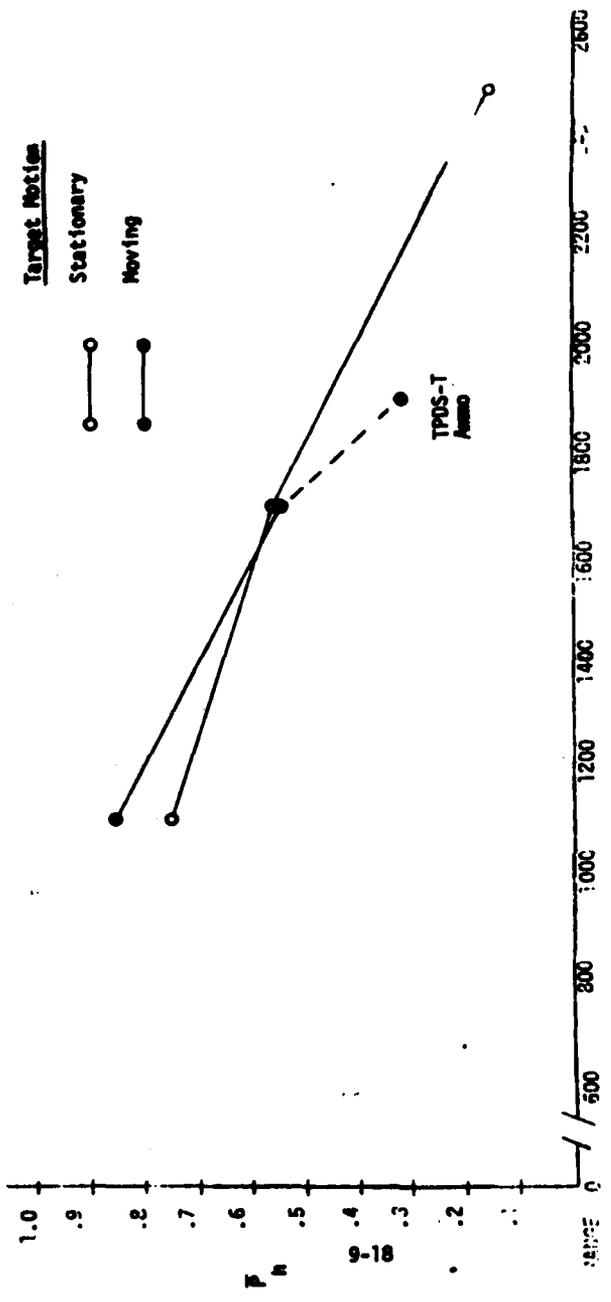


Figure 9-7 First Round Mean Hit Probabilities ( $P_h$ ) of COMUS Tank Crews on Table VIII A (Day). Target Motion: Stationary and Moving; Engagement Method: Precision; Ammo: HEAT. Included is one target at which TPDS-T was fired.



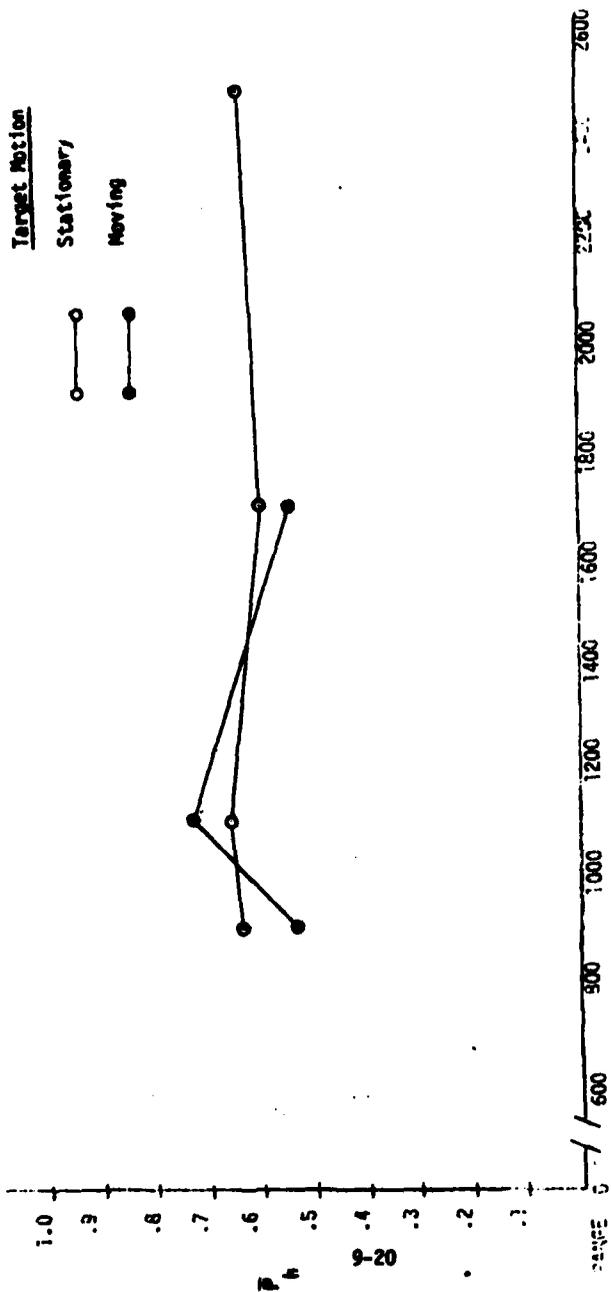
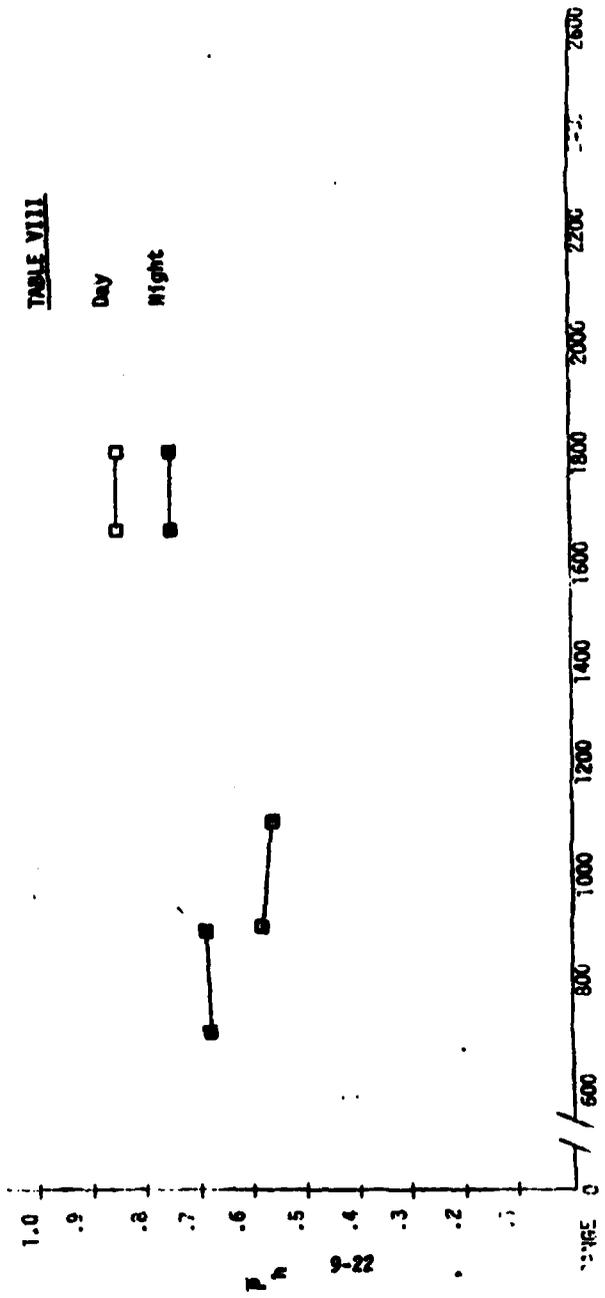


Figure 9-8 First Round Mean Hit Probabilities ( $P_h$ ) of CONUS Tank Crews on Table VIII B (right). Engagement Method: Precision; Target Motion: Stationary and Moving; Ammo: HEAT



**TABLE VIII**



**Figure 9-9** First Round Mean Hit Probabilities ( $P_h$ ) of USMCUR Tank Crews on Table VIII A (Day) and 3 (Night).  
Engagement Method: Battlesights; Target Motion: Moving; Ammo: TPDS-T



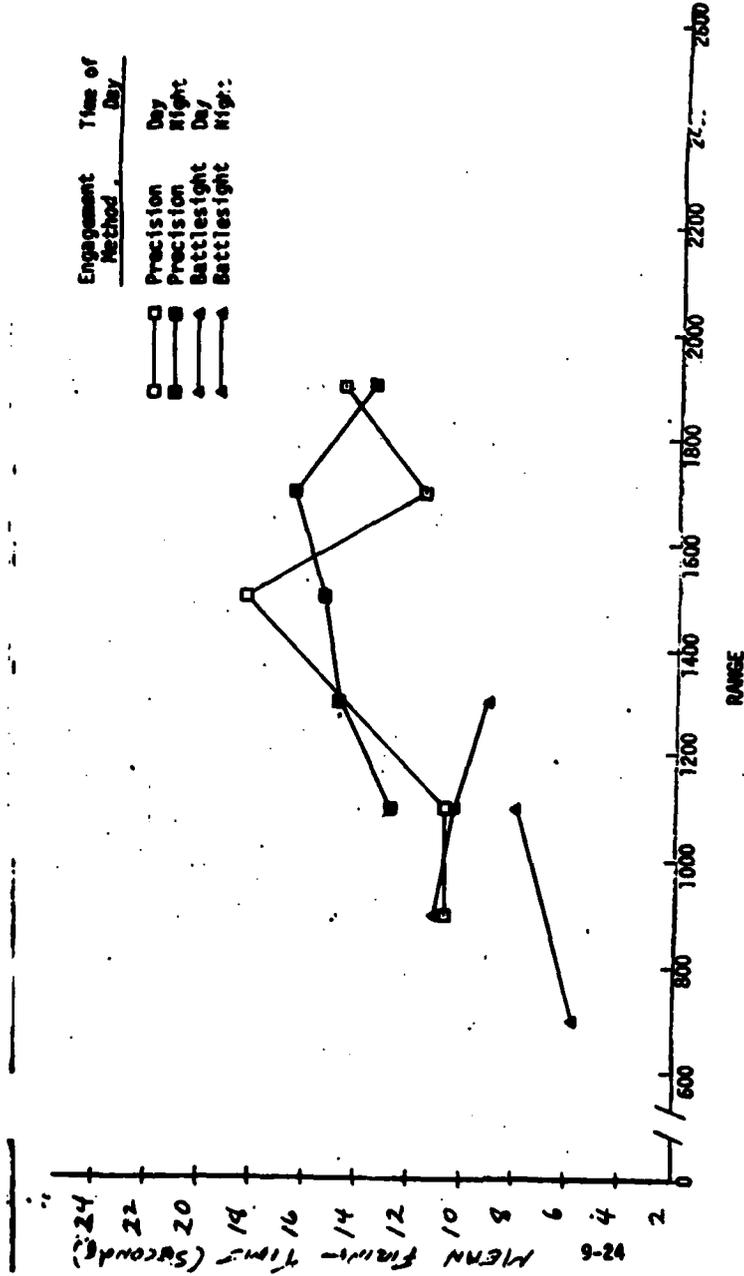


Figure 9-10 First Round Mean Firing Time of USAREUR Tank Crews on Table VIII A (Day) and B (Night). Engagement Method: Precision and Battlesight; Target Motion: Stationary, Ammo: HEAT

TABLE 9-11A  
 First Round Mean Firing Time  
 USAREUR Tank Crews  
 Table VIII A (Day) and B (Night)

TARGET RANGE BAND	Table VIII A (Day)			Table VIII B (Night)		
	Engagement Method: Precision; Target Motion: Stationary; Ammo: HEAT		TOTAL ROUNDS	Engagement Method: Precision; Target Motion: Stationary; Ammo: HEAT		TOTAL ROUNDS
	MEAN FIRING TIME (SECONDS)	S.D.		MEAN FIRING TIME (SECONDS)	S.D.	
600-799	(G) 10.83	9.69	99	(G) 12.89	4.67	102
800-999	(G) 10.82	3.64	102	(G) 14.90	6.43	48
1000-1199	(TC) 18.35	4.86	216	(TC) 15.45	6.62	81
1200-1399	(TC) 11.46	10.95	78	(TC) 16.48	5.60	222
1400-1599	(TC) 14.66	7.01	102	(TC) 13.60	4.91	30
1600-1799						
1800-1999						
2500						
TOTAL	14.29	7.74	597	15.39	5.53	513
OVERALL MEAN						

TABLE 9-11B

First Round Mean Firing Time  
USAMRIID Tank Crews  
Table VIII A (Day) and B (Night)

TARGET RANGE BAND	Table VIII A (Day)				Table VIII B (Night)			
	Engagement Method: Battlesight; Target Motion: Stationary; Ammo: HEAT		Engagement Method: Battlesight; Target Motion: Stationary; Ammo: HEAT		Engagement Method: Battlesight; Target Motion: Stationary; Ammo: HEAT		Engagement Method: Battlesight; Target Motion: Stationary; Ammo: HEAT	
	MEAN FIRING TIME (SECONDS)	S.D.	TOTAL ROUNDS	TOTAL ROUNDS	MEAN FIRING TIME (SECONDS)	S.D.	TOTAL ROUNDS	TOTAL ROUNDS
600-799	5.97	4.28	42		11.16	6.80	22	
800-999								
1000-1199	8.09	3.59	132		10.41	2.64	59	
1200-1399								
1400-1599					9.10	6.07	32	
1600-1799								
1800-1999								
2500								
TOTAL				174				237
OVERALL MEAN	7.58	3.86			10.78	6.03		

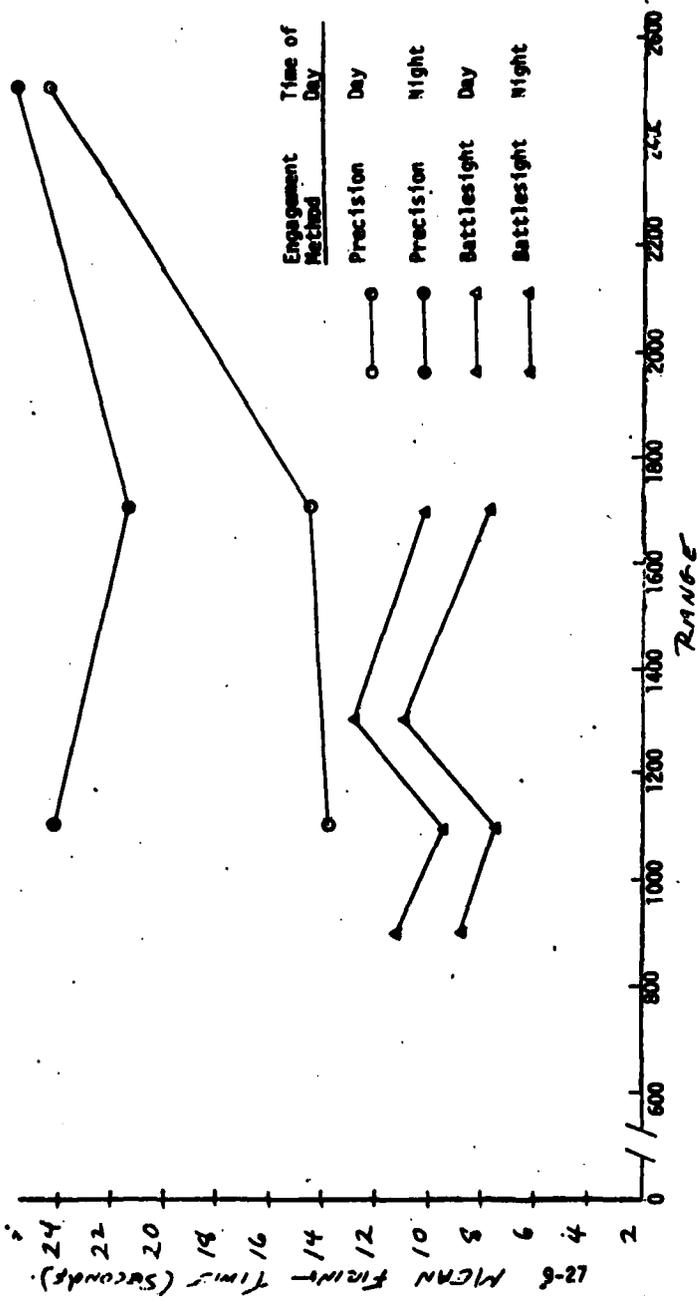


Figure 9-11 First Round Mean Firing Time of COMUS Tank Crews on Table VIII A (Day) and B (Night).  
 Engagement Method: Precision and Battlesight; Target Motion: Stationary; Ammo: HEF.





smoothed out, the slopes of the curves would be fairly close to the horizontal, although they would be positively angled to some extent. This relationship indicates that the factor of range has much less influence on firing time than it has on accuracy performance.

(1) Day/Night influences firing time in the expected direction. Overall mean firing times for precision and battlesight targets were generally faster during the day than during the night. Tables 9-11A and B and 9-12A and B indicate that the magnitude of the increase was about 1 to 5 seconds for precision engagements and from 2.0 to 2.5 seconds for battlesight engagements.

(2) Engagement method appears to have considerable effect on firing time. Mean firing times for battlesight engagements were much faster than for precision engagements. Tables 9-11B and 9-12B denote that overall mean firing times for USAREUR and CONUS tank crews on Table VIII A battlesight engagements were 7.58 and 9.49, respectively, while their corresponding values for precision engagements in tables 9-11A and 9-12A were 14.29 and 18.97 seconds. The overall mean firing times were compared in a series of t-tests to determine if the battlesight engagements were significantly faster than precision engagements. The results are presented in table 9-13. The results in table 9-13 show that in all four comparisons, the first round mean firing time for battlesight engagements were significantly faster than for precision engagements.

TABLE 9-13

t-Tests of Overall First Round Mean Firing Times  
(Target Motion: Stationary; Ammo: Heat)

Source	Engagement Method		Mean Difference	S.E. Diff	t	p
	Precision	Battlesight				
<b>Table VIIIA (Day)</b>						
USAREUR	14.29	7.58	6.71	0.4308	15.58	< .001
CONUS	18.97	9.49	9.48	0.7823	12.12	< .001
<b>Table VIIIB (Night)</b>						
USAREUR	15.39	10.78	4.61	0.8457	5.45	< .001
CONUS	23.90	11.59	12.31	0.1825	67.45	< .001

(b) The Effects of Target Motion. Figures 9-12 and 9-13 present plots of mean firing times for USAREUR and CONUS tank crews on moving target engagements. The conditions of target motion and type of ammo are confounded in figure 9-12 and should be taken into consideration when making comparisons. Nevertheless, the curves in figure 9-12 do not show any apparent increase in firing time produced by the effects of target motion. Statistics from the CONUS sample provide additional evidence to support this interpretation. A comparison of the mean firing times between moving and stationary targets from tables 9-12A and 9-15 reveal that the overall means for moving targets were 17.02 and 19.32 for Table VIII A and B, while the corresponding means for stationary targets were 18.97 and 23.90.

(c) The Correlation Between Mean Hit Probability and Mean Firing Time. The point-biserial correlation coefficients ( $r_{pb}$ ) between the first round accuracy and firing time score on all main gun target engagements were calculated for each battalion on Table VIII A and B. The coefficient provides an estimate of the strength and direction of the linear association between accuracy and firing time. The question under study was to determine if a strong association exists between accuracy and firing speed and if so, to determine the nature of the relationship; whether they are positively or negatively associated.

(1) Fifty-nine individual point-biserial correlation coefficients from the USAREUR battalions were arranged into a table according to type of engagement. They were examined to detect any patterns or relationships. The results were negative. Fifty-one of the correlations were not significant. Six negative correlations were statistically significant. The results were similar for the CONUS battalions. From a total of 36  $r_{pb}$  correlations that were compared, 31 were not significant, and 5 negative correlations were significant.

(2) These results can only be interpreted to mean that there is very little association between time taken to fire the first round and hit probability. Furthermore, if there is any association, it seems to be in the negative direction which means that as firing time increases, accuracy decreases. There was a total of 13 significant  $r_{pb}$  correlations out of 95 for the combined USAREUR-CONUS sample. Eleven of the 13 significant correlations were negative. Figure 9-14 presents, graphically, two typical battalion examples of the functional relations between first round  $P_h$  and firing time. Included are curves for a precision and a battlesight target. The function for the precision target is U shaped, while the function for the battlesight target is at first positively angled and then tails off into a negative slope. The curves suggest that the function may not be linear. It may be curvilinear, perhaps in the form of an inverted U ( $\cap$ ). In this case, maximum accuracy would be achieved at an optimum firing time and would decline if firing time were faster or slower than the optimum. Additional analysis is required to define the true relationship. In any case, a study

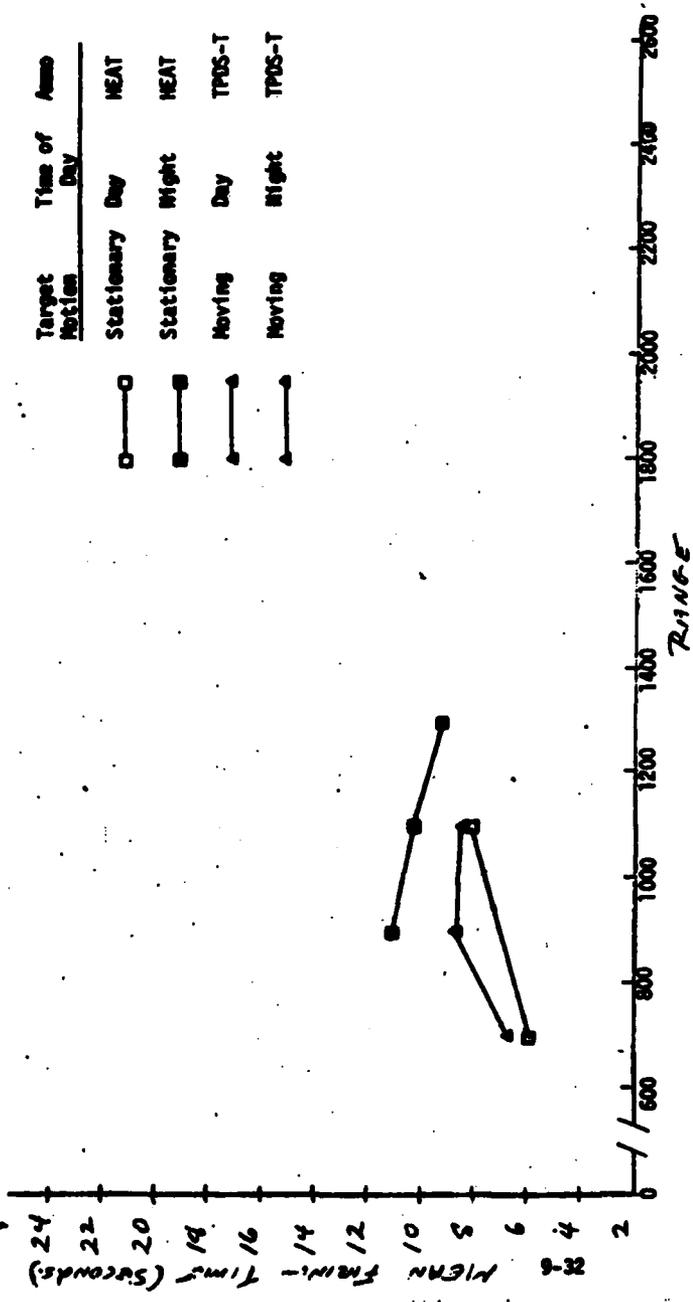


Figure 9-12 First Round Mean Firing Time of ISRAEL Tank Crews on Table VIII A (Day) and B (Night). Engagement Method: Battlesight; Target Motion and Ammo: Stationary and HEAT and Moving and TPDS-T respectively.

TABLE 5-14A

First Round Mean Firing Time  
USARMC Tank Crews  
Table VIII A (Day) and B (Night)

TARGET RANGE BAND	Table VIII A (Day)				Table VIII B (Night)			
	Engagement Method: Battlesight; Target Motion: Stationary; Ammo: HEAT		Engagement Method: Battlesight; Target Motion: Stationary; Ammo: HEAT		Engagement Method: Battlesight; Target Motion: Stationary; Ammo: HEAT		Engagement Method: Battlesight; Target Motion: Stationary; Ammo: HEAT	
	MEAN FIRING TIME (SECONDS)	S.D.	TOTAL ROUNDS	MEAN FIRING TIME (SECONDS)	S.D.	TOTAL ROUNDS	MEAN FIRING TIME (SECONDS)	S.D.
600-799	5.97	4.28	42	11.16	6.80	198		
800-999								
1000-1199	8.09	3.59	132	10.41	2.64	69		
1200-1399								
1400-1599								
1600-1799				9.10	6.07	30		
1800-1999								
2500								
TOTAL			174					297
OVERALL MEAN	7.58			10.78				

TABLE 9-706

First Round Mean Firing Time  
USARJUR Tank Crews  
Table VIII A (Day) and B (Night)

TARGET RANGE BAND	Table VIII A (Day)				Table VIII B (Night)			
	Engagement Method: Battlesight; Target Motion: Moving; Ammo: TPDS-T		Engagement Method: Battlesight; Target Motion: Moving; Ammo: TPDS-T		Engagement Method: Battlesight; Target Motion: Moving; Ammo: TPDS-T		Engagement Method: Battlesight; Target Motion: Moving; Ammo: TPDS-T	
	MEAN FIRING TIME (SECONDS)	S.D.	TOTAL ROUNDS	TOTAL ROUNDS	MEAN FIRING TIME (SECONDS)	S.D.	TOTAL ROUNDS	TOTAL ROUNDS
600-799					6.83	2.29	30	
800-999	8.67	3.79	210		8.76	3.05	267	
1000-1199	8.69	3.56	48					
1200-1399								
1400-1599								
1600-1799								
1800-1999								
2500								
TOTAL				258				297
OVERALL MEAN	8.67				8.57			

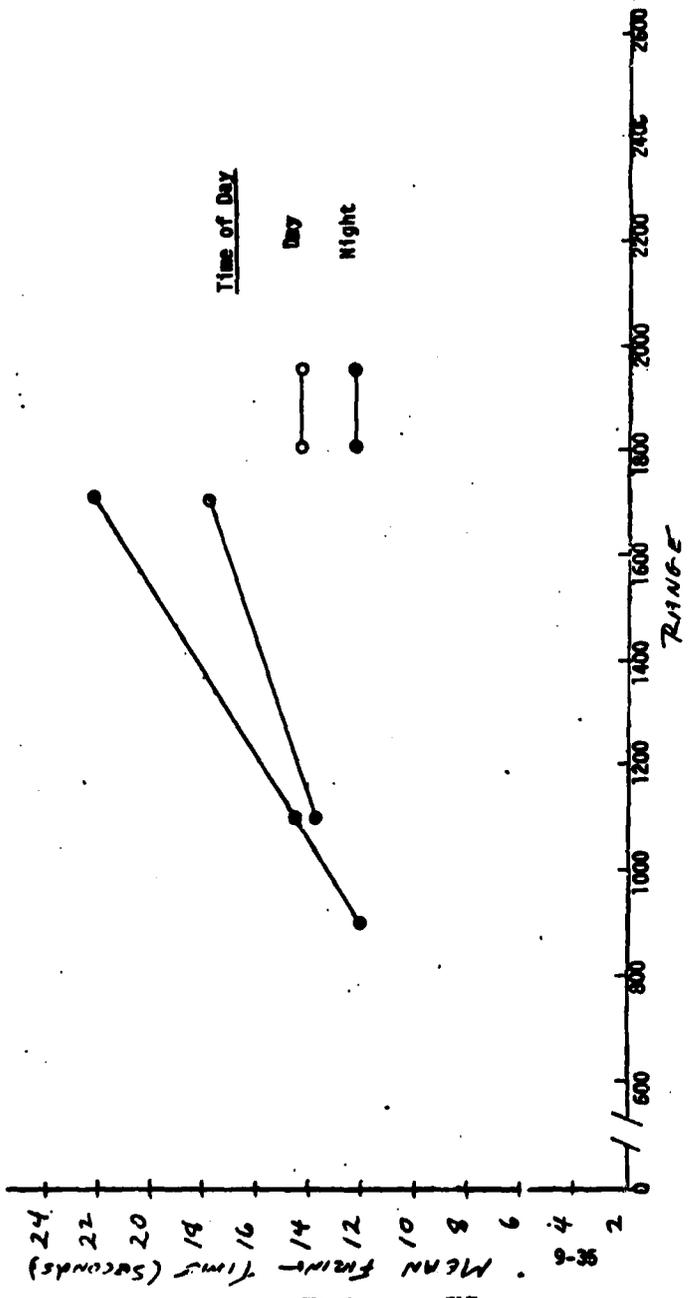


Figure 9-13 First Round Mean Firing Time of COMUS Tank Crews on Table VIII A (Day) and B (Night).  
 Target Motion: Moving; Engagement Method: Precision; Ammo: HEAT

TABLE 9-15

First Round Mean Firing Time  
COMUS Tank Crews  
Table VIII A (Day) and B (Night)

TARGET RANGE BAND	Table VIII A (Day)			Table VIII B (Night)		
	Engagement Method: Precision; Target Motion: Moving; Ammo: HEAT		TOTAL ROUNDS	Engagement Method: Precision; Target Motion: Moving; Ammo: HEAT		TOTAL ROUNDS
	MEAN FIRING TIME (SECONDS)	S.D.		MEAN FIRING TIME (SECONDS)	S.D.	
600-799	13.73	5.78	48	12.02	4.40	51
800-999				14.50	8.24	48
1000-1199						
1200-1399						
1400-1599						
1600-1799	17.80	9.54	204	22.28	9.93	204
1800-1999						
2500						
TOTAL			252			303
OVERALL MEAN	17.02			19.32		

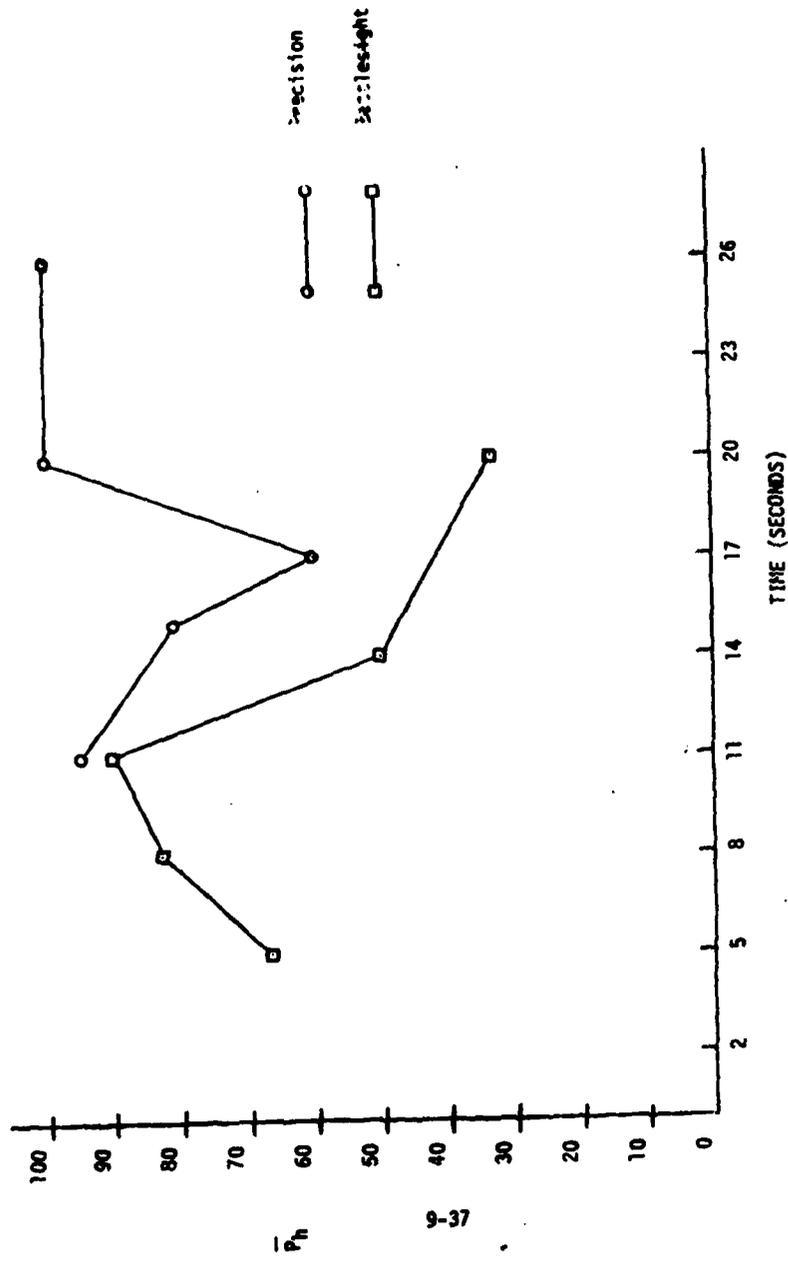


Figure 9-14 First Round Mean Hit Probability ( $\bar{P}_h$ ) by Firing Time on Table VIII A (Day). The  $\bar{P}_h$  Biserial Correlation Coefficients ( $r_{pb}$ ) for Each Curve are: Precision  $r_{pb} = .07$ , Not Significant, Battlesight  $r_{pb} = -.23$ , Not Significant.

TABLE 9-15A

TABLE VIII A  
 First Round Mean Hit Probability ( $\bar{P}_h$ )  
 by Time Interval

UJD Bn., Target 4: Range: 1600-1800 Meters; Engagement  
 Method: Precision; Target Motion: Stationary; Ammo: HEAT  
 rpb = .01, Not Significant

Time Interval (Seconds)	Hits	Misses	TOTAL	$\bar{P}_h$
10-12	20	1	21	95.24
13-15	17	4	21	80.95
16-18	3	2	5	60.00
19-21	2	0	2	100.00
22-24	0	0	0	-----
25-27	1	0	1	100.00

TABLE 9-158

TABLE VIII A  
 First Round Mean Hit Probability ( $\bar{P}_h$ )  
 by Time Interval

EDB Bn., Target 5: Range: 1000-1200 Meters; Engagement  
 Method: Battlesight; Target Motion: Stationary; Ammo: HEAT  
 $r_{pb} = -.23$ , Not Significant

Time Interval (Seconds)	Hits	Misses	TOTAL	$\bar{P}_h$
4-6	4	2	6	66.67
7-9	15	3	18	83.33
10-12	9	1	10	90.00
13-15	1	1	2	50.00
16-18	0	0	0	-----
19-21	1	2	3	33.33

of the data in tables 9-15A and 9-15B seem to indicate that little improvement results in accuracy by taking more time to fire than is necessary for a rapid, precise, gun lay in which the gunner does not sacrifice precision for speed.

9-3. Findings and Conclusions. The analysis of the overall main gun performance of the USAREUR and CONUS tank crews on Table VIII has produced some broad estimates of performance parameters which partly describe the present state of tank gunnery on Table VIII in the Army. These findings and conclusions are summarized below:

- (1) Table VIII data from the sample USAREUR battalions appears to be more valid and reliable than data from the CONUS battalions.
- (2) Both USAREUR and CONUS tank crews seem to fire most accurately at the middle ranges from approximately 1000-1800 meters. First round accuracy at the short ranges from 600-1000 meters is relatively poor.
- (3) There does not seem to be any practical difference in main gun accuracy performance between Table VIII A (Day) and Table VIII A (Night).
- (4) There is no difference in first round accuracy between precision and battlesight engagement methods in the battlesight range band (from 600-1800 meters).
- (5) There is little difference in first round accuracy and firing time when engaging either stationary or moving targets.
- (6) Target range does not have much influence on first round firing times.
- (7) Time of day does affect first round firing time, and in the expected direction. Generally speaking, first round firing time during the day is faster than during the night.
- (8) Engagement method has considerable effect on first round firing time. Mean firing times for battlesight engagements were much faster than for precision engagements.
- (9) There does not seem to be a strong linear correlation between first round accuracy and firing time.

#### 9-4. Individual Analyses of the Sample Tank Battalions.

a. This section presents separate analyses of the 15 sample tank battalions. Each analysis presents a description of how a battalion performed on Table VIII. Results are provided showing how engagement variables and their interactions affected gunnery performance. The analyses should be useful for evaluating the gunnery performance of individual battalions on Table VIII in relation to the particular set of main gun engagement conditions which comprised each test.

#### b. Contents and Organization.

(1) Each analysis is presented in a separate section which consists of written text followed by a set of tables and figures. The results of the analysis appear in these graphics. Each set of graphics begins with a summary table entitled Gunnery Performance Measures. It presents specifications of each target engagement and data and descriptive statistics of the two performance variables. Included are the first round mean hit probability ( $P_h$ ) scores, firing time scores, and point-biserial correlation coefficients for each target engagement. The table provides a reference for the rest of the analysis. Following the first table are two identical sets of graphs, each comprising two tables and a figure. In the first set, the first table is an analysis of variance summary table which presents the results of a three-factor analysis of variance of first round hit probability scores. Second is a companion table listing the mean values for the factors in the analysis of variance which are  $P_h$  values converted into percentages. Third, is a figure displaying plots of the means for the Tables X Targets interaction. Provided in the second set of two tables and a figure are the results of the analysis of variance of first round firing time measures. At the time of writing, these seven tables and figures comprised the basic set of graphics for each battalion analysis. The set of figures does not describe a complete analysis in every case and needs to be expanded for complete coverage.

(2) The analysis of variance test used for the analyses was a computer program from Dixon, W. J. (ed.) BMD Biomedical Computer Programs, 1974, University of California Press, (BMD08V, pp. 693-704). The program had one major restriction that produced some discrepancies in the results. The program required an equal number of tank crews in each company or it would not run. Thus the number of tank crews for all companies was determined by the company which had the smallest number. For example, if A Company had 17 tank crews, B Company had 16 tank crews, and C Company had 14 tank crews, the number of tank crews tested in the analysis of variance would be the first 14 crews in each company. Data from the last three crews in A Company and the last two crews in B Company would not be included in the test. The mean values derived from an analysis of variance which did not use data from all tank crews in the battalion differed somewhat from the means presented

in the Summary of Gunnery Performance Measures table which did use the data from all tank crews. In most analyses the number of crews not included did not amount to more than three or four and their loss did not affect the results substantially. In battalions with large differences in number of crews between companys, a different approach was taken. The company factor was dropped from the analysis of variance design and the data from all crews were then included in the analysis.

c. Analysis of the Sample Battalions.

(1) The analyses of the individual battalions are presented in the following sections. Analyses of the eight USAREUR battalions are presented first followed by the analyses of the seven CONUS battalions.

(2) Before the analyses are presented, it is necessary to explain the code system used for identifying individual battalions. The identification code for each battalion consists of three letters. The first letter will be either an E or a U. They specify whether it is either a USAREUR battalion (E) or a CONUS battalion (U). The second letter identifies the individual battalion and will be used when referring to it; such as the "A" Battalion. The third letter specifies the division or brigade to which the battalion is assigned; such as the "C" Division.

(3) Analysis of the EBB Battalion.

(a) B Battalion had a mixed organization. A Company was equipped with M60A0S tanks, while B and C Company were equipped with M60A1 tanks. Table 9-B-1 presents the Summary of Gunnery Performance Measures for the B Battalion. The statistics in table 9-B-1 were based on data from a total N of 34 tank crews: 12 in A Company, 10 in B Company, and 12 in C Company. The statistics in the analyses of variance were based on data from a total N of 30 tank crews, the first 10 from each company.

(b) Table 9-B-2 presents the results of the analysis of variance of first round  $\bar{P}_h$  scores. The results show that the main effect of targets was statistically significant ( $F=9.35, p < .001$ ), and the interaction effects of Companies X Targets was statistically significant ( $F=2.55, p < .05$ ). Mean  $\bar{P}_h$  values for these effects are presented in table 9-B-3 which contains an abridged list of all  $\bar{P}_h$  values for the main effects and interactions except for the Companies X Tables X Targets interaction. The Targets main effect was analyzed by a Tukey's (HSD)\*Test. The results indicated that the battalion tank crews  $\bar{P}_h$  value on Target 4, the only engagement firing HEP ammo, was significantly less ( $p < .01$ ) than on the other targets. Target numbers used in the text refer to the order in which the targets appear in the first table, 9-B-1, Summary of Gunnery Performance Measures, i.e., the first target entered in table 9-B-1 is Target 1, the second is Target 2, etc. There was no other statistically significant difference in  $\bar{P}_h$  between the targets. Examination of the means for the Companies X Targets interaction indicated that C Company had the highest  $\bar{P}_h$  values on Targets 1, 2, and 5, but the lowest  $\bar{P}_h$  on Target 3.

(c) Table 9-B-4 presents the results of the analysis of variance of firing time measures. The results show that significant main effects were Companies ( $F=4.67, p < .05$ ), and Targets ( $F=50.10, p < .001$ ), and significant interaction effects were Tables X Targets ( $F=4.43, p < .01$ ). Mean firing time values for these effects are presented in table 9-B-5. The Companies main effect was analyzed by examining the Company means. They indicated that A and B Companies' overall mean firing times were significantly faster ( $p < .05$ ) than C Company's. The Targets main effect and the Tables X Target interaction effect were related. The target means were analyzed in a Tukey's (HSD) Test. The results indicated that the mean firing times on Targets 1, 2, and 5 were significantly faster ( $p < .01$ ) than the mean firing times for Targets 3 and 4. The Tables X Targets interaction is graphically presented in figure 9-B-2 and shows that the mean firing time on Targets 3 and 4 were longer on Table VIII A (Day) than on Table VIII B (Night), while the reverse relation was the situation on the other targets.

(d) Company A in B Battalion was equipped with M60A0S tanks, whereas B and C Company had M60A1 tanks. Nevertheless, comparison of between

\* Honestly Significant Difference.

Company  $\bar{P}_h$  values showed no difference in accuracy. Also A Company did not differ in any way from the other Companies in terms of firing time. The main findings appear to be the following: One, first round accuracy was similar for all targets except the HEP target where accuracy was much poorer, only 11 percent overall. Two, mean firing time for the two precision engagements were slower than for the other two which were battlesight (Target 3 was mixed).

TABLE 9-R-1

GUNNERY PERFORMANCE MEASURES

UNIT EBB ROUND 1 GUNNERY RANGE 2

TABLE VIII	TARGET CHARACTERISTICS					MEASURES								
	TARGET SE-QUENCE	RANGE (ME-TERS)	E M *	No. RNDS. AMMO	TARGET	I L L**	NO. OF CREWS	NO. OF HITS	NO. OF MISSES	P h	σ <sub>M</sub>	MEAN FIRING TIME	S.D.	rpb
A	1	700-1000	B	2 TPDS-T	Moving Panel	A	34	15	19	.44	.09	8.77	4.47	.21
A	2	950-1200	B-P	2 HEAT	Hull	A	34	16	18	.47	.09	8.83	5.69	.14
A	3	1500-1900	T	2 HEAT	Hull	A	34	14	20	.41	.09	19.03	6.73	.46
A	4	1600-1750	P	2 HEP	Hull	A	34	5	29	.15	.06	16.77	6.00	.23
A	5	950-1200	B	2 HEAT	Hull	A	34	19	15	.56	.09	6.90	3.70	.34
B	1	700-1300	B	2 TPDS-T	Moving Panel	W	34	20	14	.59	.09	8.27	4.26	.47
B	2	950-1200	B-P	2 HEAT	Hull	W	34	17	17	.50	.09	8.57	3.45	.26
B	3	1500-1800	T	2 HEAT	Hull	W	34	9	25	.27	.08	15.17	5.56	.06
B	4	1500-1750	P	2 HEP	Hull	W	34	4	30	.12	.06	13.43	4.82	.09
B	5	850-1900	I	2 HEAT	Hull	I	34	18	14	.56	.09	9.10	6.07	.02

\* Engagement Method

\*\* Illumination

- B = Gunner: Daylight Battlesight
- C = TC, Gunner: Rangecard
- I = Gunner: IR Battlesight
- P = Gunner: Daylight Precision
- R = Gunner: IR Precision
- S = TC: Daylight Battlesight
- T = TC: Daylight Precision
- X = TC: IR 50 Cal. Sight

- A = Ambient Light
- W = Artificial White Light
- I = Infrared Light

1 B-P Target No. 2 A&B were battlesight targets for A Co (M60A0S), and precision targets for B&C Co (M60A1).

TABLE 9-B-2

TABLE VIII A and B

## ANALYSIS OF VARIANCE SUMMARY

UNIT EBB GUNNERY MEASURE 1st Round Ph

SOURCE OF VARIATION	d.f.	MEAN SQUARE	F	P
A - Companys	2	4133.332	1.12	N.S.
B - Table	1	533.333	----	N.S.
C - Targets	4	18383.330	9.35	<.001
N(A) - Error	27	3688.873	<del>      </del>	
AB - Companys X Table	2	933.331	----	N.S.
AC - Companys X Targets	8	5008.313	2.55	<.05
BC - Table X Targets	4	2116.641	1.18	N.S.
NB(A) - Error	27	2577.766	<del>      </del>	
NC(A) - Error	108	1966.651	<del>      </del>	
ABC - Companys X Table X Target	8	1891.644	1.05	N.S.
NBC(A) - Error	108	1799.865	<del>      </del>	

## P Values of F

N.S = F value is not statistically significant.

&lt;.05, &lt;.01, &lt;.005, &lt;.001 = F value is significant at less than the percent value indicated.

TABLE 9-B-3

First Round Mean Values

UNIT	EBB	PERFORMANCE MEASUREMENT				
1. Overall Mean = 40.7						
2. Table VIII A		Table VIII B				
	42.0	39.3				
3. Company	Co A	Co B	Co C			
	38.0	36.0	48.0			
4. Targets	1	2	3	4	5	
	51.7	50.0	36.7	11.7	53.3	
5. Company	A (Day)	Table VIII		B (Night)		
	A	40.0		36.0		
	B	34.0		38.0		
	C	52.0		44.0		
6.	Target					
Table VIII	1	2	3	4	5	
A (Day)	46.7	46.7	46.7	13.3	56.7	
B (Night)	66.7	63.3	26.7	10.0	50.0	
7.	Target					
Company	1	2	3	4	5	
A	45.0	55.0	40.0	5.0	45.0	
B	50.0	25.0	50.0	15.0	40.0	
C	60.0	70.0	20.0	15.0	75.0	

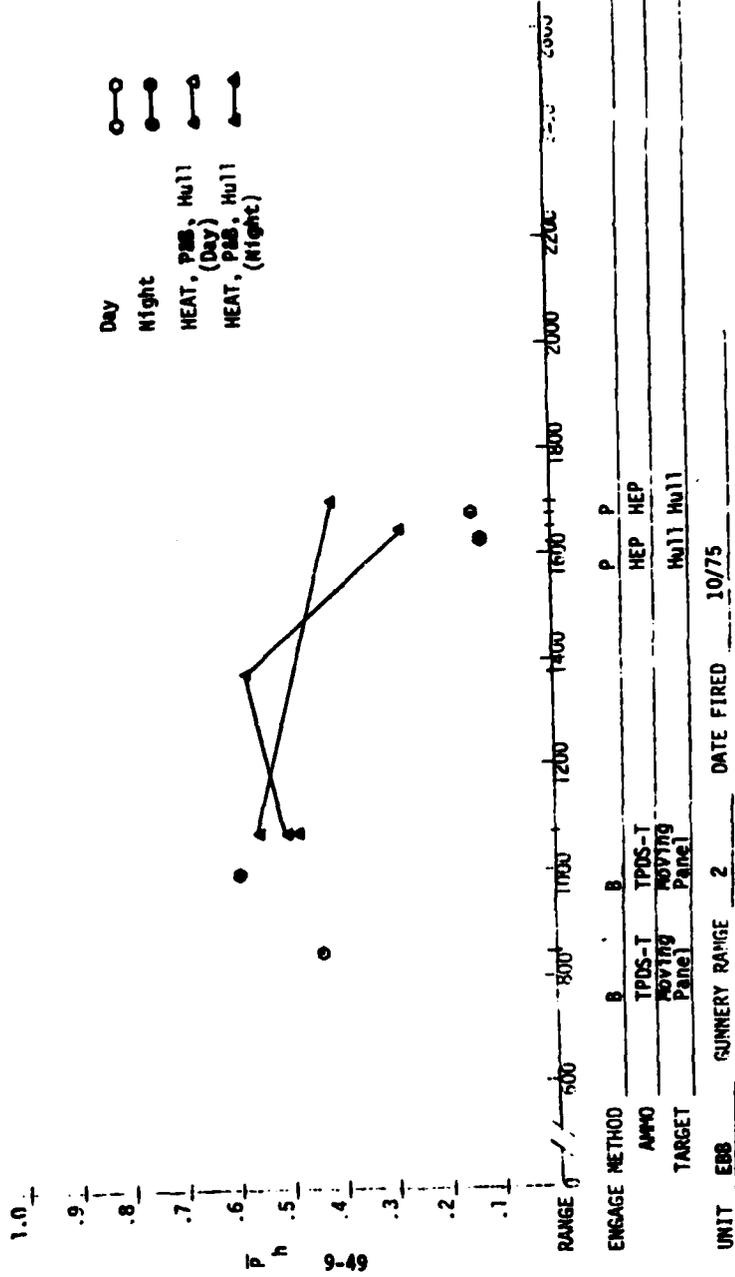


Figure 9-8-1 Mean First Round Hit Probability ( $P_h$ ) Performance on Table VIII Main Gun Targets

TABLE 9-R-4

TABLE VIII A and B

## ANALYSIS OF VARIANCE SUMMARY

UNIT EBB GUNNERY MEASURE 1st Round Firing Time

SOURCE OF VARIATION	d.f.	MEAN SQUARE	F	P
A - Companys	2	242.003	4.67	< .05
B - Table	1	99.763	4.04	N.S.
C - Targets	4	1099.633	50.10	< .001
N(A) - Error	27	51.837	<del> </del>	
AB - Companys X Table	2	58.323	2.36	N.S.
AC - Companys X Targets	8	32.114	1.46	N.S.
BC - Table X Targets	4	92.145	4.43	< .01
NB(A) - Error	27	24.699	<del> </del>	
NC(A) - Error	108	21.947	<del> </del>	
ABC - Companys X Table X Target	8	30.971	1.49	N.S.
NBC(A) - Error	108	20.789	<del> </del>	

## P Values of F

N.S = F value is not statistically significant.

&lt; .05, &lt; .01, &lt; .005, &lt; .001 = F value is significant at less than the percent value indicated.

TABLE 9-B-5

First Round Mean Values

UNIT	EBB	PERFORMANCE MEASURE: Firing Time				
1.	Overall Mean = 11.5					
2.	Table VIII A (Day)	Table VIII B (Night)				
	12.1	10.9				
3.	Company	Co A	Co B	Co C		
		10.9	10.3	13.2		
4.	Target	1	2	3	4	5
		8.5	8.7	17.1	15.1	8.0
5.	Company	A (Day)	Table VIII	B (Night)		
	A	11.4		10.4		
	B	10.1		10.4		
	C	14.6		11.9		
6.		Target				
	Table VIII	1	2	3	4	5
	A (Day)	8.8	8.8	19.0	16.8	6.9
	B (Night)	8.3	8.6	15.2	13.4	9.1
7.		Target				
	Company	1	2	3	4	5
	A	8.7	6.8	16.1	14.7	8.5
	B	7.4	7.2	16.2	15.2	5.5
	C	9.5	12.2	19.0	15.5	10.1

Day  
Night

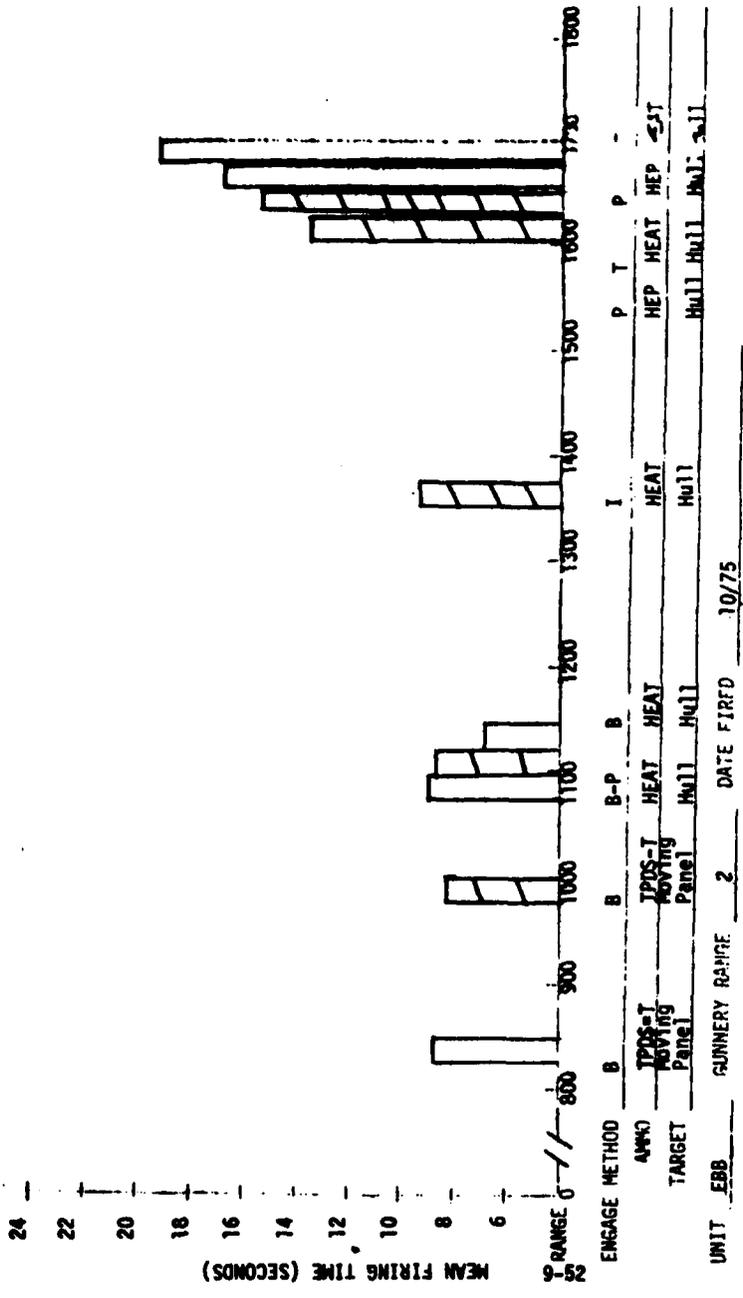


Figure 9-8-2 First Round Mean Firing Time on Table VIII Main Gun Targets

(4) Analysis of the ECB Battalion.

(a) Table 9-C-1 presents the Summary of Gunnery Performance Measures for the C Battalion. The statistics in table 9-C-1 were based on data from a total N of 32 tank crews: 10 in A Company, 10 in B Company, and 12 in C Company. The statistics in the analyses of variance were based on data from a total N of 30 tank crews, the first 10 from each company.

(b) Table 9-C-2 presents the results of the analysis of variance of first round  $\bar{P}_h$  scores. The results show that only one main effect in the analysis was statistically significant. It was the Targets effect ( $F=18.24$ ,  $p<.001$ ). A Tukey's (HSD) Test of the target means, presented in table 9-C-3, indicated that Targets 3 and 4 had  $\bar{P}_h$  values significantly lower ( $p<.001$ ) than the  $\bar{P}_h$  scores for Targets 1, 2, and 5.

(c) Table 9-C-4 presents the results of the analysis of variance of first round mean firing time. There was one significant effect, Targets ( $F=14.91$ ,  $p<.001$ ). Target means, presented in table 9-C-5, were analyzed in a Tukey's (HSD) Test. The results indicated that Targets 3 and 4 had significantly longer mean firing times ( $p<.01$ ) than Targets 1, 2, and 5.

(d) Examination of figure 9-C-1 shows that Targets 3 and 4 had longer ranges than the other targets. Also, Target 3 was a TC-precision engagement and Target 4 used HEP ammo. These factors may have contributed to the performance differences.

TABLE 9-C-1

GUNNERY PERFORMANCE MEASURES

UNIT LCB

NUMBER 1

GUNNERY RANGE

TARGET CHARACTERISTICS							MEASURES							
TABLE VIII	TARGET SE-QUENCE	RANGE (ME-TERS)	E M *	No. RND. AMMO	TARGET	I L L**	NO. OF CREWS	NO. OF HITS	NO. OF MISSES	F h	O'M	MEAN FIRING TIME	S.D.	rpb
A	1	700-1000	B	2 TPDS-T	Moving Panel	A	32	19	13	.59	.09	8.77	3.31	-.29
A	2	1100-1200	P	2 HEAT	Mull	A	32	21	11	.66	.09	9.50	3.43	-.36
A	3	1750-1900	T	2 HEAT	Mull	A	32	4	27	.13	.06	14.20	5.25	-.06
A	4	1500-1750	P	2 HEP	Mull	A	32	9	23	.28	.08	12.60	5.81	-.27
A	5	850-1200	B	2 HEAT	Mull	A	32	22	9	.71	.08	7.97	3.35	-.34
B	1	700-1000	B	2 TPDS-T	Moving Panel	W	32	23	9	.72	.08	8.83	3.22	.06
B	2	1100-1200	P	2 HEAT	Mull	W	32	21	11	.66	.09	10.77	5.32	-.26
B	3	1750-1900	T	2 HEAT	Mull	W	32	10	21	.32	.09	13.60	4.91	.04
B	4	1500-1750	P	2 HEP	Mull	W	32	8	24	.25	.08	13.47	4.26	.18
B	5	850-1200	I	2 HEAT	Mull	I	32	22	9	.71	.08	9.37	4.34	.13

\* Engagement Method

\*\* Illumination

B = Gunner: Daylight Battlesight  
 C = TC, Gunner: Rangecard  
 I = Gunner: IR Battlesight  
 P = Gunner: Daylight Precision  
 R = Gunner: IR Precision  
 S = TC: Daylight Battlesight  
 T = TC: Daylight Precision  
 X = TC: IR 50 Cal. Sight

A = Ambient Light  
 W = Artificial White Light  
 I = Infrared Light

TABLE 9-2

Table VIII A and B

ANALYSIS OF VARIANCE SUMMARY

UNIT ECB GUNNERY MEASURE 1st Round P<sub>h</sub>

SOURCE OF VARIATION	d.f.	MEAN SQUARE	F	P
A - Companys	2	5733.328	2.55	N.S.
B - Table	1	1633.333	----	N.S.
C - Targets	4	33749.980	18.24	<.001
N(A) - Error	27	2248.142	<del>XXXX</del>	
AB - Companys X Table	2	2533.334	----	N.S.
AC - Companys X Targets	8	899.961	----	N.S.
BC - Table X Targets	4	1883.297	----	N.S.
NB(A) - Error	27	2899.981	<del>XXXX</del>	
NC(A) - Error	108	1849.981	<del>XXXX</del>	
ABC - Companys X Table X Target	8	2533.276	1.23	N.S.
NBC(A) - Error	108	2057.280	<del>XXXX</del>	

P Values of F

N.S = F value is not statistically significant.

<.05, <.01, <.005, <.001 = F value is significant at less than the percent value indicated.

TABLE 9-C-3

First Round Mean Values

UNIT	ECB	PERFORMANCE MEASURE (Ph)				
1. Overall Mean		= 48.3				
2. Table VIII A (Day)		Table VIII B (Night)				
	46.0	50.7				
3. Company	Co A	Co B	Co C			
	43.0	45.0	57.0			
4. Target	1	2	3	4	5	
	63.3	65.0	20.0	25.0	68.3	
5. Company	A (Day)	Table VIII		B (Night)		
	A			46.0		
	B			52.0		
	C			54.0		
6.		Target				
Table VIII	1	2	3	4	5	
A (Day)	56.7	66.7	10.0	26.7	70.0	
B (Night)	70.0	63.3	30.0	23.3	66.7	
7.		Target				
Company	1	2	3	4	5	
A	65.0	55.0	10.0	15.0	70.0	
B	60.0	65.0	15.0	20.0	65.0	
C	65.0	75.0	35.0	40.0	70.0	

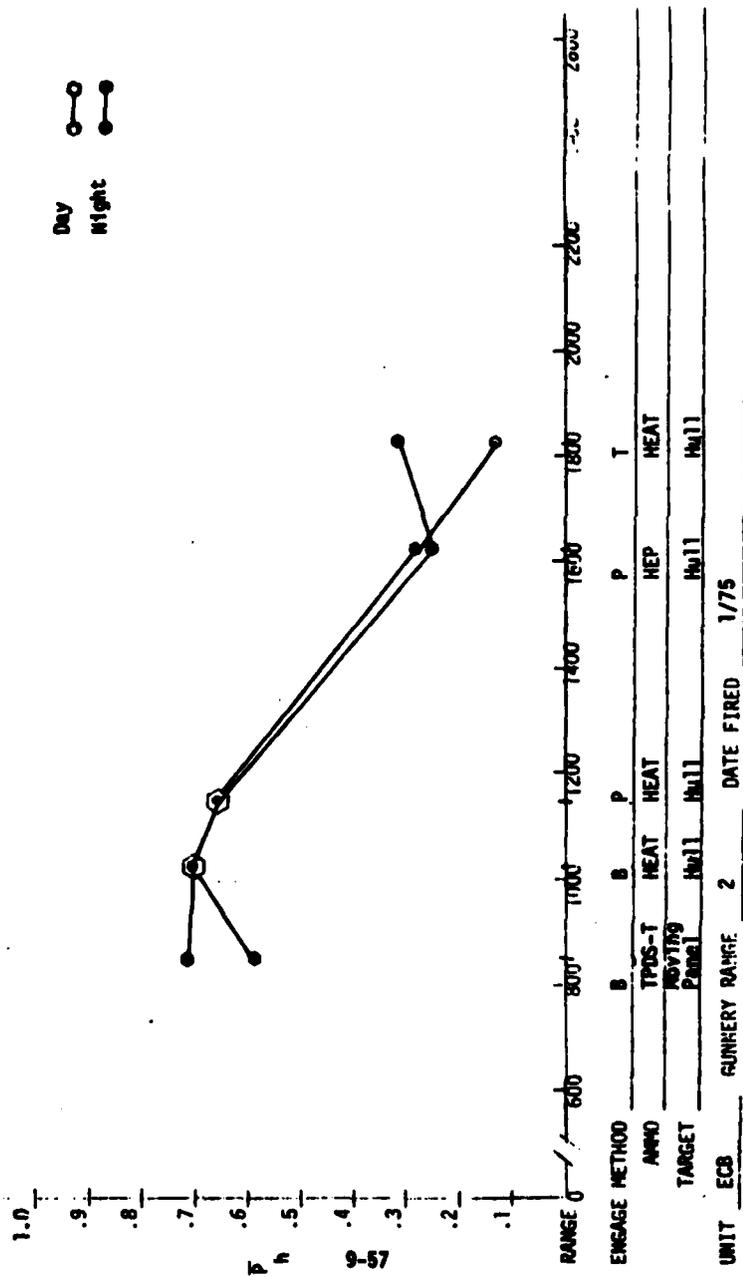


Figure 9-C-1 Mean First Round Hit Probability ( $P_h$ ) Performance on Table VIII Main Gun Targets

ENGAGE METHOD	B	B	P	P	T
AMMO	TPDS-T	HEAT	HEAT	HEP	HEAT
TARGET	Moving Panel	Hull	Hull	Hull	Hull
UNIT	ECB	GUNNERY RANGE	2	DATE FIRED	1/75

TABLE 9-C-4

TABLE VIII A and B

ANALYSIS OF VARIANCE SUMMARY

UNIT ECB GUNNERY MEASURE 1st Round Firing Time

SOURCE OF VARIATION	d.f.	MEAN SQUARE	F	P
A - Companys	2	38.973	1.51	N.S.
B - Table	1	48.000	1.96	N.S.
C - Targets	4	322.447	14.91	< .001
N(A) - Error	27	25.823	<del>      </del>	
AB - Companys X Table	2	66.280	2.71	N.S.
AC - Companys X Targets	8	9.832	----	N.S.
BC - Table X Targets	4	19.800	1.42	N.S.
NB(A) - Error	27	24.482	<del>      </del>	
NC(A) - Error	108	21.623	<del>      </del>	
ABC - Companys X Table X Target	8	13.730	----	N.S.
NBC(A) - Error	108	17.333	<del>      </del>	

P Values of F

N.S = F value is not statistically significant.

< .05, < .01, < .005, < .001 = F value is significant at less than the percent value indicated.

TABLE 9-C-5

First Round Mean Values

	UNIT FCR	PERFORMANCE Fixing Time				
1.	Overall Mean = 11.0					
2.	Table VIII A (Day) 10.6	Table VIII B (Night) 11.4				
3.	Company	Co A	Co B	Co C		
		10.6	10.7	11.7		
4.	Target	1	2	3	4	5
		8.8	10.1	13.9	13.0	9.2
5.	Company	A (Day)	Table VIII		B (Night)	
	A	9.7			11.4	
	B	11.3			10.2	
	C	10.8			12.6	
6.		Target				
	Table VIII	1	2	3	4	5
	A (Day)	8.8	9.5	14.2	12.6	8.0
	B (Night)	8.8	10.8	13.6	13.5	10.4
7.		Target				
	Company	1	2	3	4	5
	A	7.7	9.9	13.5	12.7	9.1
	B	8.7	9.5	14.0	13.6	8.0
	C	10.0	11.1	14.3	12.9	10.4



(5) Analysis of the EDD Battalion.

(a) Table 9-D-1 presents the Summary of Gunnery Performance Measures for the D Battalion. The statistics in table 9-D-1 were based on data from a total N of 39 tank crews: 13 in A Company, 13 in B Company, and 13 in C Company. The statistics in the analyses of variance were also based on data from a total N of 39 tank crews.

(b) Table 9-D-2 presents the results of the analysis of variance of first round  $P_h$  scores. There was one significant effect, Targets ( $F=50.94$ ,  $p < .001$ ). The target means, presented in table 9-D-3, were compared for differences in a Tukey's (HSD) Test. The results indicated that  $P_h$  scores on Targets 1, 2, and 5 were significantly higher ( $p < .01$ ) than  $P_h$  scores on Targets 3 and 4.

(c) The results of the analysis of variance of first round firing time are presented in table 9-D-4. Significant effects were Tables ( $F=6.74$ ,  $p < .05$ ), Targets ( $F=24.99$ ,  $p < .001$ ), and Companys X Targets ( $F=3.48$ ,  $p < .01$ ). Examination of the means for tables, presented in table 9-D-5, indicates that the mean firing time on Table VIII A (Day) was significantly faster ( $p < .05$ ) than on Table VIII B (Night). The Target means were compared for differences in a Tukey's (HSD) Test. The results indicated that mean firing time on Targets 1, 2, and 5 were significantly faster ( $p < .01$ ) than on Targets 3 and 4. Inspection of the means for the Companys X Targets interaction revealed that C Company had the fastest mean firing time on Targets 1 and 5, and the slowest on Targets 2 and 4.

(d) Examination of figure 9-D-1 shows that Targets 3 and 4 had longer ranges than the other targets. Thus the range factor probably accounted for most of the differences in  $P_h$  and mean firing time scores between targets.

TABLE 9-D-1

GUNNERY PERFORMANCE MEASURES

UNIT EOB ROUND 1 GUNNERY RANGE ?

TABLE VIII	TARGET CHARACTERISTICS						MEASURES							
	TARGET SEQUENCE	RANGE (METERS)	EN *	NO. RND. AMMO	TARGET	I L L**	NO. OF CREWS	MT. OF HITS	NO. OF MISSES	P h	σ <sub>M</sub>	MEAN FIRING TIME	S.D.	rpb
A	1	700-1000	B	2 TPDS-T	Moving Panel	A	39	30	9	.77	.07	9.97	3.90	-.15
A	2	1100	P	2 HEAT	Hull	A	39	30	9	.77	.07	11.23	3.34	-.33
A	3	1800	T	2 HEAT	Hull	A	39	5	30	.14	.06	15.10	7.24	.05
A	4	1500-1750	P	2 HEP	Hull	A	39	4	35	.10	.05	12.90	5.43	-.17
A	5	1100	B	2 HEAT	Hull	A	39	30	9	.77	.07	9.56	3.73	-.23
B	1	700-1000	B	2 TPDS-T	Moving Panel	W	39	33	6	.85	.06	9.95	4.81	.03
B	2	1100-1200	P	2 HEAT	Hull	W	39	31	8	.80	.07	12.87	3.78	-.20
B	3	1750-1800	T	2 HEAT	Hull	W	39	12	24	.33	.08	17.56	8.55	.43
B	4	1600-1700	P	2 HEP	Hull	W	39	8	31	.21	.07	15.59	5.55	-.04
B	5	850-1200	I	2 HEAT	Hull	I	39	27	11	.71	.08	10.44	3.70	.14

\* Engagement Method

- B = Gunner: Daylight Battlesight
- C = TC, Gunner: Rangecard
- I = Gunner: IR Battlesight
- P = Gunner: Daylight Precision
- R = Gunner: IR Precision
- S = TC: Daylight Battlesight
- T = TC: Daylight Precision
- X = TC: IR 50 Cal. Sight

\*\* Illumination

- A = Ambient Light
- W = Artificial White Light
- I = Infrared Light

TABLE 9-D-2

TABLE VIIIA and II

ANALYSIS OF VARIANCE SUMMARY

UNIT EDB GUNNERY MEASURE 1st Round Ph

SOURCE OF VARIATION	d.f.	MEAN SQUARE	F	P
A - Companys	2	692.307	----	N.S.
B - Table	1	3692.308	2.64	N.S.
C - Targets	4	81794.810	50.94	< .001
N(A) - Error	36	1995.719	<del>      </del>	
AB - Companys X Table	2	999.997	----	N.S.
AC - Companys X Targets	8	948.719	----	N.S.
BC - Table X Targets	4	1769.250	1.01	N.S.
NB(A) - Error	36	1397.420	<del>      </del>	
NC(A) - Error	144	1605.674	<del>      </del>	
ABC - Companys X Table X Target	8	1769.149	1.01	N.S.
NBC(A) - Error	144	1755.288	<del>      </del>	

P Values of F

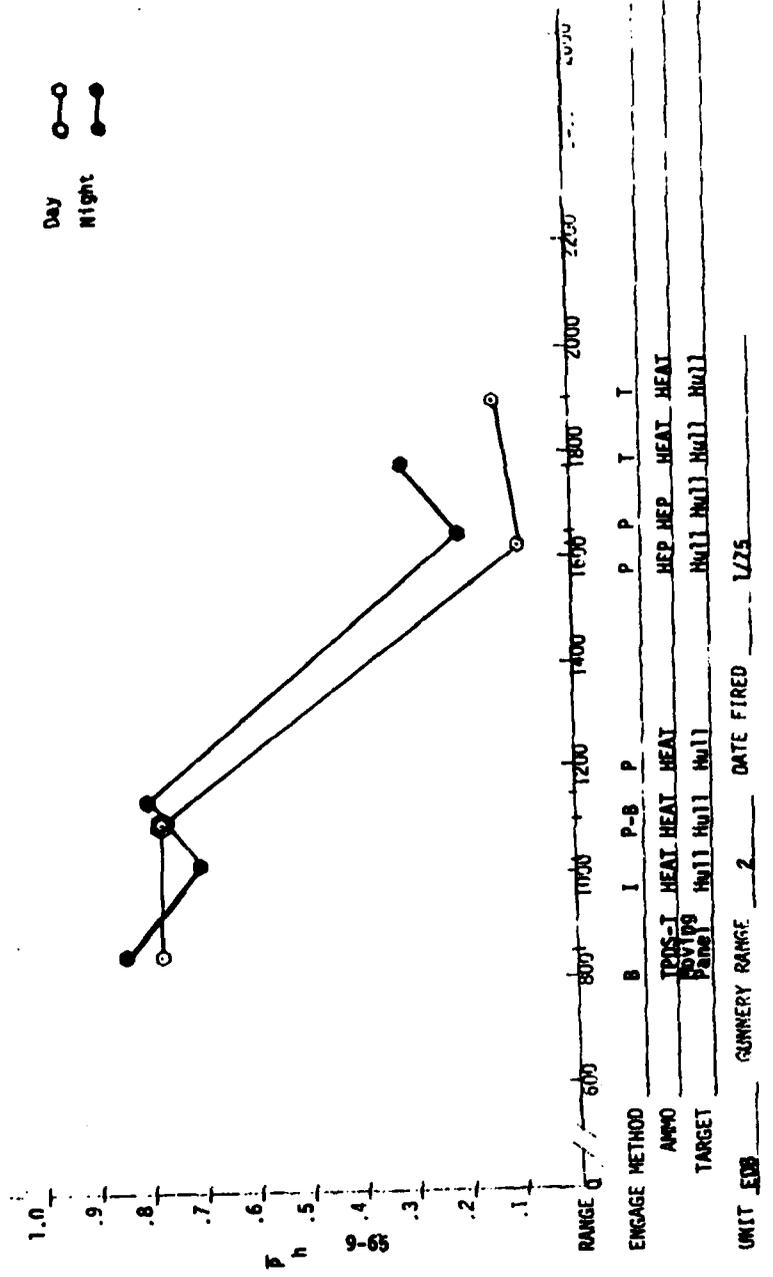
N.S = F value is not statistically significant.

< .05, < .01, < .005, < .001 = F value is significant at less than the percent value indicated.

TABLE 9-D-3

First Round Mean Values

	WIN	DM	PERFORMANCE (%)		
1. Overall Mean =	53.8				
2. Table VIII A (Day)	50.8		Table VIII B (Night)		
			56.9		
3. Companys	Co A	Co B	Co C		
	51.5	53.8	56.2		
4. Target	1	2	3	4	5
	80.8	78.2	21.8	15.4	73.1
5. Company	A (Day)	Table VIII		B (Night)	
A	50.8			52.3	
B	47.7			60.0	
C	53.8			58.5	
6.	Target				
Table VIII	1	2	3	4	5
A (Day)	76.9	76.9	12.8	10.3	76.9
B (Night)	84.6	79.5	30.8	20.5	69.2
7.	Target				
Company	1	2	3	4	5
A	84.6	76.9	23.1	11.5	61.5
B	76.9	73.1	23.1	15.4	80.8
C	80.8	84.6	19.2	19.2	76.9



Day ○—○  
Night ●—●

ENGAGE METHOD B I P-S P P P T T  
 AMMO TPDS-I HEAT HEAT HEAT HEAT HEAT HEAT HEAT HEAT  
 TARGET Pans Hull Hull Hull Hull Hull Hull Hull  
 UNIT EOB GUNNERY RANGE 2 DATE FIRED 1/25

Figure 9-D-1 Mean First Round Hit Probability ( $P_h$ ) Performance on Table VIII Main Gun Target.

TABLE 9-D-4

TABLE VIII A and H

ANALYSIS OF VARIANCE SUMMARY

UNIT EDB GUNNERY MEASURE 1st Round Firing Time

SOURCE OF VARIATION	d.f.	MEAN SQUARE	F	P
A - Companys	2	9.972	----	N.S.
B - Table	1	227.703	6.74	<.05
C - Targets	4	597.247	24.99	<.001
N(A) - Error	36	48.478	<del>XXXX</del>	
AB - Companys X Table	2	12.002	----	N.S.
AC - Companys X Targets	8	83.065	3.48	<.01
BC - Table X Targets	4	24.786	1.11	N.S.
NB(A) - Error	36	33.791	<del>XXXX</del>	
NC(A) - Error	144	23.900	<del>XXXX</del>	
ABC - Companys X Table X Target	8	25.711	1.15	N.S.
NBC(A) - Error	144	22.341	<del>XXXX</del>	

P Values of F

N.S = F value is not statistically significant.

<.05, <.01, <.005, <.001 = F value is significant at less than the percent value indicated.

TABLE 9-D-5

First Round Mean Values

UNIT	EDB	PERFORMANCE Firing Time				
1.	Overall Mean =	12.5				
2.	Table VIII A (Day)	Table VIII B (Night)				
	11.8	13.3				
3.	Company	Co A	Co B	Co C		
		12.2	12.8	12.5		
4.	Target	1	2	3	4	5
		10.0	12.1	16.3	14.2	10.0
5.	Company	A (Day)	Table VIII		B (Night)	
	A	11.2			13.3	
	B	12.0			13.6	
	C	12.1			13.0	
6.		Target				
	Table VIII	1	2	3	4	5
	A (Day)	10.0	11.2	15.1	12.9	9.6
	B (Night)	9.9	12.9	17.6	15.6	10.4
7.		Target				
	Company	1	2	3	4	5
	A	9.3	11.5	16.0	14.8	9.5
	B	12.4	11.8	16.7	11.5	11.5
	C	8.2	12.8	16.3	16.3	9.0



(6) Analysis of the LEB Battalion.

(a) Table 9-E-1 presents the Summary of Gunnery Performance Measures for the E Battalion. The statistics in table 9-E-1 were based on data from a total N of 35 tank crews: 13 in A Company, 11 in B Company, and 11 in C Company. The statistics in the analyses of variance were based on a total N of 33 tank crews, the first 11 from each company.

(b) Table 9-E-2 presents the results of the analysis of variance of first round  $\bar{P}_h$  scores. Significant effects were Targets ( $F=37.56$ ,  $p < .001$ ), Companies X Targets ( $F=2.16$ ,  $p < .05$ ) and Companies X Tables X Targets ( $F=2.07$ ,  $p < .05$ ). The Target means, presented in table 9-E-3, were analyzed in a Tukey's (HSD) Test. The results indicated that the  $\bar{P}_h$  score on Target 2 was significantly higher ( $p < .01$ ) than on the other targets, and the  $\bar{P}_h$  scores on Targets 1 and 5 were significantly higher ( $p < .01$ ) than those for Targets 3 and 4. Examination of the means in the Companies X Targets interaction disclosed that B Company had the highest  $\bar{P}_h$  scores on Targets 2, 3, and 5, while A Company had the highest score on Target 4, and C Company had the highest score on Target 1. Examination of the means for the Companies X Tables X Targets interaction revealed that A Company's  $\bar{P}_h$  scores on Targets 3 and 4, Table VIII A (Day) were both 0.0, and C Company's  $\bar{P}_h$  scores on Target 3, (Day) and Target 4 (Night) were both 0.0.

(c) The results of the analysis of variance of first round mean firing time are presented in table 9-E-4. Significant effects were Tables ( $F=28.16$ ,  $p < .001$ ), Targets ( $F=20.37$ ,  $p < .001$ ), and Companies X Tables ( $F=5.77$ ,  $p < .01$ ). Inspection of the means for tables, presented in table 9-E-5, shows that mean firing time on Table VIII A (Day) was significantly faster ( $p < .001$ ) than on Table VIII B (Night). The Target means were analyzed in a Tukey's (HSD) Test. The results indicated that the mean firing times on Targets 1 and 5 were significantly faster ( $p < .01$ ) than on Targets 2, 3, and 4, and the mean firing time on Target 2 was significantly faster ( $p < .05$ ) than on Target 3. Examination of the means for the Companies X Tables interaction indicated that A Company had the slowest mean firing time on Table VIII A (Day) and the fastest mean firing time on Table VIII B (Night).

(d) It is not readily apparent why  $\bar{P}_h$  performance on Target 2 was significantly higher than on all the other targets. In another comparison, Targets 1 and 5 were battlesight engagements, while 3 and 4 were precision engagements, and the difference in engagement method could have produced the difference in  $\bar{P}_h$  scores between these targets. Differences between targets on mean firing time disclosed that the battlesight engagements produced faster mean firing times than on the precision engagements.

TABLE 9-E-1

## GUNNERY PERFORMANCE MEASURES

UNIT EEB ROUND 1 GUNNERY RANGE 2

TABLE VIII	TARGET CHARACTERISTICS						MEASURES							
	TARGET SE-QUENCE	RANGE (ME-TERS)	E M *	NO. RND. AMMO	TARGET	T L L**	NO. OF CREWS	NO. OF HITS	NO. OF MISSES	P h	O'M	MEAN FIRING TIME	S.D.	rpb
A	1	700-1000	B	2 TPDS-T	Moving Panel	A	35	13	22	.37	.08	8.37	2.59	.07
A	2	1100-1250	P	2 HEAT	Mull	A	35	28	7	.80	.07	11.52	3.99	.22
A	3	1800-1900	T	2 HEAT	Mull	A	35	4	29	.12	.06	14.55	3.23	.08
A	4	1600-1750	P	2 HEP	Mull	A	35	3	32	.09	.05	13.45	3.99	.10
A	5	1100	B	2 HEAT	Mull	A	35	23	12	.66	.08	7.55	3.03	.35
B	1	700-900	B	2 TPDS-T	Moving Panel	W	35	17	18	.49	.09	10.24	3.05	.14
B	2	1150-1200	P	2 HEAT	Mull	W	35	30	5	.86	.06	14.85	4.21	.16
B	3	1750-1800	T	2 HEAT	Mull	W	35	4	27	.13	.06	17.88	3.85	.11
B	4	1100-1500	P	2 HEP	Mull	W	35	7	27	.21	.07	17.39	5.58	.17
B	5	850-1100	I	2 HEAT	Mull	I	35	17	16	.52	.09	12.94	7.43	.18

\* Engagement Method

B = Gunner: Daylight Battlesight  
 C = TC, Gunner: Rangecard  
 I = Gunner: IR Battlesight  
 P = Gunner: Daylight Precision  
 R = Gunner: IR Precision  
 S = TC: Daylight Battlesight  
 T = TC: Daylight Precision  
 X = TC: IR 50 Cal. Sight

\*\* Illumination

A = Ambient Light  
 W = Artificial White Light  
 I = Infrared Light

TABLE 9-E-2

TABLE VIIIA and II

## ANALYSIS OF VARIANCE SUMMARY

UNIT EEB GUNNERY MEASURE 1st Round P<sub>h</sub>

SOURCE OF VARIATION	d.f.	MEAN SQUARE	F	P
A - Companys	2	5848.480	2.08	N.S.
B - Table	1	757.576	----	N.S.
C - Targets	4	57469.690	37.56	<.001
N(A) - Error	30	2818.175	<del>      </del>	
AB - Companys X Table	2	6575.738	3.86	N.S.
AC - Companys X Targets	8	3310.570	2.16	<.05
BC - Table X Targets	4	2196.922	1.57	N.S.
NB(A) - Error	30	1703.009	<del>      </del>	
NC(A) - Error	120	1530.274	<del>      </del>	
ABC - Companys X Table X Target	8	2901.448	2.07	<.05
NBC(A) - Error	120	1399.891	<del>      </del>	

## P Values of F

N.S = F value is not statistically significant.

&lt;.05, &lt;.01, &lt;.005, &lt;.001 = F value is significant at less than the percent value indicated.

TABLE 9-E-3

First Round Mean Values

UNIT	EED	PITCHMAN: Ph				
1.	Overall Mean =	41.5				
2.	Table VIII A (Day)	Table VIII B (Night)				
	40.0	43.0				
3.	Company	Co A	Co B	Co C		
		34.5	49.1	40.1		
4.	Target	1	2	3	4	5
		43.9	81.8	12.1	13.6	56.1
5.	Company	A (Day)	Table VIII		B (Night)	
	A	27.3			41.8	
	B	56.4			41.8	
	C	36.4			45.5	
6.		Target				
	Table VIII	1	2	3	4	5
	A (Day)	36.4	78.8	12.1	9.1	63.6
	B (Night)	61.6	84.8	12.1	18.2	48.5
7.		Target				
	Company	1	2	3	4	5
	A	27.3	77.3	4.5	22.7	40.9
	B	45.5	86.4	27.3	9.1	77.3
	C	59.1	81.8	4.5	9.1	50.0

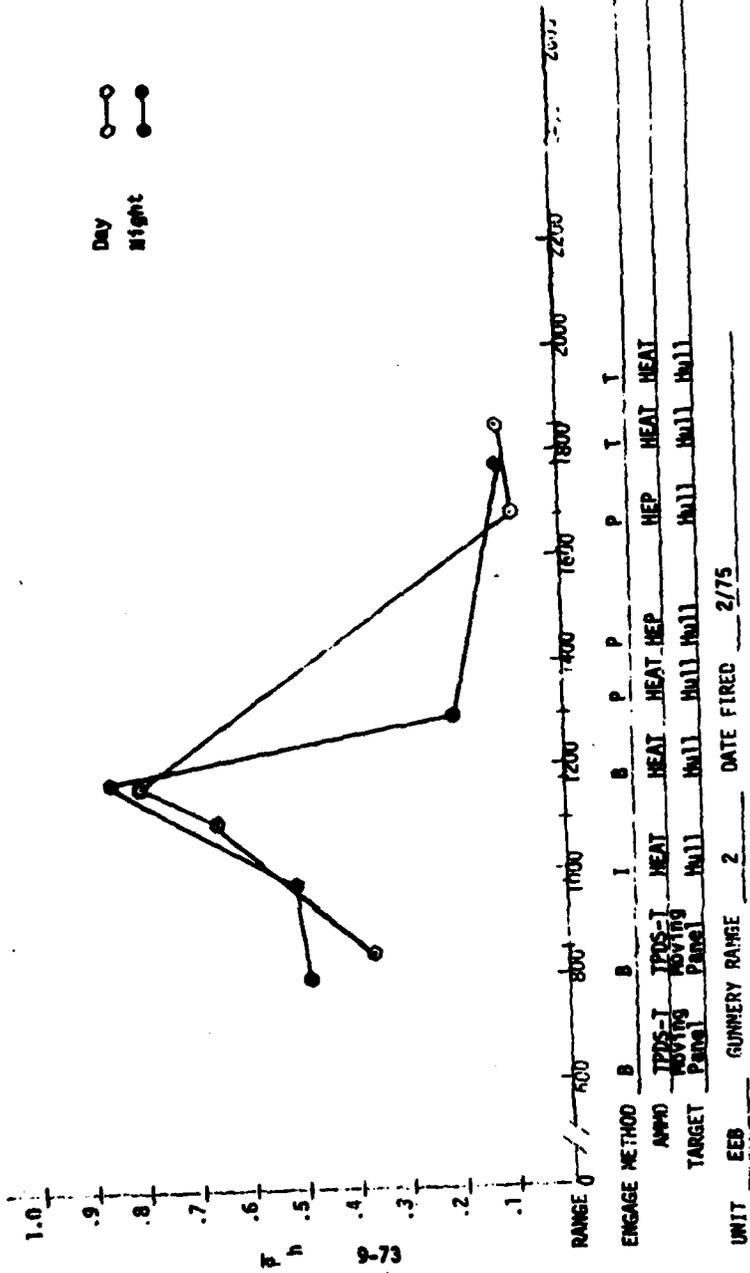


Figure 9-E-1 Mean First Round Hit Probability ( $P_h$ ) Performance on Table VIII Main Gun Targets.

TABLE 9-E-4

TABLE VIIIA and B

ANALYSIS OF VARIANCE SUMMARY

UNIT EEB GUNNERY MEASURE 1st Round Firing Time

SOURCE OF VARIATION	d.f.	MEAN SQUARE	F	P
A - Companys	2	5.055	----	N.S.
B - Table	1	1012.376	28.16	<.001
C - Targets	4	596.424	20.37	<.001
N(A) - Error	30	41.045	<del>      </del>	
AB - Companys X Table	2	207.284	5.77	<.01
AC - Companys X Targets	8	33.411	1.14	N.S.
BC - Table X Targets	4	32.072	1.12	N.S.
NB(A) - Error	30	35.948	<del>      </del>	
NC(A) - Error	120	29.281	<del>      </del>	
ABC - Companys X Table X Targets	8	33.891	1.18	N.S.
NBC(A) - Error	120	28.612	<del>      </del>	

P Values of F

N.S. = F value is not statistically significant.

<.05, <.01, <.005, <.001 = F value is significant at less than the percent value indicated.

TABLE 9-E-5

First Round Mean Values

UNIT	EFB	PITCHMAN			Timing Time	
1.	Overall Mean =	12.9				
2.	Table VIII A (Day)	11.2				
		Table VIII B (Night)				
		14.7				
3.	Company	Co A	Co B	Co C		
		13.1	12.7	13.0		
4.	Target	1	2	3	4	5
		9.5	13.2	16.2	15.4	10.2
5.	Company	A (Day)	Table VIII		B (Night)	
	A	12.9			13.3	
	B	10.3			15.0	
	C	10.2			15.7	
6.		Target				
	Table VIII	1	2	3	4	5
	A (Day)	8.7	11.5	14.5	13.5	7.5
	B (Night)	10.2	14.8	17.9	17.4	12.9
7.		Target				
	Company	1	2	3	4	5
	A	9.8	13.3	18.5	14.7	9.1
	B	9.1	12.5	15.4	15.9	10.5
	C	9.5	13.7	14.7	15.7	11.2



(7) Analysis of the ELF Battalion.

(a) Table 9-L-1 presents the Summary of Gunnery Performance Measures for the L Battalion. The statistics in table 9-L-1 were based on data from a total N of 34 tank crews: 12 in A Company, 10 in B Company, and 12 in C Company. The statistics in the analyses of variance were based on a total N of 30 tank crews, the first 10 from each company.

(b) Table 9-L-2 presents the results of the analysis of variance of first round  $P_h$  scores. Significant effects were Targets ( $F=2.78$ ,  $p < .05$ ), and Tables X Targets ( $F=8.39$ ,  $p < .001$ ). The target means, presented in table 9-L-3, were analyzed for significant differences in a Tukey's (HSD) Test. The results were negative. None of the comparisons attained the .05 level of confidence. It is, therefore, concluded that there were no statistically significant differences between the means for the targets effect. However the related Tables X Targets interaction was highly significant and the means for the interaction are plotted in figure 9-L-1. Examination of the means in table 9-L-3 and figure 9-L-1 indicate the  $P_h$  scores on Target 1, Table VIII A (Day), and Target 4, Table VIII B (Night), were much higher, around 70 percent, than the  $P_h$  scores on the other engagements. Both of these were battlesight engagements at short ranges.

(c) Table 9-L-4 presents the results of the analysis of variance of first round mean firing time scores. Significant main effects were Tables ( $F=15.62$ ,  $p < .001$ ) and Targets ( $F=47.74$ ,  $p < .01$ ). Significant interaction effects were Companys X Tables ( $F=4.60$ ,  $p < .05$ ), and Tables X Targets ( $F=24.54$ ,  $p < .001$ ). Examination of the Tables means, presented in table 9-L-5, reveals that mean firing time during Table VIII A (Day) was significantly faster than during Table VIII B (Night). The means for the Targets effect were compared in a Tukey's (HSD) Test. The results indicated that the mean firing time on Target 3, the TC-precision engagement, was significantly slower than on the other targets. Inspection of the means for the Companys X Tables interaction indicates that the mean firing time for C Company on Table VIII B (Night) was much slower than the means for the other Companys. Examination of the means for the Tables X Targets interaction, plotted in figure 9-L-2, was biased because there were no measures for Target 2 on Table VIII A (Day). However, comparing the other means indicated that there were no large differences except on Target 1 where mean firing time doubled from Table VIII A (Day) to Table VIII B (Night). Target 1 was a battlesight engagement using Infrared illumination on the Table VIII B (Night) engagement.

TABLE 9-L-1

## GUNNERY PERFORMANCE MEASURES

UNIT ELF ROUND 1 GUNNERY RANGE 2

TABLE VIII	TARGET CHARACTERISTICS						MEASURES								
	TARGET SE-QUENCE	RANGE (ME-TERS)	E M *	No. RNDOS. AMMO	TARGET	I L L**	NO. OF CREWS	NO. OF HITS	NO. OF MISSES	P <sub>h</sub>	σ <sub>M</sub>	MEAN FIRING TIME	S.D.	rpb	
A	-9	650***	B	2	HEAT-T	Null	A	34	24	10	.71	.08	6.23	3.18	.05
A	-9	1700***	P	2	HEAT-T	Null	A	34	9	25	.27	.08	---	--	--
A	-9	1500		2											
A	-9	1650	T	2	HEAT-T	Null	A	34	13	21	.38	.09	19.80	6.25	.09
A	-9	800 &		2		Moving									
A	-9	1000	B	2	TPDS-T	Panel	A	34	11	23	.32	.08	7.17	2.28	.14
A	-9	1600	P	2	HEP-T	Null	A	34	6	28	.18	.07	10.20	4.14	.02
B	-9	850 &		2											
B	-9	1100	I	2	HEAT-T	Null	I	34	7	27	.21	.07	12.03	13.29	.38
B	-9	1750	P	2	HEAT-T	Null	W	34	10	24	.29	.08	14.60	6.61	.15
B	-9	1200 &		2											
B	-9	1700	T	2	HEAT-T	Null	W	34	14	20	.41	.09	17.50	9.16	.07
B	-9	700	B	2	TPDS-T	Moving Panel	W	34	23	11	.68	.08	6.83	2.29	.15
B	-9	1300	P	2	HEP-T	Null	W	34	15	19	.44	.09	9.40	3.66	.15

\* Engagement Method

B = Gunner: Daylight Battlesight  
 C = TC, Gunner: Rangecard  
 I = Gunner: IR Battlesight  
 P = Gunner: Daylight Precision  
 R = Gunner: IR Precision  
 S = TC: Daylight Battlesight  
 T = TC: Daylight Precision  
 X = TC: IR 50 Cal. Sight

\*\* Illumination

A = Ambient Light  
 W = Artificial White Light  
 I = Infrared Light

\*\*\* Multiple Target Engagement

TABLE 2-1-2

TABLE VIII and II

## ANALYSIS OF VARIANCE SUMMARY

UNIT ELF GUNNERY MEASURE First Round P<sub>1</sub>

SOURCE OF VARIATION	d.f.	MEAN SQUARE	F	P
A - Companys	2	1733.333	----	N.S.
B - Table	1	1200.000	----	N.S.
C - Targets	4	6283.328	2.78	<.05
N(A) - Error	27	2296.290	<del>XXXX</del>	
AB - Companys X Table	2	3599.996	1.08	N.S.
AC - Companys X Targets	8	2108.333	----	N.S.
BC - Table X Targets	4	14783.280	8.39	<.001
NB(A) - Error	27	3318.493	<del>XXXX</del>	
NC(A) - Error	108	2259.236	<del>XXXX</del>	
ABC - Companys X Table X Target	8	1558.313	----	N.S.
NBC(A) - Error	108	1762.837	<del>XXXX</del>	

## P Values of F

N.S = F value is not statistically significant.

&lt;.05, &lt;.01, &lt;.005, &lt;.001 = F value is significant at less than the percent value indicated.

TABLE 9-L-3  
First Round Mean Values

UNIT	ELF	PERFORMANCE P <sub>h</sub>				
1.	Overall Mean =	38.7				
2.	Table VIII A (Day)	Table VIII B (Night)				
	36.7	40.7				
3.	Company	Co A	Co B	Co C		
		34.0	40.0	42.0		
4.	Target	1	2	3	4	5
		46.7	28.3	36.7	51.7	30.0
5.	Company	A (Day)	Table VIII	B (Night)		
	A	32.0		36.0		
	B	44.0		36.0		
	C	34.0		50.0		
6.		Target				
	Table VIII	1	2	3	4	5
	A (Day)	70.0	23.3	36.7	33.3	20.0
	B (Night)	23.3	33.3	36.7	70.0	40.0
7.		Target				
	Company	1	2	3	4	5
	A	30.0	35.0	30.0	50.0	25.0
	B	60.0	20.0	30.0	60.0	30.0
	C	50.0	30.0	50.0	45.0	35.0

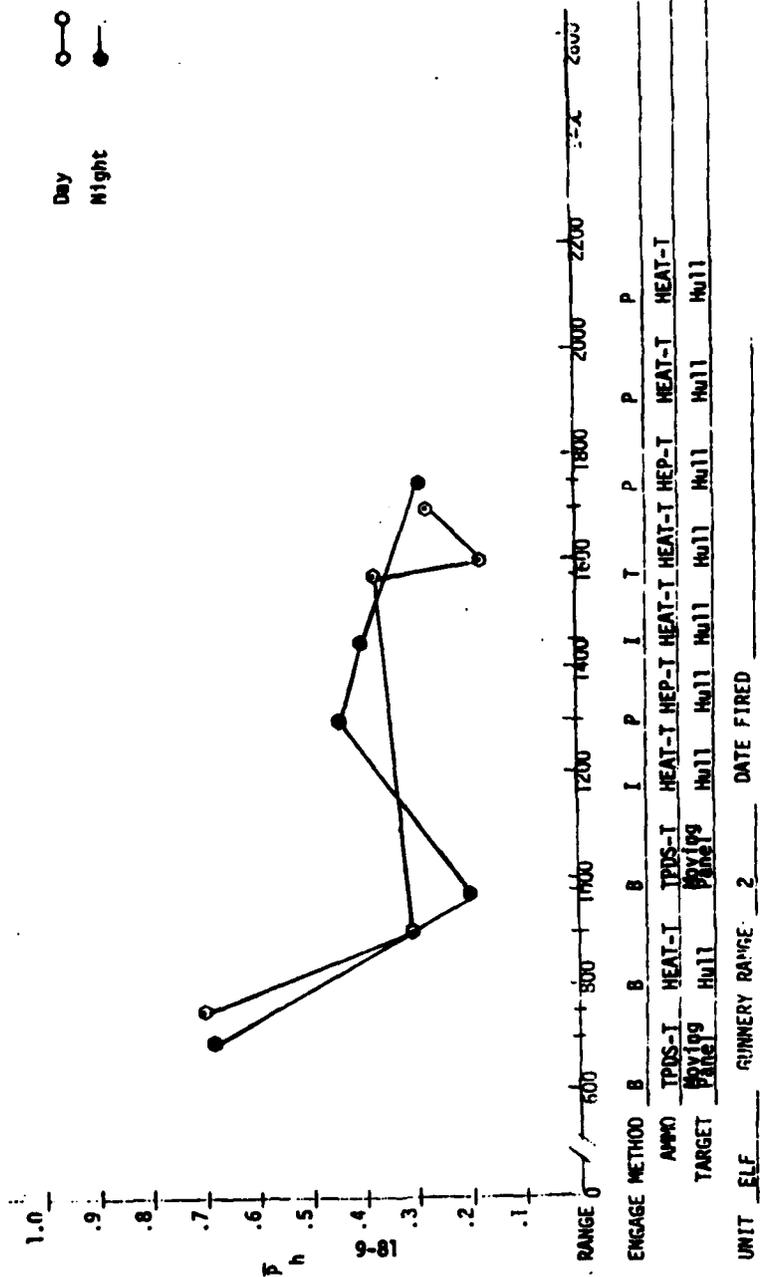


Figure 9-L-1 Mean First Round Hit Probability ( $P_h$ ) Performance on Table VIII Main Gun Targets.

IANI 2-1-4

TABLE VIIIA and B

ANALYSIS OF VARIANCE SUMMARY

UNIT ELF GUNNERY MEASURE First Round Firing Time

SOURCE OF VARIATION	d.f.	MEAN SQUARE	F	P
A - Companys	2	246.493	2.91	N.S.
B - Table	1	863.603	15.62	<.001
C - Targets	4	1367.912	47.74	<.001
N(A) - Error	27	84.672	<del>      </del>	
AB - Companys X Table	2	254.333	4.60	<.05
AC - Companys X Targets	8	22.566	----	N.S.
BC - Table X Targets	4	732.252	25.54	<.001
NB(A) - Error	27	55.282	<del>      </del>	
NC(A) - Error	108	28.653	<del>      </del>	
ABC - Companys X Table X Target	8	18.857	----	N.S.
NBC(A) - Error	108	29.843	<del>      </del>	

P Values of F

N.S = F value is not statistically significant.

<.05, <.01, <.005, <.001 = F value is significant at less than the percent value indicated.

TABLE 9-L-5

First Round Mean Values

UNIT IIF	PERFORMANCE (Timing Time)				
1. Overall Mean = 1.04					
2. Table VIII A (Day)	Table VIII B (Night)				
8.7	12.1				
3. Company	Co A	Co B	Co C		
	8.8	10.4	11.9		
4. Target	1	2	3	4	5
	9.1	7.3	18.6	7.0	9.8
5. Company	A (Day)	Table VIII			B (Night)
A	8.2				9.4
B	9.4				11.3
C	8.4				15.5
6.	Target				
Table VIII	1	2	3	4	5
A (Day)	6.2	---	19.8	7.2	10.2
B (Night)	12.0	14.6	17.5	6.8	9.4
7.	Target				
Company	1	2	3	4	5
A	8.3	5.2	16.6	5.8	8.3
B	7.5	7.3	18.7	8.2	10.2
C	11.6	9.5	20.6	7.1	11.0



(8) Analysis of the EMC Battalion (A Brigade 75 Battalion).

(a) Table 9-M-1 presents the Summary of Gunnery Performance Measures for the M Battalion. The figures are based on data from a total N of 27 tank crews: 4 in A Company, 9 in B Company, and 14 in C Company. Since the programmed analysis of variance tests required an equal N for the Company factor, data from only the first four crews in each company would have been used in the three-factor analysis. It was decided that this approach would not process data from enough crews. The analysis was changed by dropping out the Company factor and retaining the factors of Tables and Targets. In this way, data from all 27 crews were included in the two analyses of variance.

(b) Table 9-M-2 presents the results of the analysis of variance of first round  $\bar{P}_h$  scores. Significant effects were Targets ( $F=3.76$ ,  $p<.01$ ) and Tables X Targets ( $F=2.81$ ,  $p<.05$ ). The Target means, presented in Table 9-M-3, were compared in a Tukey's (HSD) Test. The results indicated that the  $\bar{P}_h$  score on Target 5 was significantly greater ( $p<.01$ ) than the  $\bar{P}_h$  score on Target 2. Examination of the means in the Tables X Targets interaction shows that on Targets 1, 2, and 3 higher scores were achieved on Table VIII A (Day) while on Targets 4 and 5 the higher  $\bar{P}_h$  scores were achieved on Table VIII B (Night).

(c) Table 9-M-4 presents the results of the analysis of variance of mean firing time. All effects were highly significant: Tables ( $F=23.89$ ,  $p<.001$ ), Targets ( $F=29.56$ ,  $p<.001$ ), and Tables X Targets ( $F=9.83$ ,  $p<.001$ ). Comparison of the means for Tables, presented in Table 9-M-5, indicated that first round mean firing time on Table VIII A (Day) was significantly faster ( $p<.001$ ) than on Table VIII B (Night). The means for Targets were analyzed in Tukey's (HSD) Test. The results indicated that the first round mean firing time on Target 3 was significantly slower ( $p<.01$ ) than on the other targets. Examination of the means of the Tables X Targets interaction, plotted in figure 9-M-2, reveals that there were no firing time measures for Target 2, Table VIII A (Day), which tends to bias the results of the analysis. Nevertheless, comparison of the means on the other targets uncovers some interesting relations. On Target 1, mean firing time was considerably faster on Table VIII A (Day) compared with Table VIII B (Night), whereas on Target 5, mean firing time was faster on Table VIII B (Night), than on Table VIII A (Day). On Targets 3 and 4, there was no practical difference in mean firing time between Table VIII A (Day) and B (Night).

(d) It is interesting to note that the best  $\bar{P}_h$  score occurred on Target 5, the moving target. Apparently, target motion, by itself, did not produce a decrease in marksmanship proficiency under the conditions of that engagement. Also, accuracy performance on the two shorter range battlesight engagements, Targets 1 and 5, were higher than on the longer range precision engagements. Turning to firing time measures, it was noticed that Target 3 was a TC-precision engagement. This suggests that the longer firing time could have been due to the tank commander taking more time than the gunner to fire precision engagements. Target 1 was the only target illuminated by Infrared light on Table VIII B and this factor might have produced the slower mean firing time.

TABLE 9-M-1

GUNNERY PERFORMANCE MEASURES

UNIT EMC ROUND 1 GUNNERY RANGE 2

TABLE VIII	TARGET CHARACTERISTICS						MEASURES							
	TARGET SE-QUENCE	RANGE (ME-TERS)	E M *	No. RNOS. AMMO	TARGET	I L L**	NO. OF CREWS	NO. OF HITS	NO. OF MISSES	F <sub>h</sub>	σ <sub>M</sub>	MEAN FIRING TIME	S.D.	rpb
A	1-9	650 & 750***	B	2 HEAT-T	Hull	A	27	20	7	.74	.09	5.33	6.39	-.27
A	1-9	1550 & 1800***	P	2 HEAT-T	Hull	A	27	12	14	.46	.10	-	-	-
A	1-9	1500	T	2 HEAT-T	Hull	A	27	13	14	.48	.10	20.08	8.56	.03
A	1-9	1200 & 1500	P	2 HEP-T	Hull	A	27	9	18	.33	.09	12.42	3.73	-.18
A	1-9	700 & 1000	B	2 TPDS-T	Moving Panel	A	27	16	11	.59	.10	10.00	3.52	.10
B	1-9	850 & 1100	I	2 HEAT-T	Hull	I	27	12	15	.44	.10	9.50	7.01	-.39
B	1-9	1500 & 1750	P	2 HEAT-T	Hull	W	27	8	19	.30	.09	16.33	7.15	.20
B	1-9	1550 & 1700	T	2 HEAT-T	Hull	W	27	11	15	.42	.10	22.17	8.38	.32
B	1-9	1100 & 1300	P	2 HEP-T	Hull	W	27	15	12	.56	.10	14.00	5.03	-.07
B	1-9	700 & 1000	B	2 TPDS-T	Moving Panel	W	27	21	2	.91	.06	7.92	5.00	.74

\* Engagement Method

- B = Gunner: Daylight Battlesight
- C = TC, Gunner: Rangecard
- I = Gunner: IR Battlesight
- P = Gunner: Daylight Precision
- R = Gunner: IR Precision
- S = TC: Daylight Battlesight
- T = TC: Daylight Precision
- X = TC: IR 50 Cal. Sight

\*\* Illumination

- A = Ambient Light
- P = Artificial White Light
- I = Infrared Light

\*\*\* Multiple Target Engagement

TABLE 9-M-2

TABLE VIII A and B

## ANALYSIS OF VARIANCE SUMMARY

UNIT EMC GUNNERY MEASURE First Round  $P_h$ 

SOURCE OF VARIATION	d.f.	MEAN SQUARE	F	P
B - Table	1	333.333	----	N.S.
C - Targets	4	8851.844	3.76	<.01
BC - Tables X Targets	4	6629.613	2.81	<.05
N(BC) - Error	260	2356.066		

## P Values of F

N.S. = F value is not statistically significant.  
 <.05, <.01, <.005, <.001 = F value is significant at less than the percent value indicated.

**TABLE 9-M-3**  
**First Round Mean Values**

UNIT	EMC	Performance Measure P <sub>h</sub>				
1. Overall Mean = 50.74						
2. Table VIII A (Day)			Table VIII B (Night)			
	51.85			49.63		
3. Target	1	2	3	4	5	
	59.3	37.0	44.4	44.4	68.5	
4.		TARGET				
Table VIII	1	2	3	4	5	
A (Day)	74.1	44.4	48.1	33.3	59.2	
B (Night)	44.4	29.6	40.7	55.6	77.8	

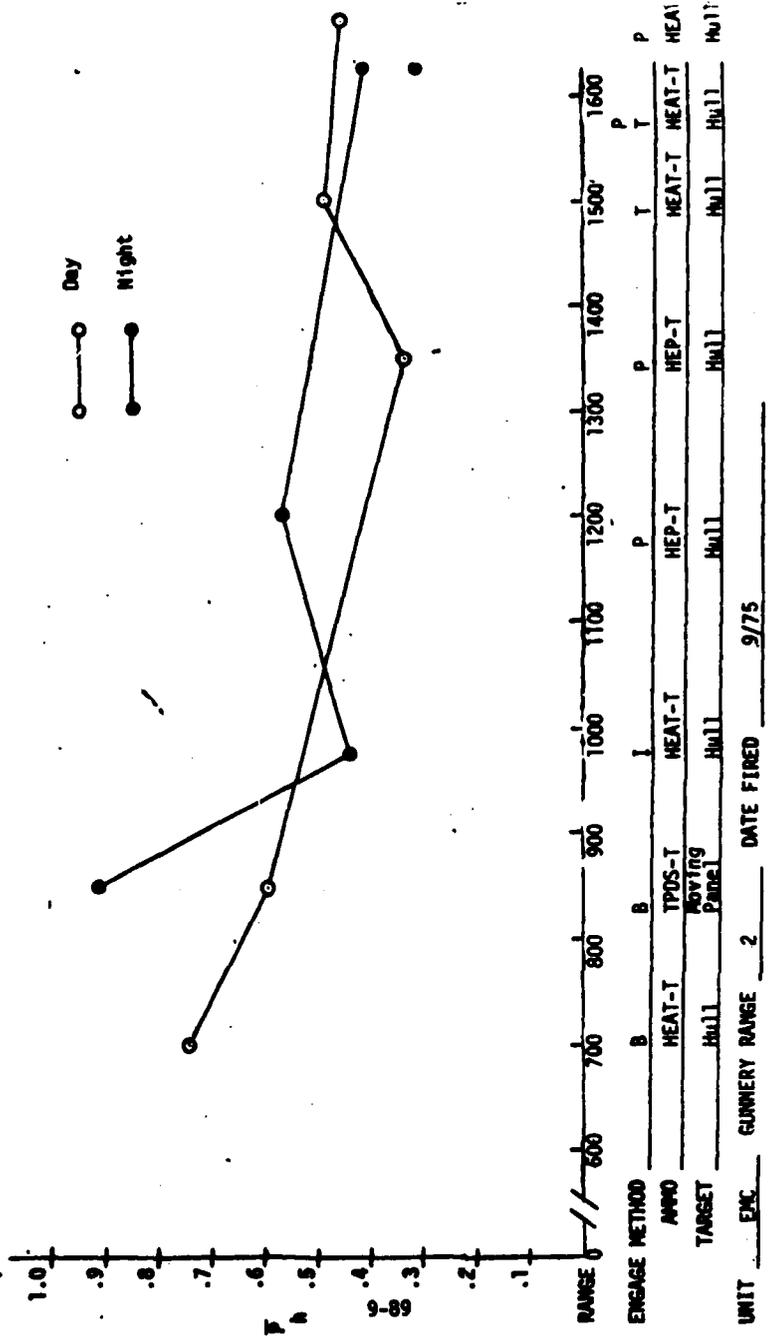


Figure 9-M-1 Mean First Round Hit Probability ( $F_h$ ) Performance on Table VIII Main Gun Targets.

TABLE 9-M-4  
 TABLE VIII A and B  
 ANALYSIS OF VARIANCE SUMMARY

UNIT EMC GUNNERY MEASURE First Round Firing Time

SOURCE OF VARIATION	d.f.	MEAN SQUARE	F	P
B - Table	1	1893.426	23.89	< .001
C - Targets	4	2025.734	29.56	< .001
BC - Tables X Targets	4	779.211	9.83	< .001
N (BC) - Error	260	79.255	----	

P Values of F

N.S. = F value is not statistically significant.

<.05, <.01, <.005, <.001 = F value is significant at less than the percent value indicated.

TABLE 9-M-5

First Round Mean Values

UNIT	EMC	PERFORMANCE MEASURE					Firing Time
1. Overall Mean		= 12.6					
2. Table VIII A (Day)		9.9					Table VIII B (Night)
		15.2					
3. Target	1	2	3	4	5		
	10.1	8.3	23.0	12.9	8.5		
4.	TARGET						
Table VIII	1	2	3	4	5		
A (Day)	5.5	0	21.8	12.7	9.6		
B (Night)	14.8	16.6	24.2	13.4	7.3		

Day   
 Night

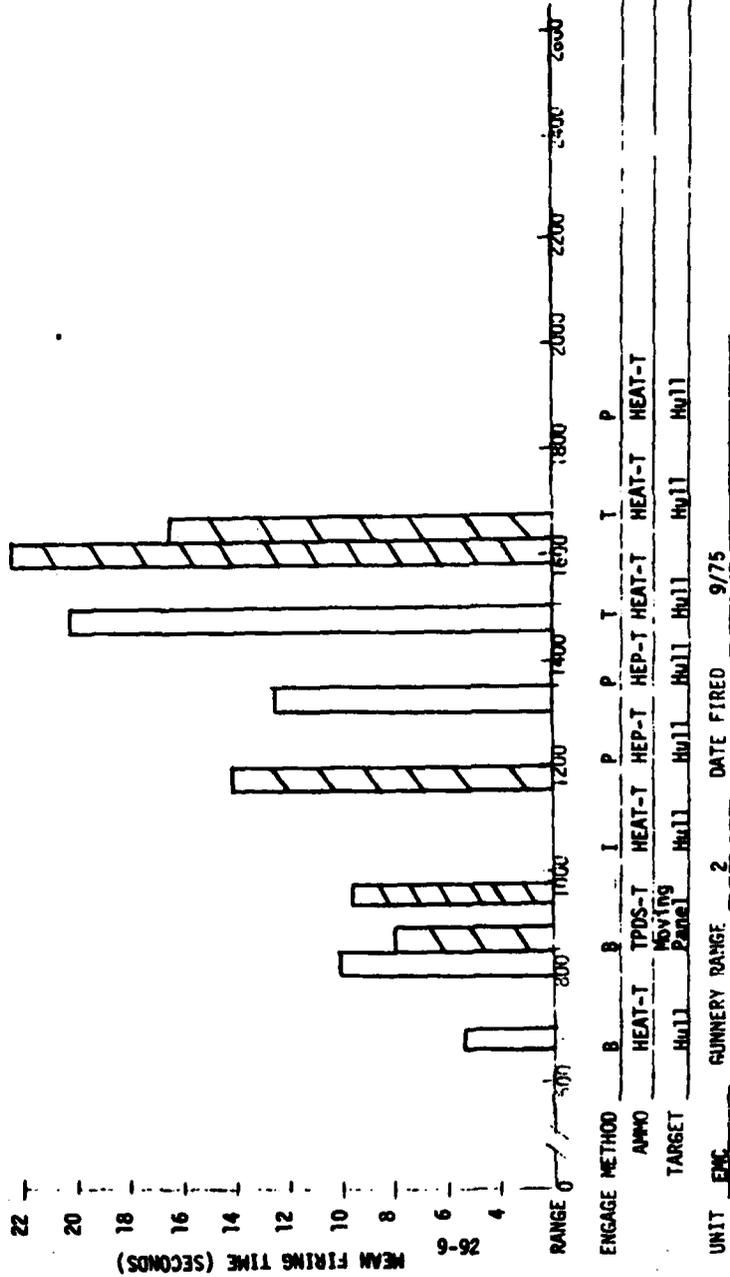


Figure 9-M-2 First Round Mean Firing Time on Table VIII Main Gun Targets

UNIT ENC GUNNERY RANGE 2 DATE FIRED 9/75

(9) Analysis of the ENG Battalion.

(a) Table 9-N-1 presents the Summary of Gunnery Performance Measures for the N Battalion. The statistics in table 9-N-1 and in the analyses of variance were based on data from a total N of 51 tank crews; 17 from each company.

(b) Table 9-N-2 presents the results of the analysis of variance of first round  $\bar{P}_h$  scores. Significant effects were Targets ( $F=8.77$ ,  $p < .005$ ), and Tables X Targets ( $F=3.71$ ,  $p < .01$ ). The Target means, presented in table 9-N-3, were analyzed in a Tukey's (HSD) Test. The results indicated that the  $\bar{P}_h$  score on Target 3 was significantly higher ( $p < .01$ ) than the  $\bar{P}_h$  scores on Target 2 and 5, while the  $\bar{P}_h$  score on Target 4 was significantly higher ( $p < .05$ ) than the  $\bar{P}_h$  score on Target 2. Examination of the  $\bar{P}_h$  scores for the Tables X Targets interaction, plotted in figure 9-N-1, indicated that on Targets 1 and 2,  $\bar{P}_h$  scores on Table VIII B (Night) were higher than  $\bar{P}_h$  scores on Table VIII A (Day), whereas on Target 5, the  $\bar{P}_h$  score attained on Table VIII A (Day) was much higher than the Table VIII B (Night) score.

(c) Table 9-N-4 presents the results of the analysis of variance of first round mean firing time scores. Table 9-N-4 shows that all main effects and interaction effects were statistically significant. The mean scores for the Companys effect ( $F=6.00$ ,  $p < .01$ ), presented in table 9-N-5, were analyzed in a Tukey's (HSD) Test. The results indicated that the mean firing time for C Company was significantly faster ( $p < .01$ ) than the mean firing time for B Company. Comparison of the means for the Tables effect ( $F=5.56$ ,  $p < .05$ ), revealed that the mean firing time on Table VIII B (Night) was significantly faster ( $p < .05$ ) than on Table VIII A (Day). The means for the Targets effect ( $F=39.42$ ,  $p < .001$ ) were analyzed in a Tukey's (HSD) Test. The results indicated that the mean firing time on Targets 3 and 4 were significantly faster ( $p < .01$ ) than the mean firing times on Targets 1, 2, and 5, while the mean firing time on Target 2 was significantly faster ( $p < .05$ ) than on Target 5. Inspection of the means for the Companys X Tables interaction ( $F=3.78$ ,  $p < .05$ ) revealed that A and B Company had faster mean firing times on Table VIII B (Night) compared with Table VIII A (Day), while C Company had its faster mean firing time on Table VIII A (Day). Examination of the means for the Companys X Targets interaction ( $F=7.19$ ,  $p < .001$ ) indicated that C Company's mean firing time on Target 5 was twice as fast as those for A and B Company. The means for the Tables X Targets interaction ( $F=5.13$ ,  $p < .005$ ), plotted in figure 9-N-2, indicated that there was virtually no difference in mean firing between Table VIII A (Day) and B (Night) on Targets 2 and 3, but a substantial difference on Targets 1 and 5 where mean firing time on Table VIII B (Night) was faster than on Table VIII A (Day). Inspection of the means in the Companys X Tables X Targets interaction ( $F=3.22$ ,  $p < .01$ ) revealed several differences; the two major ones were that Company A and B had much faster mean firing times on Target 5, Table VIII B (Night), than on Table VIII A (Day).

(d) Comparison of the target means in table 9-N-3 suggests that there was a decrement in  $\bar{P}_h$  performance on Target 2, probably due to the HEP ammo used for that engagement. Conversely,  $\bar{P}_h$  performance on Target 3, the battlesight engagement, using TPDS-T ammo, was relatively better even though it was a moving target.

TABLE 9-N-1

## GUNNERY PERFORMANCE MEASURES

UNIT ENG ROUND 1 GUNNERY RANGE 2

TABLE VIII	TARGET CHARACTERISTICS						MEASURES							
	TARGET SE-QUENCE	RANGE (ME-TERS)	E M *	No. RNDOS. AMMO	TARGET	I L L**	NO. OF CREWS	WT. OF HITS	NO. OF MISSES	P h	σ <sup>2</sup> M	MFAN FIRING TIME	S.D.	rpb
A	-9	1300-1750	T	2 HEAT-T	Hull	A	51	13	37	26	.06	17.29	6.38	-.04
A	-9	1500-1750	P	2 HEP-T	Hull	A	51	6	45	12	.05	14.94	5.05	-.05
A	-9	650-1500	B	2 TPDS-T	Moving Panel	A	51	29	22	57	.07	8.69	3.58	.05
A	-9	550-*** 1200	P	2 HEAT-T	Hull	A	51	21	30	41	.07	11.23	8.40	.02
A	-9	1100-*** 1800	P	2 HEAT-T	Hull	A	51	22	28	44	.07	19.94	13.65	.21
B	-9	1300-1800	T	2 HEAT-T	Hull	W	51	21	28	43	.07	14.27	5.55	.03
B	-9	1300-1500	P	2 HEP-T	Hull	W	51	18	33	35	.07	14.42	5.13	-.35
B	-9	700-1000	R	2 TPDS-T	Moving Panel	W	51	31	20	61	.07	8.96	5.04	-.23
B	-9	750-1100	T	2 HEAT-T	Hull	I	51	25	25	50	.07	10.04	5.61	-.21
B	-9	1550-1800	P	2 HEAT-T	Hull	W	51	11	40	22	.06	13.69	6.76	-.27

\* Engagement Method

B = Gunner: Daylight Battlesight  
 C = TC, Gunner: Rangecard  
 I = Gunner: IR Battlesight  
 P = Gunner: Daylight Precision  
 R = Gunner: IR Precision  
 S = TC: Daylight Battlesight  
 T = TC: Daylight Precision  
 X = TC: IR 50 Cal. Sight

\*\* Illumination

A = Ambient Light  
 W = Artificial White Light  
 I = Infrared Light

\*\*\* Multiple Target Engagement

TABLE 9-N-2  
TABLE VIII A and B  
ANALYSIS OF VARIANCE SUMMARY

UNIT EMB GUNNERY MEASURE First Round Ph

SOURCE OF VARIATION	d.f.	MEAN SQUARE	F	P
A - Companys	2	6372.547	2.80	N.S.
B - Table	1	4411.762	1.34	N.S.
C - Targets	4	17284.300	8.77	<.005
N(A) - Error	48	2276.936	X	
AB - Companys X Table	2	411.760	----	N.S.
AC - Companys X Targets	8	1813.711	----	N.S.
BC - Table X Targets	4	7990.172	3.71	<.01
NB(A) - Error	48	3286.669	X	
NC(A) - Error	192	1970.531	X	
ABC - Companys X Table X Target	8	2078.373	----	N.S.
NBC(A) - Error	192	2152.812	X	

P Values of F

N.S = F value is not statistically significant.

<.05, <.01, <.005, <.001 = F value is significant at less than the percent value indicated.

TABLE 9-N-3  
First Round Mean Values

UNIT ENG		PERFORMANCE MEASURE P <sub>h</sub>				
1. Overall Mean = 38.6						
2. Table VIII A (Day)		Table VIII B (Night)				
35.7		41.6				
3. Companys	Co A	Co B		Co C		
	40.6	43.5		31.8		
4. Target	1	2	3	4	5	
	33.3	24.5	57.8	45.1	32.4	
5. Company	A (Day)	Table VIII			B (Night)	
	A	36.5			44.7	
	B	42.4			44.7	
	C	28.2			35.3	
6.	Target					
Table VIII	1	2	3	4	5	
A (Day)	25.5	11.8	56.9	41.2	43.1	
B (Night)	41.2	37.3	58.8	49.0	21.6	
7.	Target					
Company	1	2	3	4	5	
A	38.2	23.5	52.9	52.9	35.3	
B	29.4	29.4	70.6	44.1	44.1	
C	32.4	20.6	50.0	38.2	17.6	

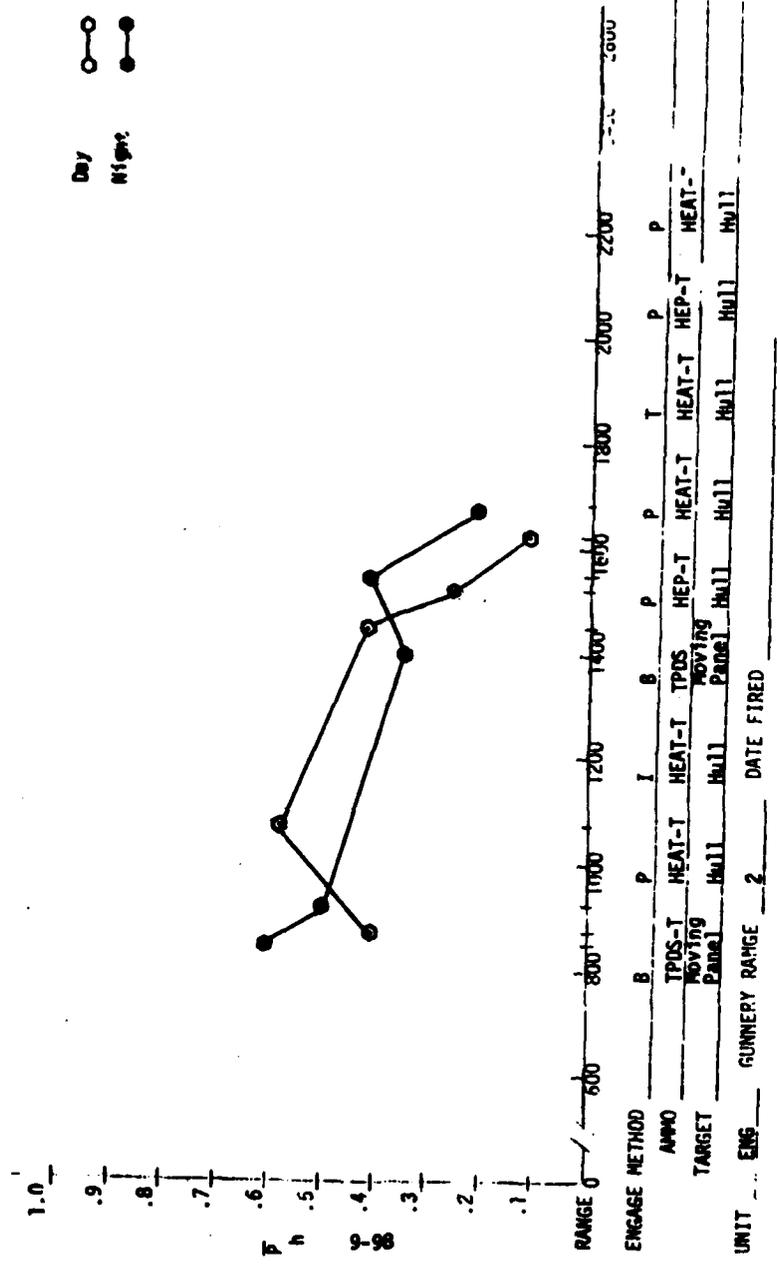


Figure 9-N-1 Mean First Round Hit Probability (P<sub>h</sub>) Performance on Table VIII Main Gun Target

TABLE 9-N-4

TABLE VIII A and B

## ANALYSIS OF VARIANCE SUMMARY

UNIT ENG GUNNERY MEASURE First Round Firing Time

SOURCE OF VARIATION	d. f.	MEAN SQUARE	F	P
A - Companys	2	471.155	6.00	<.01
B - Table	1	486.282	5.56	<.05
C - Targets	4	1216.741	39.42	<.001
N(A) - Error	48	78.580		
AB - Companys X Table	2	330.570	3.78	<.05
AC - Companys X Targets	8	221.945	7.19	<.001
BC - Table X Targets	4	163.011	5.13	<.005
NB(A) - Error	48	87.398		
NC(A) - Error	192	30.865		
ABC - Companys X Table X Target	8	102.203	3.22	<.01
NBC(A) - Error	192	31.767		

## P Values of F

N.S = F value is not statistically significant.

&lt;.05, &lt;.01, &lt;.005, &lt;.001 = F value is significant at less than the percent value indicated.

TABLE 9-N-5  
First Round Mean Values

UNIT	ENG	PERFORMANCE MEASURE					Firing Time
1.	Overall Mean =	13.2					
2.	Table VIII A (Day)	14.2					Table VIII B (Night)
		12.2					
3.	Company	Co A	Co B	Co C			
		13.3	14.8	11.5			
4.	Target	1	2	3	4	5	
		15.6	14.6	8.7	10.5	16.7	
5.	Company	A (Day)	Table VIII		B (Night)		
	A	15.6				11.1	
	B	16.0				13.6	
	C	11.0				12.0	
6.		Target					
	Table VIII	1	2	3	4	5	
	A (Day)	17.0	14.7	8.6	11.0	19.7	
	B (Night)	14.2	14.4	8.8	10.0	13.7	
7.		Target					
	Company	1	2	3	4	5	
	A	15.6	13.0	7.4	11.1	19.6	
	B	15.8	16.9	9.5	11.5	20.4	
	C	15.4	13.8	9.2	8.8	10.1	

Day   
 Night 

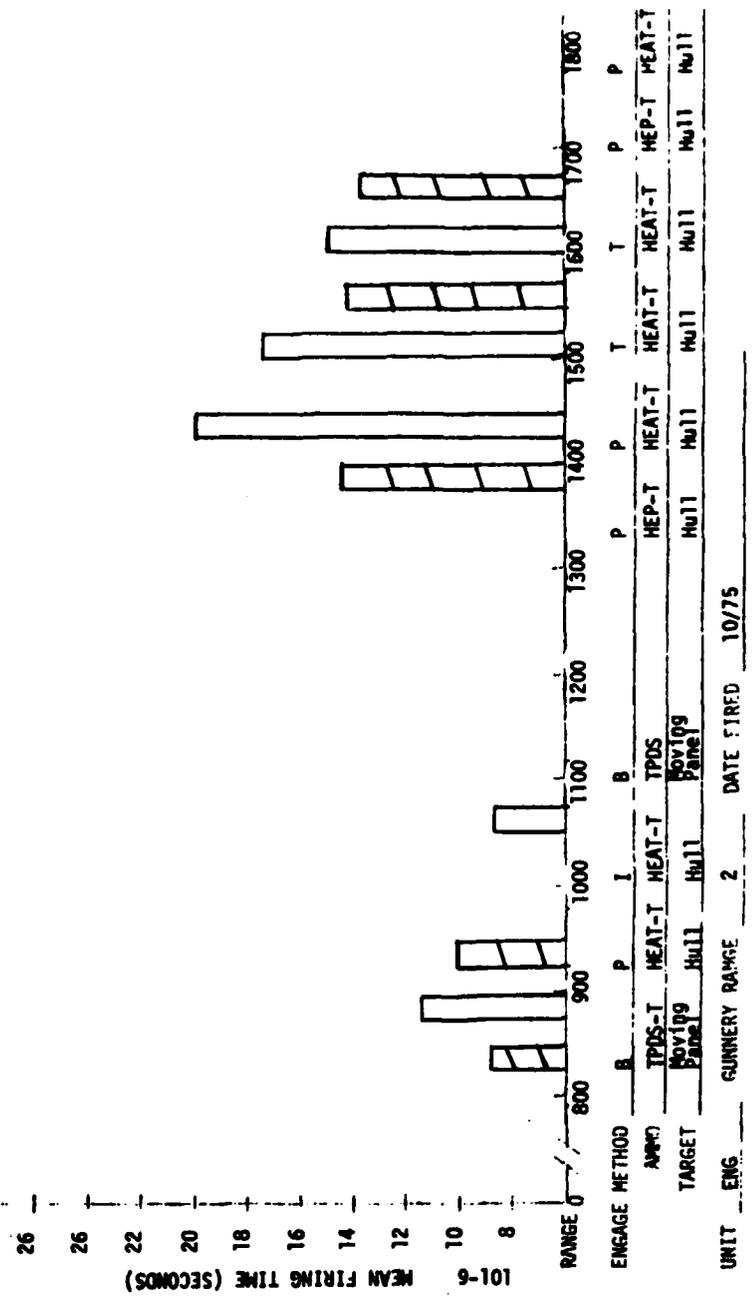


Figure 9-N-2 First Round Mean Firing Time on Table VIII Main Gun Targets

(10) Analysis of the EOG Battalion.

(a) Table 9-0-1 presents the Summary of Gunnery Performance Measures for the O Battalion. The statistics in table 9-0-1 and in the analyses of variance were based on data from a total N of 48 tank crews, 16 from each Company.

(b) Table 9-0-2 presents the results of the analysis of variance of first round  $\bar{P}_h$  scores. Significant effects were Targets ( $F=20.62$ ,  $p < .001$ ), and Companys X Targets ( $F=2.13$ ,  $p < .05$ ). The Target means, presented in table 9-0-3, were analyzed in a Tukey's (HSD) Test. The results indicated that the  $\bar{P}_h$  score attained on Target 3 was significantly higher ( $p < .01$ ) than the  $\bar{P}_h$  scores attained on the other targets. Also, the  $\bar{P}_h$  score on Target 2 was significantly lower ( $p < .05$ ) than the  $\bar{P}_h$  scores on Targets 1 and 5. Examination of the means in the Companys X Targets interaction indicated that B Company had the highest  $\bar{P}_h$  scores on Targets 1, 4 and 5; the lowest score on Target 3 and a low score on Target 2.

(c) Table 9-0-4 presents the results of the analysis of variance of first round mean firing time. Significant effects were Targets ( $F=17.99$ ,  $p < .001$ ), and Tables X Targets ( $F=10.12$ ,  $p < .005$ ). Comparison of the Targets means, presented in table 9-0-5, in a Tukey's (HSD) Test indicated that the mean firing time on Target 3, a battlesight engagement, was significantly faster than Targets 1, 2, and 4 at the .01 level of confidence and faster than Target 5 at the 0.5 level. Mean firing time for Target 1 was significantly slower ( $p < .01$ ) than on Targets 3, 4 and 5, and mean firing time on Target 5 was significantly faster ( $p < .05$ ) than on Target 2. Examination of the means for the Tables X Targets interaction, plotted in figure 9-0-2, revealed that on Targets 1, 2, and 3 mean firing time on Table VIII B (Night) was somewhat faster than on Table VIII A (Day). However, on Targets 4 and 5, Table VIII A (Day) mean firing time was faster especially on Target 5 where the day firing time was more than twice as fast as the night firing time.

(d) The target means in Table 9-0-3 show that  $\bar{P}_h$  performance on Target 3, the battlesight engagement of a moving target using TPDS-T ammo, was much better than on the other targets. It is not apparent why performance is better under these engagement conditions. The poor performance on Target 2 probably resulted because HEP was the ammo used. Study of the mean firing times revealed that mean firing time for the TC engagement, Target 1, was significantly slower than for the other targets using high velocity ammo. This suggests that the firing time for tank commanders is slower than it is for gunners.

TABLE 9-0-1

## GUNNERY PERFORMANCE MEASURES

UNIT EOG ROUND 1 GUNNERY RANGE 2

TABLE VIII	TARGET CHARACTERISTICS						MEASURES							
	TARGET SE-QUENCE	RANGE (ME-TERS)	E M *	No. RND.S. AMMO	TARGET	I L **	NO. OF CREWS	NO. OF HITS	NO. OF MISSES	P h	σ <sub>M</sub>	MEAN FIRING TIME	S.D.	rpb
A	1	1300-1700	T	2 HEAT-T	Hull	A	48	16	32	.33	.07	6.13	5.96	-.04
A	2	1500-1700	P	2 HEP-T	Hull	A	48	8	40	.17	.05	14.00	5.17	-.24
A	3	700-1000	B	2 TPDS-T	Moving Panel	A	48	40	8	.83	.05	9.04	3.19	.08
A	7	750-1100	P	2 HEAT-T	Hull	A	48	20	27	.43	.07	10.54	10.83	-.07
A	8	1200-1800	P	2 HEAT-T	Hull	A	48	21	25	.46	.07	6.73	10.45	.10
B	3	1300-1900	T	2 HEAT-T	Hull	W	48	23	25	.48	.07	14.54	5.21	-.21
B	4	600-1600	P	2 HEP-T	Hull	W	48	14	33	.30	.07	13.13	4.85	-.21
B	1	700-1000	B	2 TPDS-T	Moving Panel	W	48	36	12	.75	.06	7.56	3.01	-.07
B	5	700-1100	I	2 HEAT-T	Hull	I	48	17	30	.36	.07	11.96	6.83	-.01
B	2	1000-1700	P	2 HEAT-T	Hull	W	48	20	28	.42	.07	14.90	6.34	-.04

\* Engagement Method

B = Gunner: Daylight Battlesight  
 C = TC: Gunner: Rangecard  
 I = Gunner: IR Battlesight  
 P = Gunner: Daylight Precision  
 R = Gunner: IR Precision  
 S = TC: Daylight Battlesight  
 T = TC: Daylight Precision  
 X = TC: IR 50 Cal. Sight

\*\* Illumination

A = Ambient Light  
 W = Artificial White Light  
 I = Infrared Light

\*\*\* Multiple Target Engagement

TABLE 9-0-2

TABLE VIII A and B

ANALYSIS OF VARIANCE SUMMARY

UNIT FOG GUNNERY MEASURE First Round P<sub>h</sub>

SOURCE OF VARIATION	d. f.	MEAN SQUARE	F	P
A - Companys	2	6770.828	2.37	N.S.
B - Table	1	520.833	----	N.S.
C - Targets	4	41302.060	20.62	<.001
N(A) - Error	45	2854.119	<del>      </del>	
AB - Companys X Table	2	4645.824	1.55	N.S.
AC - Companys X Targets	8	4270.813	2.13	<.05
BC - Table X Targets	4	2760.391	1.64	N.S.
NB(A) - Error	45	3004.017	<del>      </del>	
NC(A) - Error	180	2003.376	<del>      </del>	
ABC - Companys X Table X Target	8	3135.352	1.86	N.S.
NBC(A) - Error	180	1687.819	<del>      </del>	

P Values of F

N.S. = F value is not statistically significant.

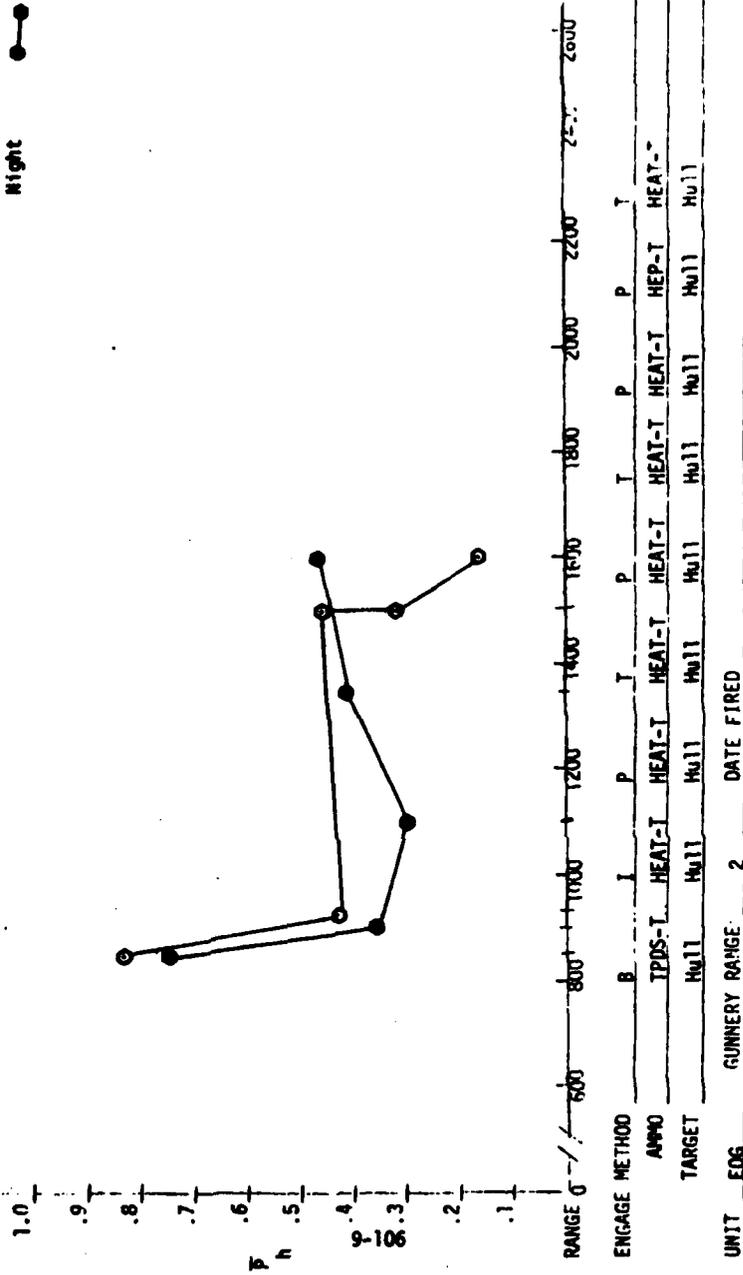
&lt;.05, &lt;.01, &lt;.005, &lt;.001 = F value is significant at less than the percent value indicated.

TABLE 9-0-3

First Round Mean Values

UNIT	FOG	PERFORMANCE (%)				
1.	Overall Mean =	44.8				
2.	Table VIII A (Day)	Table VIII B (Night)				
	43.8	45.8				
3.	Company	Co A	Co B	Co C		
		46.9	50.0	37.5		
4.	Target	1	2	3	4	5
		40.6	22.9	79.2	38.5	42.7
5.	Company	A (Day)			Table VIII B (Night)	
	A	40.0			53.8	
	B	50.0			50.0	
	C	41.3			33.8	
6.		Target				
	Table VIII	1	2	3	4	5
	A (Day)	33.3	16.7	83.3	41.7	43.8
	B (Night)	47.9	29.2	75.0	35.4	41.2
7.		Target				
	Company	1	2	3	4	5
	A	37.5	40.6	81.3	37.5	37.5
	B	53.2	15.6	71.9	50.0	59.4
	C	31.3	12.5	84.4	28.1	31.3

Day ○  
Night ●



RANGE G 800 1000 1200 1400 1600 1800 2000 2200 2400

ENGAGE METHOD B I P I P I P I P I P I P I P I

AMMO TPDS-T HEAT-T HEAT-T HEAT-T HEAT-T HEAT-T HEAT-T HEAT-T HEAT-T

TARGET Null Null Null Null Null Null Null Null Null Null

UNIT EDG GUNNERY RANGE 2 DATE FIRED

Figure 9-0-1 Mean First Round Hit Probability ( $P_h$ ) Performance on Table VIII Main Gun Target:

TABLE 9-0-4

TABLE VIIIA and B

ANALYSIS OF VARIANCE SUMMARY

UNIT EOG GUNNERY MEASURE First Round Firing Time

SOURCE OF VARIATION	d.f.	MEAN SQUARE	F	P
A - Companys	2	11.775	---	N.S.
B - Table	1	144.102	2.18	N.S.
C - Targets	4	695.894	17.99	< .001
N(A) - Error	45	57.664	<del>---</del>	
AB - Companys X Table	2	110.633	1.68	N.S.
AC - Companys X Targets	8	47.727	1.23	N.S.
BC - Table X Targets	4	406.276	10.12	< .005
NB(A) - Error	45	66.011	<del>---</del>	
NC(A) - Error	180	38.673	<del>---</del>	
ABC - Companys X Table X Target	8	55.278	1.38	N.S.
NBC(A) - Error	180	40.149	<del>---</del>	

## P Values of F

N.S = F value is not statistically significant.

&lt; .05, &lt; .01, &lt; .005, &lt; .001 = F value is significant at less than the percent value indicated.

**TABLE 9-0-5**  
**First Round Mean Values**

	UNIT EOG			PERFORMANCE Firing Time	
1.	Overall Mean = 11.9				
2.	Table VIII A (Day)			Table VIII B (Night)	
	11.3			12.4	
3.	Company	Co A	Co B	Co C	
		11.7	12.2	11.7	
4.	Target	1	2	3	4
		15.3	13.6	8.3	11.3
5.	Company	A (Day)		Table VIII B (Night)	
	A	12.1			11.3
	B	11.3			13.0
	C	10.5			12.9
6.			Target		
	Table VIII	1	2	3	4
	A (Day)	16.1	14.0	9.0	10.7
	B (Night)	14.5	13.1	7.6	12.0
7.				Target	
	Company	1	2	3	4
	A	14.6	12.8	7.1	12.2
	B	15.5	15.3	9.2	11.5
	C	15.9	12.6	8.6	10.3

Day   
 Night 

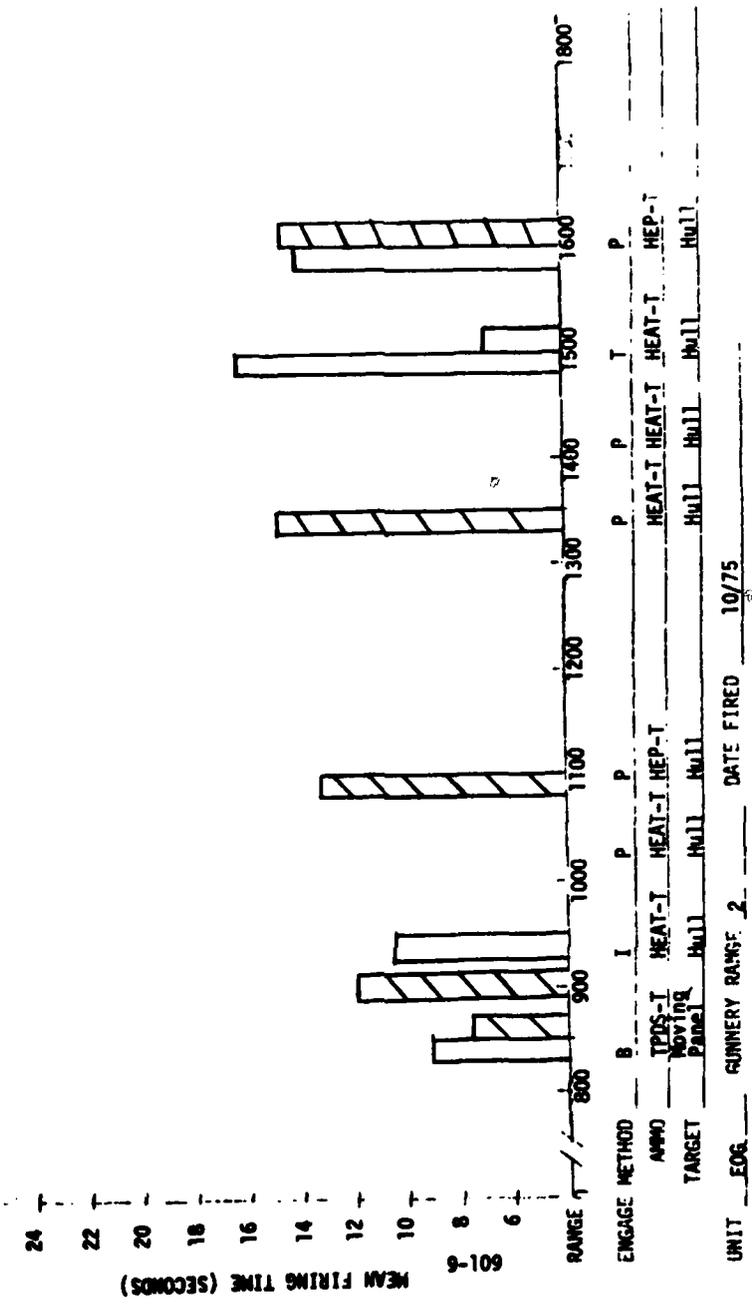


Figure 9-0-2 First Round Mean Firing Time on Table VIII Main Gun Targets

(11) Analysis of the UAA Battalion.

(a) Table 9-A-1 presents the Summary of Gunnery Performance Measures for the A Battalion. The statistics in table 9-A-1 and in the analyses of variance were based on data from a total N of 51 tank crews, 17 from each company.

(b) Table 9-A-2 presents the results of the analysis of variance of first round  $\bar{P}_h$  scores. Significant main effects were Tables ( $F=21.23, p < .001$ ), and Targets ( $F=18.92, p < .001$ ). The significant interaction was Tables X Targets ( $F=3.78, p < .05$ ). Comparison of the  $\bar{P}_h$  scores for the Tables main effect, presented in Table 9-A-3, indicates that  $\bar{P}_h$  scores were higher on Table VIII B (Night) than on Table VIII A (Day). The  $\bar{P}_h$  scores for the Targets main effect were analyzed in a Tukey's (HSD) Test. The results indicated that the  $\bar{P}_h$  scores on Targets 1 and 2 were significantly higher,  $p < .01$ , than the  $\bar{P}_h$  scores on Targets 3 and 4. Comparisons of the  $\bar{P}_h$  scores for the Tables X Targets interaction, plotted in figure 9-A-1, reveals that accuracy on Targets 1 and 3 was much less on Table VIII A (Day) than on Table VIII B (Night). The Target 3 engagement on Table VIII A (Day) used the training APDS ammo (TPDS-T) that has since been shown to have defective ballistic characteristics.

(c) Table 9-A-4 presents the results of the analysis of variance of first round firing time. Significant main effects were Companys ( $F=6.52, p < .01$ ), Tables ( $F=4.82, p < .05$ ), and Targets ( $F=40.15, p < .001$ ). A significant interaction was Companys X Tables X Targets ( $F=2.22, p < .05$ ). The means for the Companys main effect, presented in table 9-A-5, were analyzed for differences in a Tukey's (HSD) Test. The results indicated that the mean firing times for A and C Companys were significantly faster ( $p < .01$  and  $p < .05$ , respectively) than the mean firing time of B Company. Examination of the mean scores for the Tables main effect revealed that the mean firing time on Table VIII A (Day) was faster than on Table VIII B (Night). An analysis of the Target means by the Tukey's (HSD) Test indicated that the mean firing time on Targets 1 and 2 were significantly faster ( $p < .01$ ) than on Targets 3 and 4, while the mean firing time on Target 3 was also significantly faster ( $p < .01$ ) than Target 4. Examination of the mean scores for the Companys X Tables X Targets interaction indicated that A Company's mean firing time on Targets 1, Table VIII B (Night), was much faster than the means for B and C Company.

(d) The results produced three interesting findings. One,  $\bar{P}_h$  performance on Table VIII B (Night) was superior to that on Table VIII A (Day). The reason for this difference is not discernible in the examination of the specifications of the target characteristics and requires additional analysis for its cause. Two, accuracy was high on the engagements firing HEAT ammo and lower on those firing HEP ammo. The APDS-T

ammunition used on Target 4, Table VIII A was later found to be defective and was considered to be the main cause of the poor gunnery performance on that engagement. Three, mean firing time for the battlesight engagements were faster than for the precision engagements.

TABLE 9-A-1  
GUNNERY PERFORMANCE MEASURES

UNIT UAA ROUND 1 GUNNERY RANGE 1

TABLE VIII	TARGET CHARACTERISTICS						MEASURES							
	TARGET SE-QUENCE	RANGE (ME-TERS)	E M *	No. RND. AMMO	TARGET	I L L**	NO. OF CREWS	NO. OF HITS	NO. OF MISSES	P <sub>h</sub>	σ <sub>M</sub>	MEAN FIRING TIME	S.D.	rpb
A	2	1720	B	2 HEAT-T	Hull	A	51	27	24	.53	.07	7.75	2.76	-.23
A	3	1000	B	2 HEAT-T	Hull	A	51	37	13	.74	.06	7.45	4.39	-.01
A	6	1894	P	2 APDS-T	Moving Panel	A	51	10	41	.20	.06	12.71	4.94	-.17
A	7	1495	P	2 HEP-T	Hull	A	51	23	27	.46	.07	14.61	5.67	.11
B	2	1720	B	2 HEAT-T	Hull	W	51	45	6	.88	.05	10.18	5.33	-.14
B	3	1100	I	2 HEAT-T	Hull	I	51	40	10	.80	.06	9.43	4.41	.04
B	4	820	P	2 HEAT-TPT	Moving Panel	W	51	27	23	.54	.07	12.02	4.40	-.01
B	7	1495	P	2 HEP-T	Hull	W	51	25	24	.51	.07	13.96	8.73	.13

\* Engagement Method

- B = Gunner: Daylight Battlesight
- C = TC, Gunner: Rangecard
- I = Gunner: IR Battlesight
- P = Gunner: Daylight Precision
- R = Gunner: IR Precision
- S = TC: Daylight Battlesight
- T = TC: Daylight Precision
- X = TC: IR 50 Cal. Sight

\*\* Illumination

- A = Ambient Light
- W = Artificial White Light
- I = Infrared Light

TABLE 9-A-2

TABLE VIII and II

## ANALYSIS OF VARIANCE SUMMARY

UNIT UAA GUNNERY MEASURE 1st Round P<sub>h</sub>

SOURCE OF VARIATION	d.f.	MEAN SQUARE	F	P
A - Companys	2	4926.455	1.45	N.S.
B - Table	1	39215.680	21.23	<.001
C - Targets	3	35849.660	18.92	<.001
N(A) - Error	48	3397.613		
AB - Companys X Table	2	1053.904		N.S.
AC - Companys X Targets	6	776.115		N.S.
BC - Table X Targets	3	7385.625	3.78	<.05
NB(A) - Error	48	1847.377		
NC(A) - Error	144	1894.367		
ABC - Companys X Table X Target	6	1086.542		N.S.
NBC(A) - Error	144	1953.551		

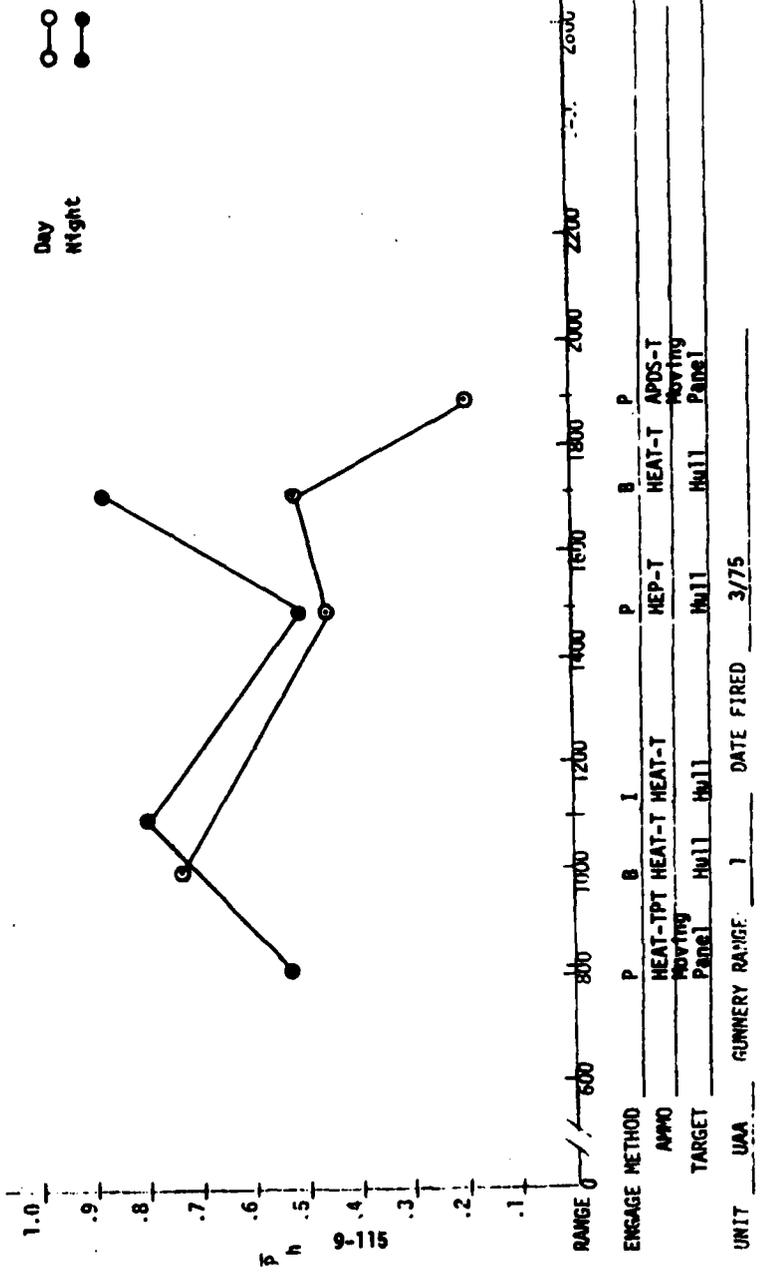
## P Values of F

N.S = F value is not statistically significant.

&lt;.05, &lt;.01, &lt;.005, &lt;.001 = F value is significant at less than the percent value indicated.

**TABLE 9-A-3**  
**First Round Mean Values**

UNIT UAA	PERFORMANCE MEASURE P <sub>h</sub>			
1. Overall Mean = 57.4				
2. Table VIII A (Day)	Table VIII B (Night)			
	47.5		67.2	
3. Companys	Co. A	Co. B	Co. C	
	62.5	50.7	58.8	
4. Target	1	2	3	4
	70.6	75.5	36.3	47.1
5. Company	A (Day)		Table VIII B (Night)	
A	55.9		69.1	
B	39.7		61.8	
C	47.1		70.6	
6.		Target		
Table VIII	1	2	3	4
A (Day)	52.9	72.5	19.6	45.1
B (Night)	88.2	78.4	52.9	49.0
7.		Target		
Company	1	2	3	4
A	76.5	82.4	35.3	55.9
B	61.8	64.7	35.3	41.2
C	73.5	79.4	38.2	44.1



ENGAGE METHOD P B I P P B P  
 AMMO HEAT-TPT HEAT-T HEAT-T HEAT-T HEAT-T APDS-T  
 MOVING Moving  
 TARGET Panel Hull Hull Hull Hull Hull  
 UNIT UAA GUNNERY RANGE 1 DATE FIRED 3/75

Figure 9-A-1 Mean First Round Hit Probability (Ph) Performance on Table VIII Main Gun Target...

TABLE 9-A-4

TABLE VIII A and B

## ANALYSIS OF VARIANCE SUMMARY

UNIT UAA GUNNERY MEASURE 1st Round Firing Time

SOURCE OF VARIATION	d.f.	MEAN SQUARE	F	p
A - Companys	2	258.900	6.52	< .01
B - Table	1	141.177	4.82	< .05
C - Targets	3	948.895	40.15	< .001
N(A) - Error	48	39.731	<del>      </del>	
AB - Companys X Table	2	17.412		N.S.
AC - Companys X Targets	6	33.875	1.43	N.S.
BC - Table X Targets	3	44.320	2.02	N.S.
NB(A) - Error	48	29.296	<del>      </del>	
NC(A) - Error	144	23.636	<del>      </del>	
ABC - Companys X Table X Target	6	48.712	2.22	< .05
NBC(A) - Error	144	21.922	<del>      </del>	

## P Values of F

N.S = F value is not statistically significant.

&lt; .05, &lt; .01, &lt; .005, &lt; .001 = F value is significant at less than the percent value indicated.

TABLE 9-A-5

First Round Mean Values

UNIT	UAA	PERFORMANCE MEASURE				Firing Time
1. Overall Mean	= 11.3					
2. Table VIII (Day)					Table VIII B (Night)	
	10.7					11.9
3. Companys	Co. A	Co. B	Co. C			
	10.1	12.8	11.0			
4. Target	1	2	3	4		
	9.1	8.7	12.3	15.2		
5. Company	A (Day)	Table VIII		B (Night)		
A	9.9			10.3		
B	12.1			13.6		
C	10.2			11.8		
6.	Target					
Table VIII	1	2	3	4		
A (Day)	7.8	7.7	12.5	14.9		
B (Night)	10.4	9.6	12.1	15.5		
7.	Target					
Company	1	2	3	4		
A	7.9	7.5	12.3	12.8		
B	10.9	10.7	12.6	17.0		
C	8.5	7.8	12.0	15.7		



(12) Analysis of the UFC Battalion (A Brigade J5 Battalion).

(a) Table 9-F-1 presents the Summary of Gunnery Performance Measures for the F Battalion. The statistics in table 9-F-1 and in the analyses of variance were based on data from a total N of 51 tank crews, 17 from each company.

(b) Table 9-F-2 presents the results of the analysis of variance of first round  $\bar{P}_h$  scores. Significant main effects were Companys (F=3.89,  $p < .05$ ), Tables (F=45.37,  $p < .001$ ), and Targets (F=29.37,  $p < .001$ ). A significant interaction effect was Tables X Targets (F=16.17,  $p < .001$ ). The Companys  $\bar{P}_h$  scores, presented in table 9-F-3, were analyzed for significant differences with a Tukey's (HSD) Test. The results indicated the  $\bar{P}_h$  score for A Company was significantly higher ( $p < .05$ ) than the  $\bar{P}_h$  value for C Company. Examination of the  $\bar{P}_h$  values for the Tables indicated that the Table VIII B (Night) mean was much higher than the Table VIII A (Day) mean. The Targets main effect and Tables X Targets interaction is best described by the latter. Examination of the means for the Tables X Targets treatments, plotted in figure 9-F-1, reveals an incredible performance difference for Target 1 on Table VIII A and B.  $\bar{P}_h$  changes from .02 on the day engagement to an exceedingly high .77 on the night engagement.  $\bar{P}_h$  values for the three other targets appear to be within the normal performance range.

(c) Table 9-F-4 presents the results of the analysis of variance of first round mean firing time. There was one significant effect, the Targets main effect (F=51.34,  $p < .001$ ). A Tukey's (HSD) Test was used to analyze differences between Target means, presented in table 9-F-5. The results indicated that the mean firing time on Target 3 was significantly faster ( $p < .01$ ) than the mean firing times on the other three targets, and that the mean firing times on Targets 1 and 2 were significantly faster than the mean firing time on Target 4. Target 3 was the battlesight engagement and Target 4 the range card engagement. Apparently, mean firing time was affected mainly by engagement method.

(d) It is difficult to believe that a  $\bar{P}_h$  score of .77 on Target 1, Table VIII B, is an accurate and reliable measure of performance. Perhaps a more plausible interpretation might be that it was difficult to sense hits and misses reliably at such a long range and that doubtful sensings were scored as hits. On the other hand,  $\bar{P}_h$  performance on Target 3, the battlesight engagement, was very high on both Table VIII A and B, indicating superior marksmanship under the conditions of that engagement. Also, the battalion tank crews performed better on Table VIII B (Night) than on Table VIII A (Day); an unexpected difference.

TABLE 9-F-1

GUNNERY PERFORMANCE MEASURES

UNIT UFC ROUND 1 GUNNERY RANGE 3

TABLE VIII	TARGET CHARACTERISTICS						MEASURES							
	TARGET SE-QUENCE	RANGE (ME-TERS)	E M *	No. RND. AMMO	TARGET	I L L**	NO. OF CREWS	NO. OF HITS	NO. OF MISSES	P h	σ <sub>M</sub>	MEAN FIRING TIME	S.D.	rpb
A	1	2500	P	2 HEAT-TPT	Hull	A	51	1	50	.02	.03	23.06	16.52	-.08
A	4	1600	P	2 HEAT-TPT	Moving Panel	A	51	17	34	.33	.05	19.57	11.76	-.08
A	6	1300	B	2 HEAT-TPT	Hull	A	51	39	11	.78	.06	11.82	5.35	-.34
A	8	870	C	1 HEP	Hull	A	51	29	21	.58	.07	37.22	22.32	-.38
B	1	2500	P	2 HEAT-TPT	Hull	W	51	39	12	.77	.04	21.67	5.96	-.23
B	4	1600	P	2 HEAT-TPT	Moving Panel	W	51	24	27	.47	.05	23.49	12.69	-.03
B	6	1300	B	2 HEAT-TPT	Hull	W	51	44	7	.86	.05	13.37	13.93	-.63
B	8	870	C	1 HEP	Hull	W	51	44	7	.86	.05	33.84	12.21	-.01

\* Engagement Method

- B = Gunner: Daylight Battlesight
- C = TC, Gunner: Rangecard
- I = Gunner: IR Battlesight
- P = Gunner: Daylight Precision
- R = Gunner: IR Precision
- S = TC: Daylight Battlesight
- T = TC: Daylight Precision
- X = TC: IR 50 Cal. Sight

\*\* Illumination

- A = Ambient Light
- W = Artificial White Light
- I = Infrared Light

TABLE 9-F-2

TABLE VIII A and B

## ANALYSIS OF VARIANCE SUMMARY

UNIT UFC GUNNERY MEASURE 1st Round  $P_h$ 

SOURCE OF VARIATION	d. f.	MEAN SQUARE	F	P
A - Companys	2	8161.758	3.89	<.05
B - Table	1	103553.900	45.37	<.001
C - Targets	3	47606.210	29.37	<.001
N(A) - Error	48	2098.641	<del>      </del>	
AB - Companys X Table	2	318.594		N.S.
AC - Companys X Targets	6	2508.135	1.55	N.S.
BC - Table X Targets	3	22442.810	16.17	<.001
NB(A) - Error	48	2282.325	<del>      </del>	
NC(A) - Error	144	1620.689	<del>      </del>	
ABC - Companys X Table X Target	6	678.063	----	N.S.
NBC(A) - Error	144	1387.787	<del>      </del>	

## P Values of F

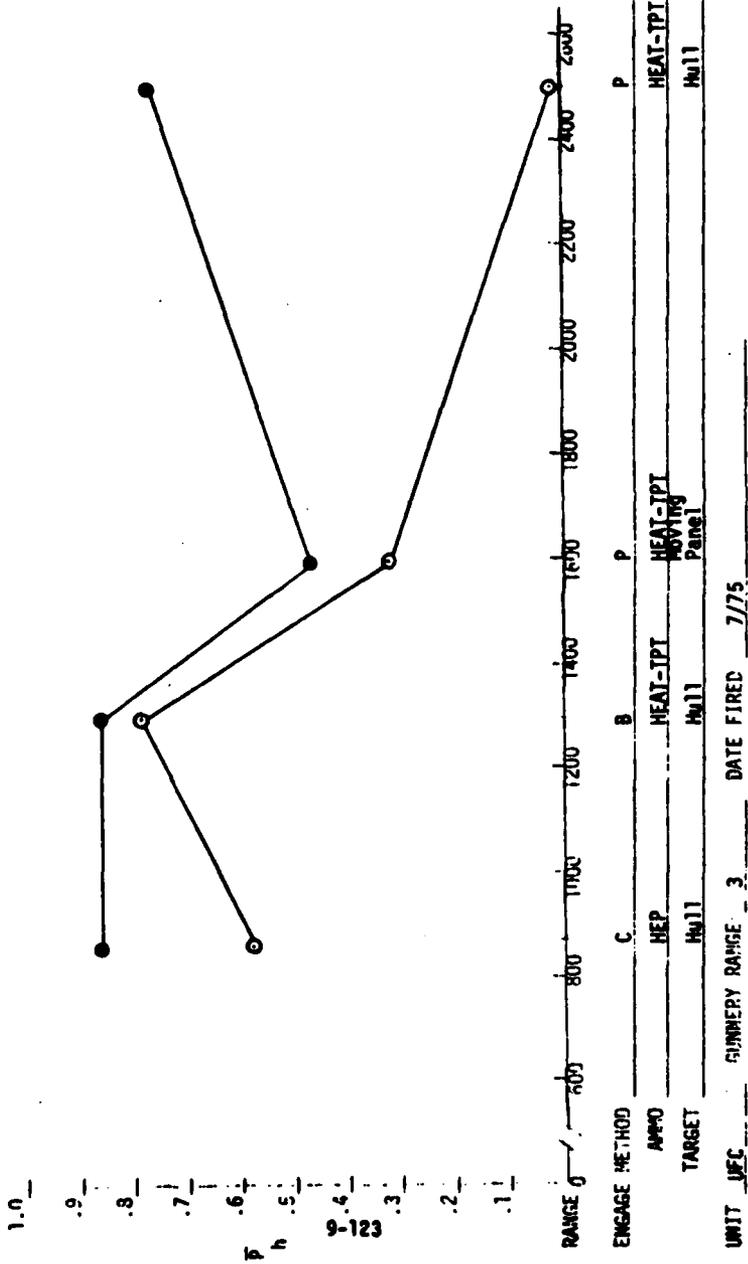
N.S = F value is not statistically significant.

&lt;.05, &lt;.01, &lt;.005, &lt;.001 = F value is significant at less than the percent value indicated.

TABLE 9-F-3  
First Round Mean Values

UNIT	UFC	PERFORMANCE Ph			
1.	Overall Mean =	58.1			
2.	Table VIII A (Day)	Table VIII B (Night)			
	42.2	74.0			
3.	Company	Co A	Co B	Co C	
		66.2	57.4	50.7	
4.	Target	1	2	3	4
		39.2	40.2	81.4	71.6
5.	Company	A (Day)	Table VIII		B (Night)
	A	51.5			80.9
	B	39.7			75.0
	C	35.3			66.2
6.		Target			
	Table VIII	1	2	3	4
	A (Day)	2.0	33.3	76.5	56.9
	B (Night)	76.5	47.1	86.3	86.3
7.		Target			
	Company	1	2	3	4
	A	41.2	52.9	82.4	88.2
	B	38.2	44.1	85.3	61.8
	C	38.2	23.5	76.5	64.7

Day ○  
Night ●



ENGAGE METHOD	C	B	P	P
AMMO	HEP	HEAT-TPI	HEAT-TPI	HEAT-TPI
TARGET	Mu11	Mu11	Moving Panel	Mu11

UNIT DEC \_\_\_\_\_ GUNNERY RANGE 3 DATE FIRED 7/75

Figure 9-F-1 Mean First Round Hit Probability (P<sub>h</sub>) Performance on Table VIII Main Gun Targets.

TABLE 9-f-4

TABLE VIIIA and B

## ANALYSIS OF VARIANCE SUMMARY

UNIT UFC GUNNERY MEASURE 1st Round Firing Time

SOURCE OF VARIATION	d. f.	MEAN SQUARE	F	P
A - Companys	2	68.708	----	N.S.
B - Table	1	3.176	----	N.S.
C - Targets	3	9103.684	51.34	<.001
N(A) - Error	48	302.649	<del>      </del>	
AB - Companys X Table	2	364.198	1.87	N.S.
AC - Companys X Targets	6	95.191	----	N.S.
BC - Table X Targets	3	263.200	1.75	N.S.
NB(A) - Error	48	194.380	<del>      </del>	
NC(A) - Error	144	177.307	<del>      </del>	
ABC - Companys X Table X Target	6	220.681	1.46	N.S.
NBC(A) - Error	144	150.821	<del>      </del>	

## P Values of F

N.S = F value is not statistically significant.

&lt;.05, &lt;.01, &lt;.005, &lt;.001 = F value is significant at less than the percent value indicated.

TABLE 9-F-5

First Round Mean Values

UNIT	UFC	PERFORMANCE	Firing Time	
1. Overall Mean	23.0			
2. Table VIII A (Day)	22.9			
	Table VIII B (Night)			
	23.1			
3. Companys	Co A	Co B	Co C	
	22.2	23.6	23.2	
4. Target	1	2	3	4
	22.4	21.5	12.6	35.5
5. Company	A (Day)	Table VIII		B (Night)
A	22.3			22.1
B	21.8			25.4
C	24.7			21.8
6.	Target			
Table VIII	1	2	3	4
A (Day)	23.1	19.7	11.8	37.2
B (Night)	21.7	23.5	13.4	33.8
7.	Target			
Company	1	2	3	4
A	22.3	19.7	11.0	35.8
B	20.8	23.5	13.2	36.9
C	24.0	21.4	13.6	33.9

Day  Night  77

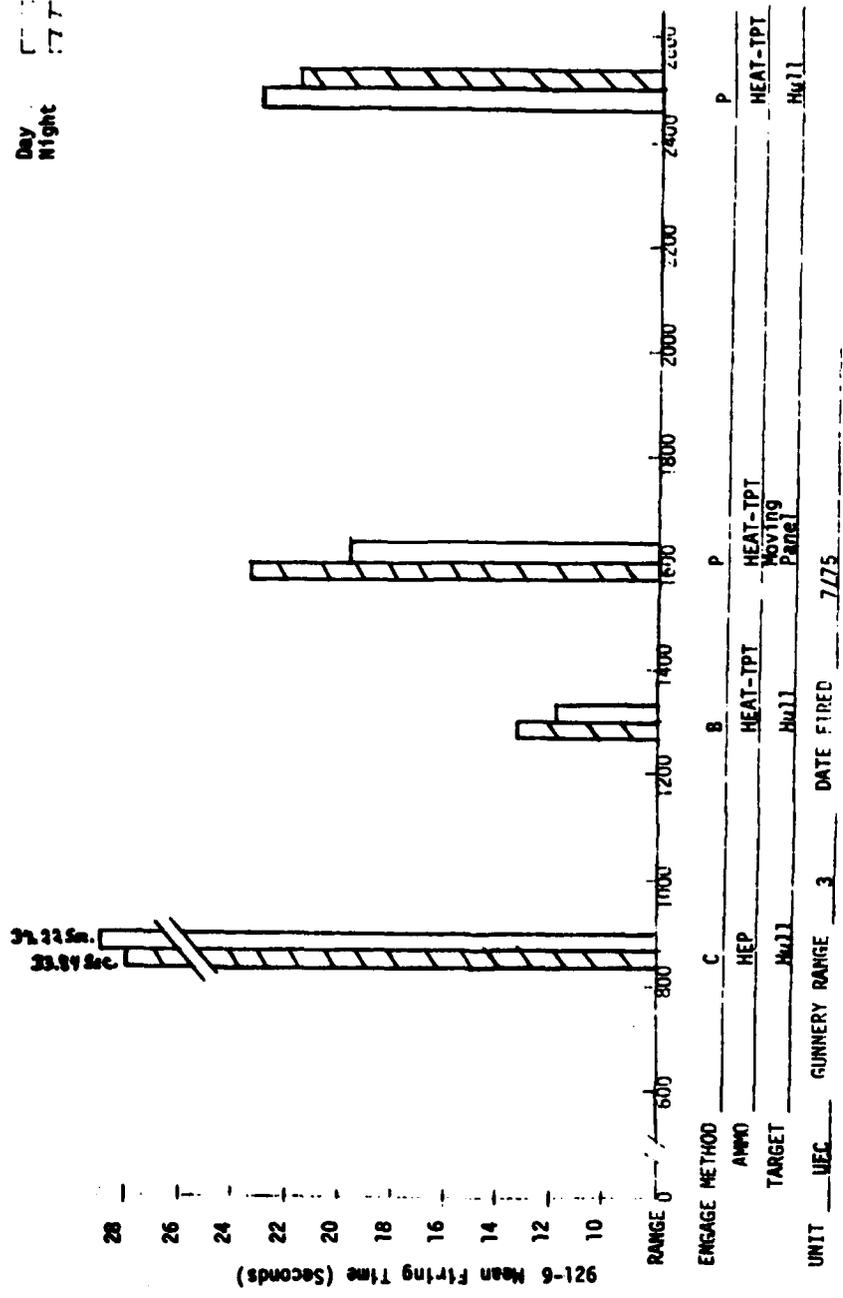


Figure 9-F-2 First Round Mean Firing Time on Table VIII Main Gun Targets

(13) Analysis of the UIC Battalion.

(a) Table 9-I-1 presents the Summary of Gunnery Performance Measures for the I Battalion. The statistics in table 9-I-1 and in the analyses of variance were based on data from a total N of 51 tank crews, 17 from each company.

(b) Table 9-I-2 presents the results of the analysis of variance of first round  $\bar{P}_h$  scores. Significant main effects were Companys ( $F=4.14, p < .05$ ), Tables ( $F=10.02, p < .005$ ) and Targets ( $F=21.65, p < .001$ ). The significant interaction effect was Tables X Targets ( $F=3.67, p < .05$ ). The Company means, presented in table 9-I-3, were compared in a Tukey's (HSD) Test. The results indicated that the  $\bar{P}_h$  score for A Company, 67.65, was significantly higher ( $p < .05$ ) than B Company's  $\bar{P}_h$  of 52.94. Comparison of the Tables means revealed that  $\bar{P}_h$  scores were significantly higher on Table VIII B (Night) than on Table VIII A (Day). The means for Targets were analyzed in a Tukey's (HSD) Test. The results indicated that  $\bar{P}_h$  scores on Targets 3 and 4 were significantly higher ( $p < .01$ ) than the  $\bar{P}_h$  scores on Targets 1 and 2. The plots of the treatment means for the Tables X Targets interaction are presented in figure 9-I-1. Examination of the graph indicates that on Targets 4 and 1,  $\bar{P}_h$  performance was higher on Table VIII B (Night) than on Table VIII A (Day), while there was no performance difference between tables on Targets 2 and 3.

(c) Table 9-I-4 presents the results of the analysis of variance of first round mean firing time. There was one significant main effect, Targets ( $F=53.29, p < .001$ ). Significant interaction effects were Tables X Targets ( $F=7.31, p < .005$ ), and Companys X Tables X Targets ( $F=3.65, p < .005$ ). The Target means, presented in table 9-I-5, were compared in a Tukey's (HSD) Test. The results indicated that the mean firing time on Target 3, 12.06 seconds, was significantly faster ( $p < .01$ ) than on the other three targets. Mean firing time on Target 2 was significantly faster than on Targets 1 and 4,  $p < .05$  and  $p < .01$ , respectively. Mean firing time on Target 4 was significantly slower ( $p < .01$ ) than on the other three targets. Examination of the means for the Tables X Targets interaction, presented in figure 9-I-2, shows that on Target 4 mean firing time was faster on Table VIII B (Night) than on Table VIII A (Day), whereas the reverse relation was the case on the other three targets. Examination of the means for the Companys X Tables X Targets interaction did not detect any relations that were noteworthy.

(d) This is the third CONUS battalion in which  $\bar{P}_h$  performance on Table VIII B (Night) was superior to that on Table VIII A (Day). Another interesting finding was that  $\bar{P}_h$  performance on the battlesight engagement, Target 3, was very high on both Table VIII A and B. Also, mean firing time on the precision engagements, Targets 1 and 2, seemed to be rather slow.

TABLE 9-1-1

GUNNERY PERFORMANCE MEASURES

UNIT UIC ROUND 1 GUNNERY RANGE 3

TABLE VIII	TARGET CHARACTERISTICS						MEASURES							
	TARGET SE-QUENCE	RANGE (ME-TERS)	E M *	No. RND. AMMO	TARGET	T L L**	NO. OF CREWS	NO. OF HITS	NO. OF MISSES	h	σ <sub>M</sub>	MEAN FIRING TIME	S.D.	rpb
A	1	2500	P	2 HEAT-TPT	Hull	A	51	13	38	26	.06	25.82	19.49	-.18
A	4	1600	P	2 HEAT-TPT	Moving Panel	A	51	26	23	53	.07	20.27	10.69	-.09
A	6	1300	B	2 HEAT-TPT	Hull	A	51	39	11	78	.06	11.16	5.41	-.12
A	8	870	C	1 HEP	Hull	A	51	31	20	61	.07	44.96	25.67	-.03
B	1	2500	P	2 HEAT-TPT	Hull	W	51	25	26	49	.07	33.02	18.42	-.14
B	4	1600	P	2 HEAT-TPT	Moving Panel	W	51	23	28	45	.07	25.45	9.73	-.12
B	6	1300	B	2 HEAT-TPT	Hull	W	51	42	9	82	.05	12.96	6.24	-.60
B	8	870	C	1 HEP	Hull	W	51	46	5	90	.04	35.90	19.83	-.14

- \* Engagement Method
- B = Gunner: Daylight Battlesight
- C = TC, Gunner: Rangecard
- I = Gunner: IR Battlesight
- P = Gunner: Daylight Precision
- R = Gunner: IR Precision
- S = TC: Daylight Battlesight
- T = TC: Daylight Precision
- X = TC: IR 50 Cal. Sight

- \*\* Illumination
- A = Ambient Light
- W = Artificial White Light
- I = Infrared Light

TABLE 9-1-2

TABLE VIIIA and B

## ANALYSIS OF VARIANCE SUMMARY

UNIT UIC GUNNERY MEASURE 1st Round P<sub>n</sub>

SOURCE OF VARIATION	d.f.	MEAN SQUARE	F	P
A - Companys	2	7377.445	4.14	<.05
B - Table	1	17867.640	10.02	<.005
C - Targets	3	43423.190	21.65	<.001
N(A) - Error	48	2610.282	<del>      </del>	
AB - Companys X Table	2	1397.045	----	N.S.
AC - Companys X Targets	6	4109.445	2.05	N.S.
BC - Table X Targets	3	6691.145	3.67	<.05
NB(A) - Error	48	1783.066	<del>      </del>	
NC(A) - Error	144	2005.672	<del>      </del>	
ABC - Companys X Table X Target	6	1004.839	----	N.S.
NBC(A) - Error	144	1823.834	<del>      </del>	

## P Values of F

N.S = F value is not statistically significant.

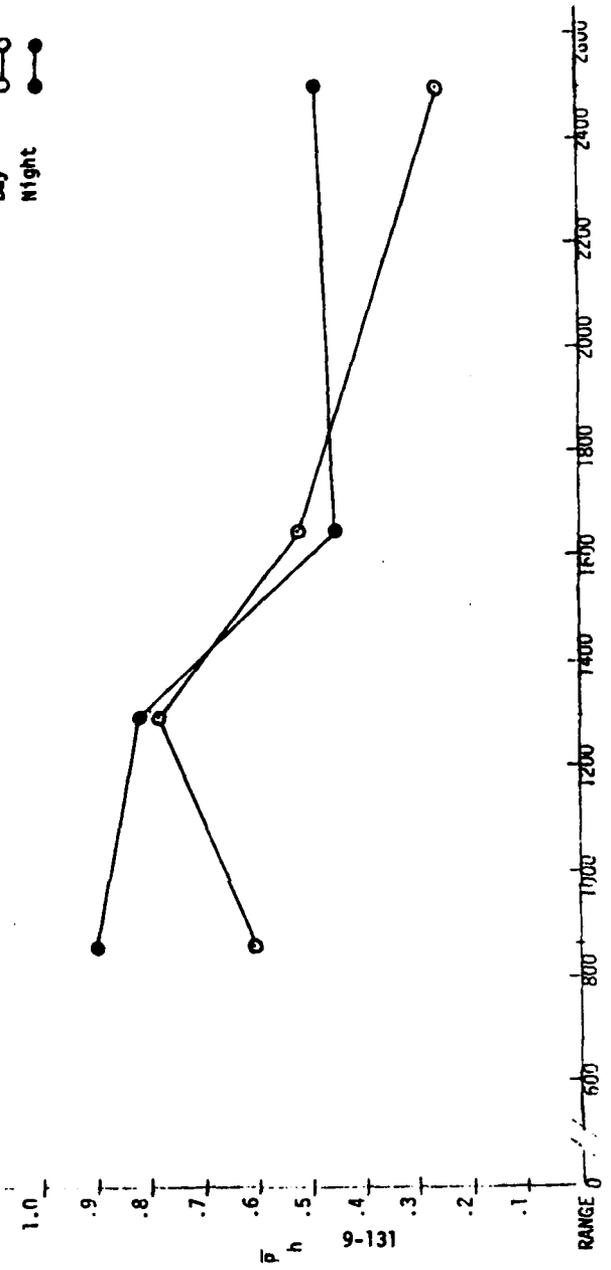
&lt;.05, &lt;.01, &lt;.005, &lt;.001 = F value is significant at less than the percent value indicated.

TABLE 9-1-3

First Round Mean Values

UNIT	UIC	PERFORMANCE				P <sub>h</sub>
1.	Overall Mean =	60.1				
2.	Table VIII A (Day)	Table VIII B (Night)				
	53.4	66.7				
3.	Company	Co A	Co B	Co C		
		67.6	52.9	59.6		
4.	Target	1	2	3	4	
		37.3	48.0	79.4	75.5	
5.	Company	A (Day)	Table VIII		B (Night)	
	A	63.2			72.1	
	B	42.6			63.2	
	C	54.4			64.7	
6.		Target				
	Table VIII	1	2	3	4	
	A (Day)	25.5	51.0	76.5	60.8	
	B (Night)	49.0	45.1	82.4	90.2	
7.		Target				
	Company	1	2	3	4	
	A	38.2	64.7	94.1	73.5	
	B	32.4	32.4	79.4	67.6	
	C	41.2	47.1	64.7	85.3	

Day ○  
Night ●



$P_h$  9-131

ENGAGE METHOD	C	B	P	P
AMMO	HEP	HEAT-TPT	HEAT-TPT	HEAT-TPT
TARGET	Hull	Hull	Moving Panel	Hull
UNIT	UTC	GUNNERY RANGE: 3	DATE FIRED: 8/75	

Figure 9-I-1 Mean First Round Hit Probability ( $P_h$ ) Performance on Table VIII Main Gun Targets.

TABLE 9-1-4.

TABLE VIII and B

ANALYSIS OF VARIANCE SUMMARY

UNIT UIC GUNNERY MEASURE 1st Round Firing Time

SOURCE OF VARIATION	d.f.	MEAN SQUARE	F	p
A - Companys	2	190.120	--	N.S.
B - Table	1	166.963	--	N.S.
C - Targets	3	14416.690	53.29	< .001
N(A) - Error	48	378.342	<del>---</del>	
AB - Companys X Table	2	373.154	1.41	N.S.
AC - Companys X Targets	6	189.520	--	N.S.
BC - Table X Targets	3	1337.449	7.31	< .005
NB(A) - Error	48	263.738	<del>---</del>	
NC(A) - Error	144	270.544	<del>---</del>	
ABC - Companys X Table X Target	6	668.257	3.65	< .005
NBC(A) - Error	144	182.941	<del>---</del>	

## P Values of F

N.S = F value is not statistically significant.

&lt; .05, &lt; .01, &lt; .005, &lt; .001 = F value is significant at less than the percent value indicated.

TABLE 9-1-5

First Round Mean Values

UNIT	UIC	PERFORMANCE			Firing Time
1. Overall Mean	26.2				
2. Table VIII A (Day)	25.6				Table VIII B (Night) 26.8
3. Companys	Co A	Co B	Co C		
	25.5	25.5	27.6		
4. Target	1	2	3	4	
	29.4	22.9	12.1	40.4	
5. Company	A (Day)	Table VIII		B (Night)	
A	24.3			26.8	
B	23.6			27.4	
C	28.8			26.3	
6.		Target			
Table VIII	1	2	3	4	
A (Day)	25.8	20.3	11.2	45.0	
B (Night)	33.0	25.5	13.0	35.9	
7.		Target			
Company	1	2	3	4	
A	26.9	23.2	10.9	41.0	
B	31.4	21.2	13.0	36.5	
C	29.9	24.2	12.3	43.8	

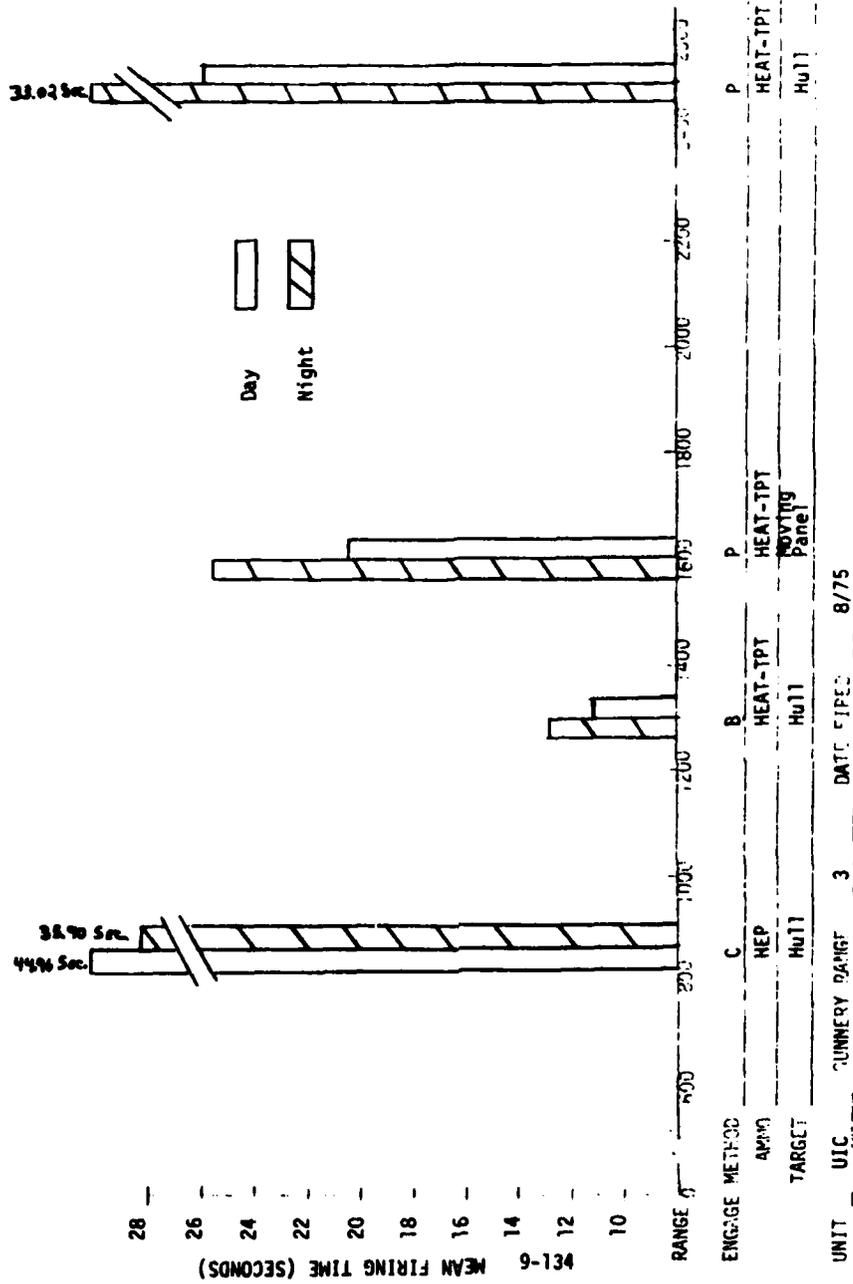


Figure 9-1-2 First Round Mean Firing Time on Table VIII Main Gun Targets

(14) Analysis of the UGC Battalion.

(a) Table 9-G-1 presents the Summary of Gunnery Performance Measures for the G Battalion. The statistics in table 9-G-1 and in the analyses of variance were based on data from a total N of 51 tank crews, 17 from each company.

(b) Table 9-G-2 presents the results of the analysis of variance of first round  $\bar{P}_h$  scores. Significant main effects were Tables ( $F=12.15, p < .01$ ), and Targets ( $F=56.10, p < .001$ ). Significant interaction effects were Companies X Targets ( $F=6.46, p < .01$ ) and Tables X Targets ( $F=7.79, p < .01$ ). Comparison of the mean scores for Tables, presented in table 9-G-3, show that  $\bar{P}_h$  on Table VIII B (Night) was significantly higher ( $p < .01$ ) than the  $\bar{P}_h$  for Table VIII A (Day). The target means were compared in a Tukey's (HSD) Test. The results indicated that  $\bar{P}_h$  performance on Targets 3 and 4 was significantly higher ( $p < .01$ ) than on Targets 1 and 2. Examination of the means for the Companies X Targets interaction seems to show the A Company achieved a higher  $\bar{P}_h$  score on Target 2 than B and C Companies, while B Company had a lower  $\bar{P}_h$  score on Target 1 than A and C Companies. The means for the Tables X Targets interaction, plotted in figure 9-G-1, show that the  $\bar{P}_h$  score for Target 1 on Table VIII B (Night) was much higher than on Table VIII A (Day).

(c) Table 9-G-4 presents the results of the analysis of variance of first round mean firing time. Significant effects were Targets ( $F=106.43, p < .001$ ), and Tables X Targets ( $F=6.54, p < .005$ ). The target means, presented in table 9-G-5, were analyzed in a Tukey's (HSD) Test. The results indicated that the mean firing time on Target 3 was significantly faster ( $p < .01$ ) than on the other three targets, while mean firing time on Target 4 was significantly slower ( $p < .01$ ) than on the other three targets. The means for the Tables X Targets interaction were presented in figure 9-G-2. They show that mean firing time on Target 2 was faster on Table VIII A (Day) than on Table VIII B (Night), whereas there were no appreciable differences in the Table VIII A and B mean firing times on the other targets.

(d) The analysis produced three main findings. One,  $\bar{P}_h$  performance was better at night on Table VIII B than during the day on Table VIII A, which seems to be a characteristic of the battalions in the C Division. Two,  $\bar{P}_h$  performance on Target 3, the battlesight engagement, was better than on Target 2, the precision engagement at a moving target. The difference might suggest that proficiency could be improved on precision engagements. Three,  $\bar{P}_h$  performance on Target 1 increased dramatically on Table VIII B well above the hypothetical maximum for the range of 2500 meters. It is difficult to accept these  $\bar{P}_h$  measures at face value without further verification and explanation.

TABLE 9-G-1

GUNNERY PERFORMANCE MEASURES

UNIT UGC ROUND 1 GUNNERY RANGE 3

TABLE VIII	TARGET CHARACTERISTICS						MEASURES							
	TARGET SE-QUENCE	RANGE (ME-TERS)	E M *	No. RND.S. AMMO	TARGET	I L L**	NO. OF CREWS	NO. OF HITS	NO. OF MISSES	P h	G M	MEAN FIRING TIME	S.D.	rpb
A	1	2500	P	2 HEAT-TPT	Hull	A	51	11	40	.22	.06	21.69	9.65	.27
A	4	1600	P	2 HEAT-TPT	Moving Panel	A	51	25	26	.49	.07	18.33	8.56	.03
A	6	1300	B	2 HEAT-TPT	Hull	A	51	43	8	.84	.05	9.94	4.61	.48
A	8	870	C	1 HEP	Hull	A	51	45	6	.88	.05	38.14	16.99	.03
B	1	2500	P	2 HEAT-TPT	Hull	W	51	34	17	.67	.07	22.12	8.06	.25
B	4	1600	P	2 HEAT-TPT	Moving Panel	W	51	22	29	.43	.07	23.49	8.29	.04
B	6	1300	B	2 HEAT-TPT	Hull	W	51	45	6	.88	.05	12.20	6.38	.16
B	8	870	C	1 HEP	Hull	W	51	50	1	.96	.02	32.14	11.69	.05

\* Engagement Method

- B = Gunner: Daylight Battlesight
- C = TC, Gunner: Rangecard
- I = Gunner: IR Battlesight
- P = Gunner: Daylight Precision
- R = Gunner: IR Precision
- S = TC: Daylight Battlesight
- T = TC: Daylight Precision
- X = TC: IR 50 Cal. Sight

\*\* Illumination

- A = Ambient Light
- W = Artificial White Light
- I = Infrared Light

TABLE 9-G-2

TABLE VIII A and B

## ANALYSIS OF VARIANCE SUMMARY

UNIT UGC GUNNERY MEASURE 1st Round P<sub>h</sub>

SOURCE OF VARIATION	d. f.	MEAN SQUARE	F	P
A - Companys	2	5465.680	2.86	N.S.
B - Table	1	17867.640	12.15	<.01
C - Targets	3	68521.190	56.10	<.001
N(A) - Error	48	1911.755	<del>      </del>	
AB - Companys X Table	2	1397.057	1.90	N.S.
AC - Companys X Targets	6	7883.988	6.46	<.01
BC - Table X Targets	3	12573.540	7.79	<.01
NB(A) - Error	48	1470.563	<del>      </del>	
NC(A) - Error	144	1221.377	<del>      </del>	
ABC - Companys X Table X Target	6	612.656	0.38	N.S.
NBC(A) - Error	144	1613.442	<del>      </del>	

## P Values of F

N.S = F value is not statistically significant.

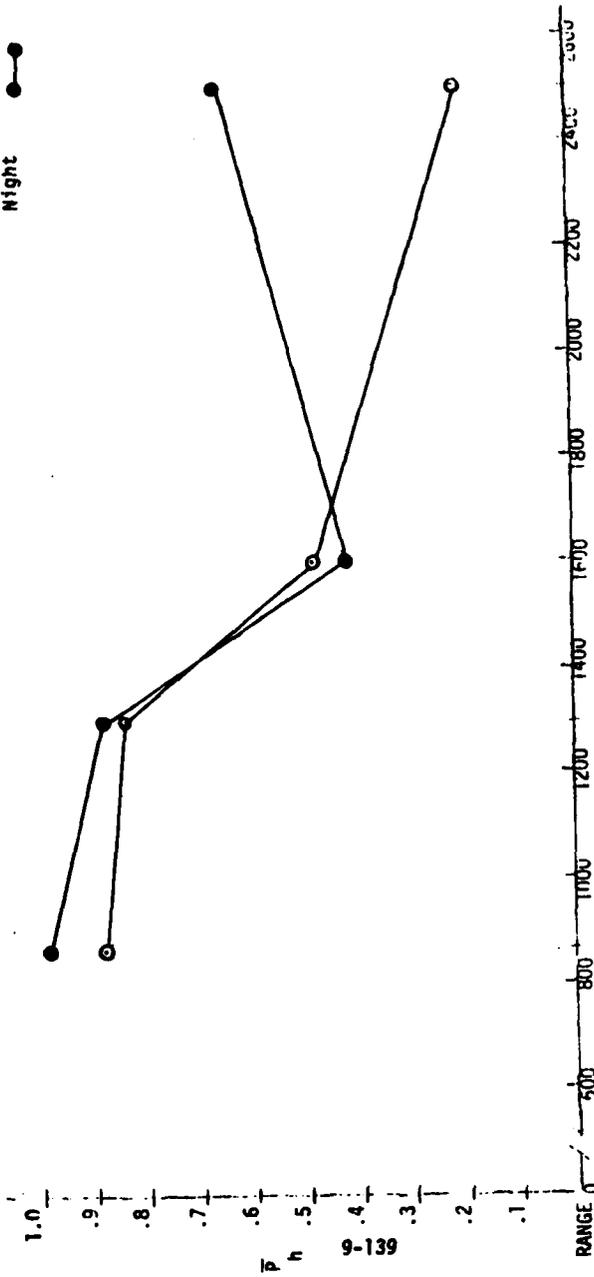
&lt;.05, &lt;.01, &lt;.005, &lt;.001 = F value is significant at less than the percent value indicated.

TABLE 9-G-3

First Round Mean Values

UNIT	UGC	PERFORMANCE P <sub>h</sub>			
1. Overall Mean =	67.4				
2. Table VIII A (Day)	60.8	Table VIII B (Night)			
		74.0			
3. Companys	Co A	Co B	Co C		
	74.3	61.8	66.2		
4. Target	1	2	3	4	
	44.1	46.1	86.3	93.1	
5. Company	A (Day)	Table VIII		8 (Night)	
A	66.2			82.4	
B	52.9			70.6	
C	63.2			69.1	
6.	Target				
Table VIII	1	2	3	4	
A (Day)	21.6	49.0	84.3	88.2	
B (Night)	66.7	43.1	88.2	98.0	
7.	Target				
Company	1	2	3	4	
A	52.9	73.5	76.5	94.1	
B	29.4	38.2	91.2	88.2	
C	50.0	26.5	91.2	97.1	

Day ○  
Night ●



9-139

ENGAGE METHOD C B P  
 AMMO HEP HEAT-TPT HEAT-TPT  
 TARGET Hull Hull Panel Hull  
 UNIT USC GUNNERY RANGE 3 DATE FIRED 8/75

Figure 9-G-1 Mean First Round Hit Probability ( $P_h$ ) Performance on Table VIII Main Gun Targets.

TABLE 9-G-4  
 TABLE VIIIA and B  
 ANALYSIS OF VARIANCE SUMMARY

UNIT UGC GUNNERY MEASURE 1st Round Firing Time

SOURCE OF VARIATION	d.f.	MEAN SQUARE	F	P
A - Companys	2	250.590	2.17	N.S.
B - Table	1	21.657	----	N.S.
C - Targets	3	9962.555	106.43	<.001
N(A) - Error	48	115.615	<del>      </del>	
AB - Companys X Table	2	65.870	----	N.S.
AC - Companys X Targets	6	145.594	1.56	N.S.
BC - Table X Targets	3	569.624	6.54	<.005
NB(A) - Error	48	119.537	<del>      </del>	
NC(A) - Error	144	93.604	<del>      </del>	
ABC - Companys X Table X Target	6	91.913	1.06	N.S.
NBC(A) - Error	144	87.059	<del>      </del>	

P Values of F

N.S = F value is not statistically significant.

<.05, <.01, <.005, <.001 = F value is significant at less than the percent value indicated.

TABLE 9-G-5  
First Round Mean Values

UNIT UGC	PERFORMANCE Firing Time			
1. Overall Mean =	22.3			
2. Table VIII A (Day)	Table VIII B (Night)			
	22.0		22.6	
3. Companys	Co A	Co B	Co C	
	20.8	23.4	22.6	
4. Target	1	2	3	4
	21.9	20.9	11.1	35.1
5. Company	A (Day)	Table VIII		B (Night)
A	21.3			20.2
B	22.9			23.9
C	21.9			23.3
6.	Target			
Table VIII	1	2	3	4
A (Day)	21.7	18.3	9.9	38.1
B (Night)	22.1	23.5	12.2	32.1
7.	Target			
Company	1	2	3	4
A	19.2	19.0	11.5	33.3
B	25.2	21.1	9.5	37.8
C	21.3	22.6	12.2	34.3

Day   
 Night 

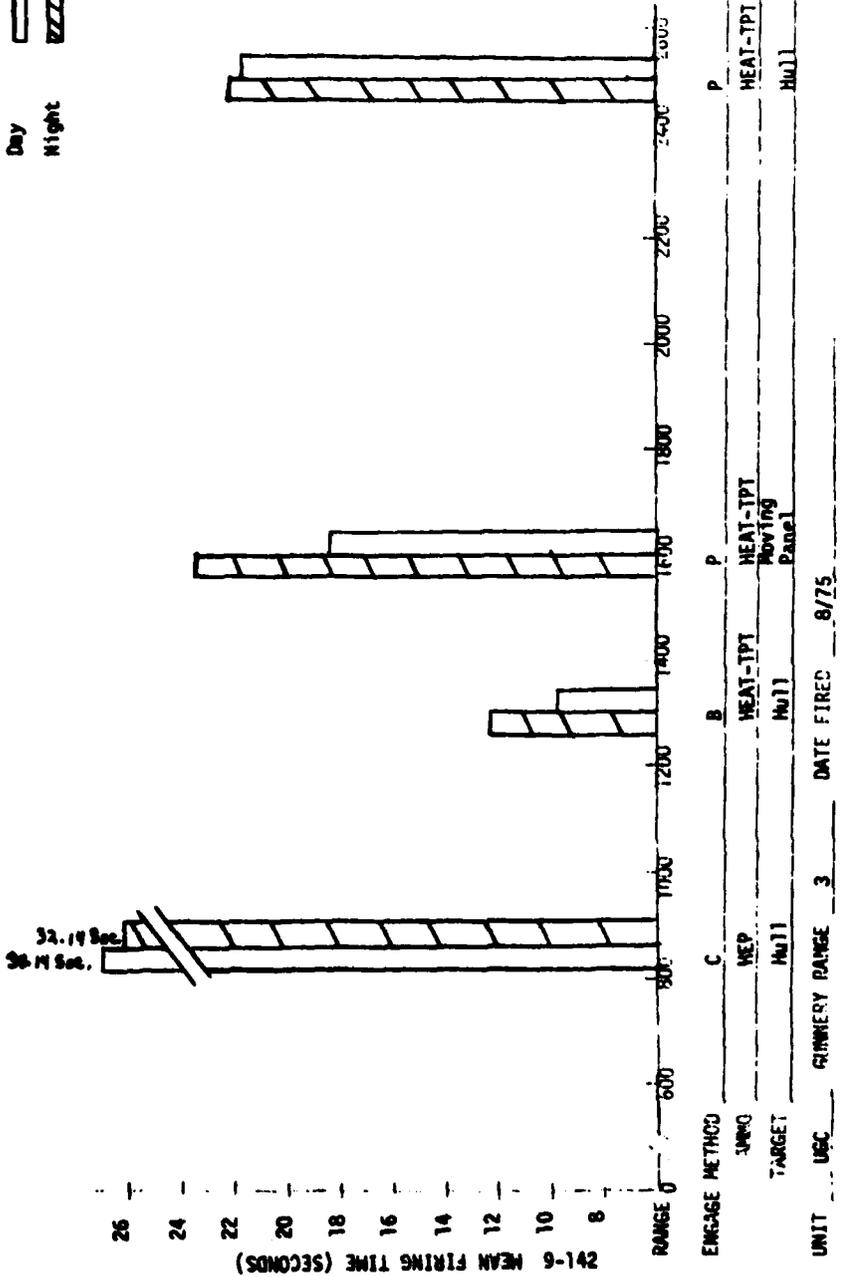


Figure 9-G-2 First Round Mean Firing Time on Table VIII Main Gun Targets

(15) Analysis of the UJD Battalion.

(a) Table 9-J-1 presents the Summary of Gunnery Performance Measures for the J Battalion. The statistics in table 9-J-1 and in the analyses of variance were based on data from a total N of 51 tank crews, 17 from each company.

(b) Table 9-J-2 presents the results of the analysis of variance of first round  $\bar{P}_h$  values. A significant main effect was Targets ( $F=19.77$ ,  $p < .001$ ). Significant interaction effects were Companies X Tables ( $F=4.05$ ,  $p < .05$ ), Tables X Targets ( $F=2.77$ ,  $p < .05$ ), and Companies X Tables X Targets ( $F=2.87$ ,  $p < .05$ ). The target means, presented in table 9-J-3, were compared for differences in a Tukey's (HSD) Test. The results indicated that  $\bar{P}_h$  performance on Target 1 was significantly less ( $p < .01$ ) than on Targets 2, 3, and 4. The means for the Companies X Tables interaction were examined and seem to indicate that on Target 3, the moving target, C Company achieved an extremely high  $\bar{P}_h$  score, 94.12. The means for the Tables X Targets interaction are plotted in figure 9-J-1. Targets 1, 3, and 4 had the same range band 1500-2000 meters and appear as a column of points at the 1750 meter midpoint. The plots and means show that on Target 4,  $\bar{P}_h$  scores for Table VIII A (Day) were higher than on Table VIII B (Night), but on Targets 1 and 2, the  $\bar{P}_h$  scores on Table VIII A (Day) were lower than the scores on Table VIII B (Night). Examination of the mean scores for the Companies X Tables X Targets interaction revealed that C Company's  $\bar{P}_h$  score on Target 1, Table VIII A (Day), was very low, 11.77.

(c) Table 9-J-4 presents the results of the analysis of variance of mean firing time. Significant effects were Companies ( $F=7.21$ ,  $p < .01$ ), Tables ( $F=44.97$ ,  $p < .001$ ), Targets ( $F=12.56$ ,  $p < .001$ ), and Tables X Targets ( $F=7.94$ ,  $p < .005$ ). The means for Companies, presented in table 9-J-5, were compared in a Tukey's (HSD) Test. The results indicated that the overall mean firing time for B Company, 14.7 seconds, was significantly faster ( $p < .01$ ) than the overall mean firing time for C Company, 18.6 seconds. Comparison of the means for Table VIII A and B indicated that mean firing time on Table VIII A (Day) was significantly faster ( $p < .001$ ) than on Table VIII B (Night). Comparison of the Target means in a Tukey's (HSD) Test indicated the following. One, the mean firing time on Target 3 was significantly faster than on Targets 1 and 4 ( $p < .01$  and  $p < .05$ , respectively). Two, mean firing time on Target 1 was significantly slower than on Targets 2, 3 and 4 ( $p < .01$ ,  $p < .01$ , and  $p < .05$ , respectively). The means for the Table X Targets interaction are plotted in figure 9-J-2. Examination of the means seems to indicate that on Targets 1 and 4 firing time was faster on Table VIII A (Day) than on Table VIII B (Night), whereas on Targets 2 and 3, there was little change in firing time from Table VIII A (Day) to Table VIII B (Night).

(d) The analysis produced three main findings. One, comparing the  $\bar{P}_H$  results of Targets 3 and 4 shows that there was no difference in performance between moving and stationary targets. Two, performance on Target 1 was much poorer for some undetermined reason. Three, mean firing time on the moving target was faster than on the stationary targets with the same range.

TABLE 9-J-1

## GUNNERY PERFORMANCE MEASURES

UNIT 000      ROUND 1      GUNNERY RANGE 4

TABLE VIII	TARGET SEQUENCE	TARGET CHARACTERISTICS				MEASURES								
		RANGE (METERS)	T M *	No. AMMO	TARGET I L**	NO. OF CREWS	NO. OF HITS	NO. OF MISSES	P h	σ M	MEAN FIRING TIME	S. D.	rph	
A	2	1500-2000	P	2	Station-ary panel	A	51	18	33	.35	.07	15.86	6.32	.23
A	5	1000	P	2	HEP-TPT Hull	A	51	38	13	.75	.06	14.73	4.10	.02
A	6	1500-2000	P	2	Moving Panel	A	51	43	8	.84	.05	13.02	3.31	.11
A	9	1500-2000	P	2	Station-ary panel	A	51	43	8	.84	.05	13.25	3.11	.01
B	2	1500-2000	P	2	Station-ary panel	W	51	25	25	.50	.07	21.88	7.75	.04
B	5	1000	P	2	HEP-TPT Hull	W	51	42	8	.84	.05	15.98	4.77	.35
B	6	1500-2000	P	2	Moving Panel	W	51	43	7	.86	.05	16.69	5.52	.06
B	9	1500-2000	P	2	Station-ary panel	W	51	35	15	.70	.07	20.63	9.98	.09

\* Engagement Method

B = Gunner: Daylight Battlesight  
 C = TC, Gunner: Rangecard  
 I = Gunner: IR Battlesight  
 P = Gunner: Daylight Precision  
 R = Gunner: IR Precision  
 S = TC: Daylight Battlesight  
 T = TC: Daylight Precision  
 X = TC: IR 50 Cal. Sight

\*\* Illumination

A = Ambient Light  
 W = Artificial White Light  
 I = Infrared Light

TABLE 9-2

TABLE VIII A and B

## ANALYSIS OF VARIANCE SUMMARY

UNIT UJD GUNNERY MEASURE 1st Round P<sub>h</sub>

SOURCE OF VARIATION	d. f.	MEAN SQUARE	F	P
A - Companys	2	1642.156	---	N.S.
B - Table	1	220.588	---	N.S.
C - Targets	3	37148.690	19.77	< .001
N(A) - Error	48	1960.777	<del>---</del>	
AB - Companys X Table	2	8014.699	4.05	< .05
AC - Companys X Targets	6	1119.250	---	N.S.
BC - Table X Targets	3	4142.125	2.77	< .05
NB(A) - Error	48	1979.145	<del>---</del>	
NC(A) - Error	144	1879.064	<del>---</del>	
ABC - Companys X Table X Target	6	4289.180	2.87	< .05
NBC(A) - Error	144	1497.007	<del>---</del>	

## P Values of F

N.S = F value is not statistically significant.

&lt; .05, &lt; .01, &lt; .005, &lt; .001 = F value is significant at less than the percent value indicated.

TABLE 9-J-3

First Round Mean Values

UNIT	UJD	PERFORMANCE P <sub>H</sub>			
1.	Overall Mean	70.1			
2.	Table VIII A (Day)	69.6	Table VIII B (Night)		
			71.1		
3.	Company	Co A	Co B	Co C	
		69.1	67.6	74.3	
4.	Target	1	2	3	4
		42.2	78.4	84.3	76.5
5.	Company	A (Day)	Table VIII		B (Night)
	A	72.1			66.2
	B	72.1			63.2
	C	64.7			83.8
6.		Target			
	Table VIII	1	2	3	4
	A (Day)	35.3	74.5	84.3	84.3
	B (Night)	49.0	82.4	84.3	68.6
7.		Target			
	Company	1	2	3	4
	A	44.1	76.5	85.3	70.6
	B	38.2	79.4	73.5	79.4
	C	44.1	79.4	94.1	79.4

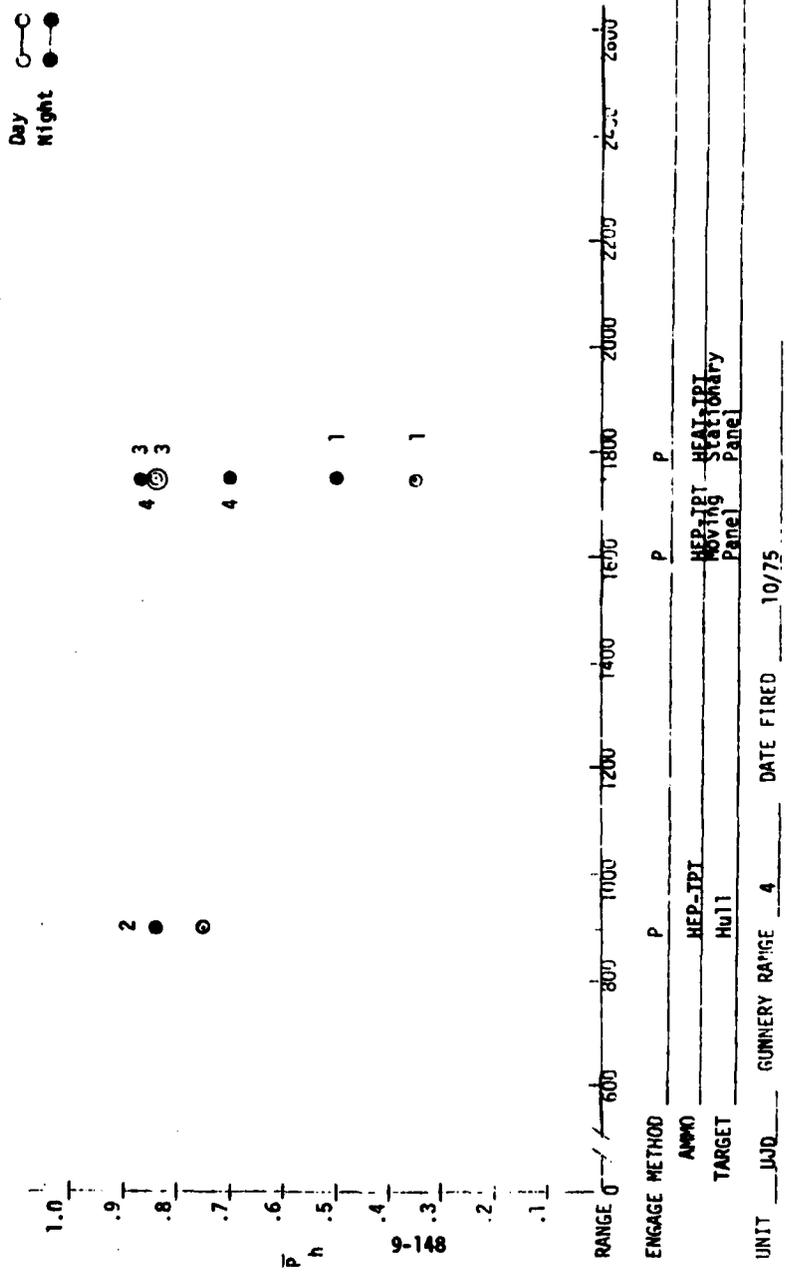


Figure 9-J-1 Mean First Round Hit Probability ( $P_h$ ) Performance on Table VIII Main Gun Targets.

TABLE 9-1-4

TABLE VIII A and B

## ANALYSIS OF VARIANCE SUMMARY

UNIT WJD GUNNERY MEASURE 1st Round Firing Time

SOURCE OF VARIATION	d.f.	MEAN SQUARE	F	p
A - Companys	2	513.679	7.21	< .01
B - Table	1	2138.127	44.97	< .001
C - Targets	3	334.971	12.56	< .001
N(A) - Error	48	71.211	<del>---</del>	
AB - Companys X Table	2	130.075	2.74	N.S.
AC - Companys X Targets	6	20.689	---	N.S.
BC - Table X Targets	3	184.971	7.94	< .005
NB(A) - Error	48	47.545	<del>---</del>	
NC(A) - Error	144	26.662	<del>---</del>	
ABC - Companys X Table X Target	6	34.594	1.48	N.S.
NBC(A) - Error	144	23.306	<del>---</del>	

## P Values of F

N.S = F value is not statistically significant.

&lt; .05, &lt; .01, &lt; .005, &lt; .001 = F value is significant at less than the percent value indicated.

TABLE 9-J-5

First Round Mean Values

	UNIT	WJD	PERFORMANCE Firing Time			
1.	Overall Mean	-	16.5			
2.	Table VIII A (Day)		Table VIII B (Night)			
		14.2	18.8			
3.	Company	Co A	Co B	Co C		
		16.2	14.7	18.6		
4.	Target	1	2	3	4	
		18.9	15.4	14.9	16.9	
5.	Company	A (Day)	Table VIII		B (Night)	
	A	13.7			18.8	
	B	13.5			15.9	
	C	15.4			21.7	
6.			Target			
	Table VIII	1	2	3	4	
	A (Day)	15.9	14.7	13.0	13.3	
	B (Night)	21.9	16.0	16.7	20.6	
7.			Target			
	Company	1	2	3	4	
	A	18.9	14.6	15.0	16.4	
	B	16.1	14.6	12.9	15.2	
	C	21.6	16.8	16.7	19.2	

Day   
 Night 

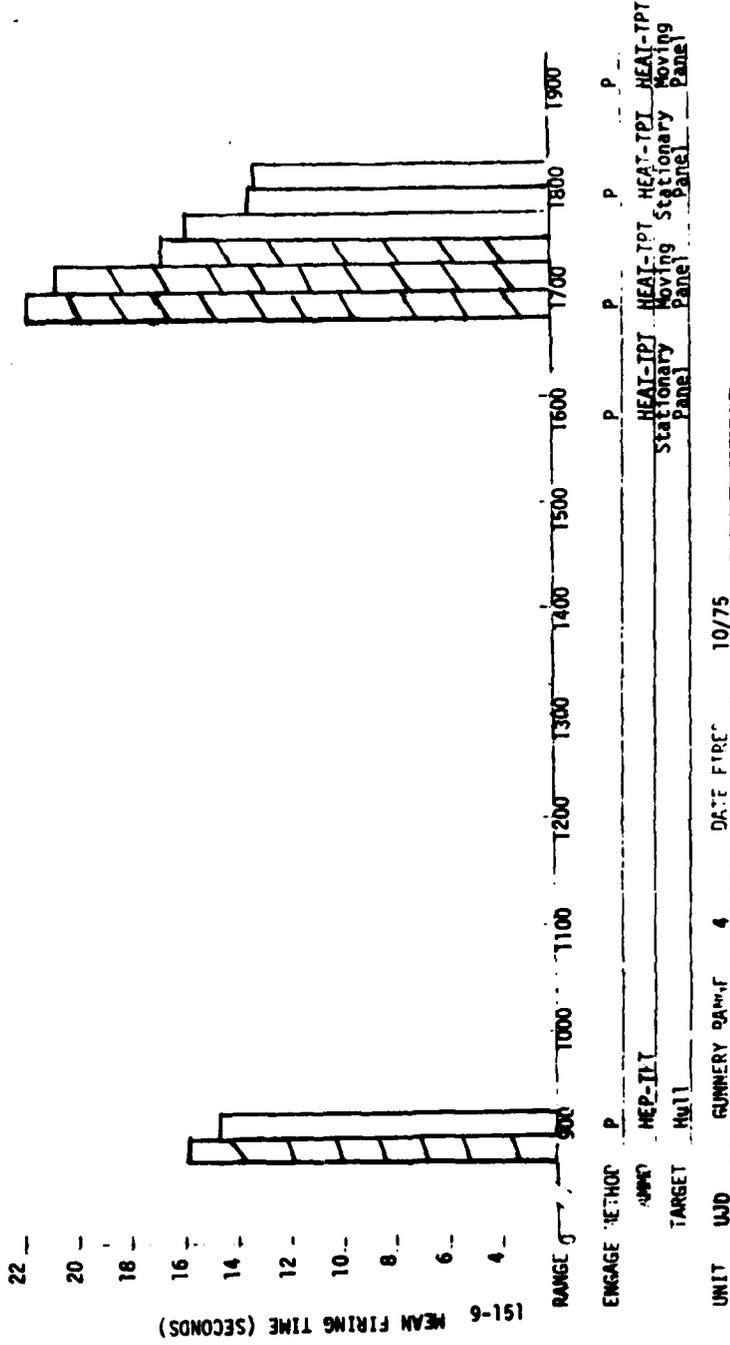


Figure 9-3-2 First Round Mean Firing Time on Table VIII Main Gun Targets

(16) Analysis of the UKE Battalion.

(a) Table 9-K-1 presents the Summary of Gunnery Performance Measures for the K Battalion. The statistics in table 9-K-1 were based on data from 50 tank crews: 17 in A Company, 17 in B Company, and 16 in C Company. The statistics in the analyses of variance were based on data from 48 tank crews, the first 16 from each company.

(b) Table 9-K-2 presents the results of the analysis of variance of first round  $\bar{P}_h$  scores. Significant effects were Targets ( $F=8.96$ ,  $p < .005$ ), Companies X Tables ( $F=3.23$ ,  $p < .05$ ), and Companies X Targets ( $F=2.69$ ,  $p < .05$ ). The Target means, presented in table 9-K-3, were compared in a Tukey's (HSD) Test. The results indicated the  $\bar{P}_h$  score on Target 4 was significantly higher than the  $\bar{P}_h$  scores for Targets 1 and 2 ( $p < .05$ , and  $p < .01$ , respectively); the  $\bar{P}_h$  score for Target 3 was significantly higher ( $p < .01$ ) than the  $\bar{P}_h$  score for Target 1. Examination of the means for the Companies X Tables interaction revealed that the  $\bar{P}_h$  value for C Company on Table VIII A (Day) was higher than its  $\bar{P}_h$  on Table VIII B (Night), whereas A and B Companies had higher  $\bar{P}_h$  values on Table VIII B (Night) than on Table VIII A (Day). Examination of the means for the Companies X Targets interaction indicated that A Company had the highest  $\bar{P}_h$  score on Target 2; B Company had the highest  $\bar{P}_h$  score on Targets 1 and 3; and C Company had the highest  $\bar{P}_h$  score on Target 4.

(c) Table 9-K-4 presents the results of the analysis of variance of mean firing time. Significant main effects were Companies ( $F=3.62$ ,  $p < .05$ ), Tables ( $F=16.51$ ,  $p < .005$ ), and Targets ( $F=25.06$ ,  $p < .001$ ). Significant interaction effects were Companies X Tables ( $F=3.78$ ,  $p < .05$ ), and Tables X Targets ( $F=5.84$ ,  $p < .005$ ). The Companies means, presented in table 9-K-5, were compared in a Tukey's (HSD) Test. The results indicated that C Company's overall mean firing time, 13.85 seconds, was significantly faster ( $p < .05$ ) than B Company's 16.72 seconds. Comparison of the Table VIII A and B means indicated that the mean firing time on Table VIII A (Day) was significantly faster ( $p < .005$ ) than on Table VIII B (Night). The means for Targets were analyzed in a Tukey's (HSD) Test. The results indicated that the mean firing time on Target 3 was significantly faster ( $p < .01$ ) than on the other three targets, and the mean firing time on Target 4 was significantly faster than on Targets 1 and 2 ( $p < .01$  and  $p < .05$ , respectively). Examination of the means of the Tables X Targets interaction, plotted in figure 9-K-2, show that on Target 1 there was a large increase in mean firing time on Table VIII B (Night) compared with Table VIII A (Day). There was no comparable difference in magnitude on the other three targets.

(d) The main finding in this analysis was that performance was very good on the moving target engagement, Target 4. Both  $\bar{P}_h$  score and mean firing time were better on Target 4 than on Targets 1 and 2. Also,  $\bar{P}_h$  performance and mean firing time on Target 3, the battlesight engagement-panel target, was better than on Targets 1 and 2 where tank hulls were used as targets.

TABLE 94-1

GUNNERY PERFORMANCE MEASURES

UNIT UKF                      ROUND 1                      GUNNERY RANGE 5

TABLE VIII	TARGET CHARACTERISTICS						MEASURES							
	TARGET SEQUENCE	RANGE (METERS)	EM*	No. RND. AMMO	TARGET	ILLUMINATION**	NO. OF CREWS	NO. OF HITS	NO. OF MISSES	P h	σ M	MEAN FIRING TIME	S.D.	rpp
A	1	1140	P	2 HEAT-T	Hull	A	50	38	12	.76	.06	13.85	9.38	.04
A	4	1000	P	2 HEP-T	Hull	A	50	29	21	.58	.07	16.17	5.47	.17
A	5	800	B	2 TP-T	Stationary panel	A	50	45	5	.90	.04	8.81	4.83	.04
A	7	1000	P	2 TP-T	Moving Panel	A	50	43	7	.86	.05	13.73	5.78	.02
B	1	1140	P	2 HEAT-T	Hull	W	50	33	17	.66	.07	24.10	15.80	.03
B	1	1000	P	2 HEP-T	Hull	W	50	34	16	.68	.07	17.71	7.35	.04
B	5	800	B	2 TP-T	Stationary panel	W	50	39	11	.78	.06	11.38	5.31	.08
B	7	1000	P	2 TP-T	Moving Panel	W	50	44	6	.88	.05	14.50	8.24	.10

- \* Engagement Method
- \*\* Illumination
- B = Gunner: Daylight Battlesight
- C = TC, Gunner: Rangecard
- I = Gunner: IR Battlesight
- P = Gunner: Daylight Precision
- R = Gunner: IR Precision
- S = TC: Daylight Battlesight
- T = TC: Daylight Precision
- X = TC: IR 50 Cal. Sight
- A = Ambient Light
- W = Artificial White Light
- I = Infrared Light

TABLE 9-K-2

TABLE VIII A and B

ANALYSIS OF VARIANCE SUMMARY

UNIT UKE GUNNERY MEASURE 1st Round  $P_h$

SOURCE OF VARIATION	d. f.	MEAN SQUARE	F	P
A - Companys	2	1276.041	---	N.S.
B - Table	1	104.167	---	N.S.
C - Targets	3	14097.220	8.96	<.005
N(A) - Error	45	2378.465	<del>---</del>	
AB - Companys X Table	2	6276.935	3.23	<.05
AC - Companys X Targets	6	4227.410	2.69	<.05
BC - Table X Targets	3	2395.833	1.66	N.S.
NB(A) - Error	45	1940.951	<del>---</del>	
NC(A) - Error	135	1572.897	<del>---</del>	
ABC - Companys X Table X Target	6	1380.186	---	N.S.
NBC(A) - Error	135	1440.839	<del>---</del>	

P Values of F

N.S = F value is not statistically significant.

<.05, <.01, <.005, <.001 = F value is significant at less than the percent value indicated.

TABLE 9-K-3

First Round Mean Values

UNIT UKE	PERFORMANCE Ph			
1. Overall Mean =	76.0			
2. Table VIII A (Day)	76.6			
	Table VIII B (Night)			
	75.5			
3. Companys	Co A	Co B	Co C	
	74.2	79.7	74.2	
4. Target	1	2	3	4
	70.8	61.5	84.4	87.5
5. Company	A (Day)	Table VIII		B (Night)
A	70.3			78.1
B	76.6			82.8
C	82.8			65.6
6.	Target			
Table VIII	1	2	3	4
A (Day)	75.0	56.3	89.6	85.4
B (Night)	66.7	66.7	79.2	89.6
7.	Target			
Company	1	2	3	4
A	59.4	78.1	75.0	84.4
B	81.3	56.3	93.8	87.5
C	71.9	50.0	84.4	90.6

Day ○—○  
 Night ●—●

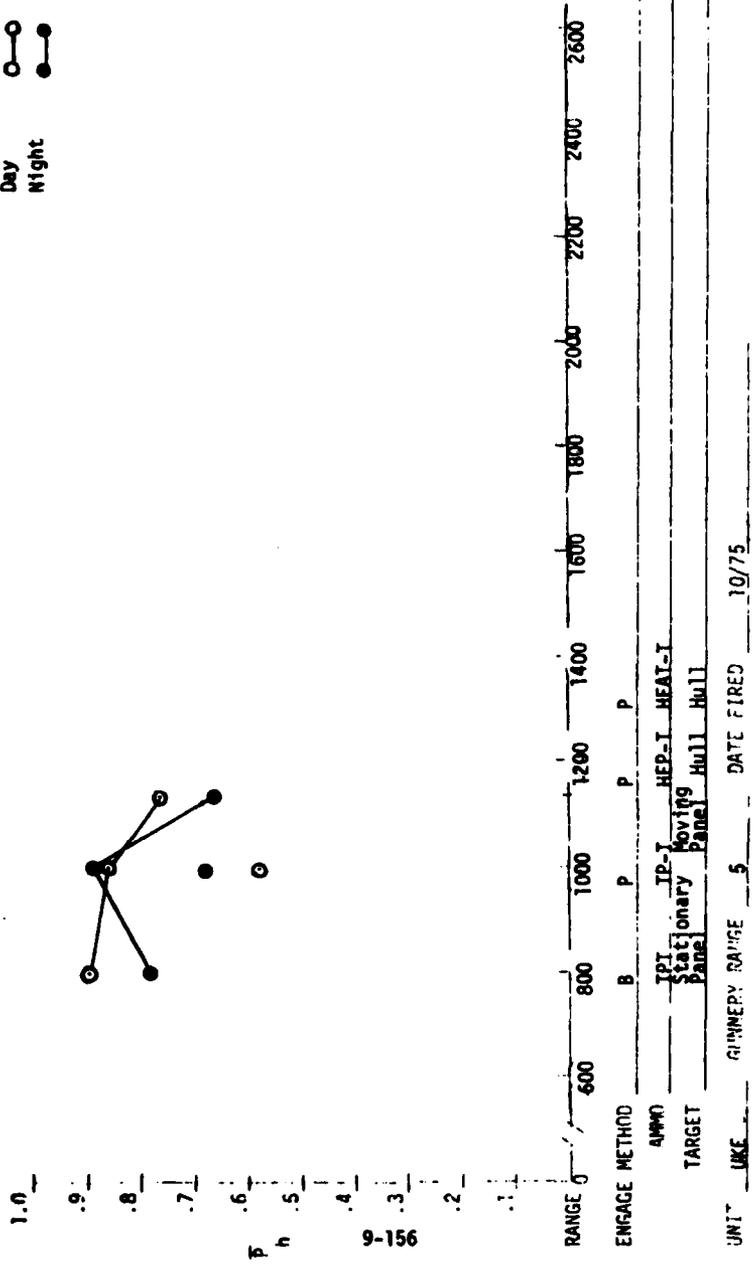


Figure 9-K-1 Mean First Round Hit Probability (P<sub>h</sub>) Performance on Table VIII Main Gun Targets.

TABLE 9-K-4

LEVEL VIII A and B

ANALYSIS OF VARIANCE SUMMARY

UNIT UKE GUNNERY MEASURE 1st Round firing Time

SOURCE OF VARIATION	d. f.	MEAN SQUARE	F	p
A - Companys	2	287.820	3.62	<.05
B - Table	1	1372.594	16.51	<.005
C - Targets	3	1422.048	25.06	<.001
N(A) - Error	45	79.538	<del>---</del>	
AB - Companys X Table	2	314.350	3.78	<.05
AC - Companys X Targets	6	63.878	1.13	N.S.
BC - Table X Targets	3	459.267	5.84	<.005
NB(A) - Error	45	83.131	<del>---</del>	
NC(A) - Error	135	56.749	<del>---</del>	
ABC - Companys X Table X Target	6	59.907	---	N.S.
NBC(A) - Error	135	78.692	<del>---</del>	

## P Values of F

N.S = F value is not statistically significant.

&lt;.05, &lt;.01, &lt;.005, &lt;.001 = F value is significant at less than the percent value indicated.

TABLE 9-K-5  
First Round Mean Values

UNIT	UKE	PERFORMANCE Firing Time			
1.	Overall Mean =	15.0			
2.	Table VIII A (Day)	Table VIII B (Night)			
	13.1	16.9			
3.	Company	Co A	Co B	Co C	
		14.5	16.7	13.9	
4.	Target	1	2	3	4
		19.0	17.0	10.1	14.1
5.	Company	A (Day)	Table VIII		B (Night)
	A	11.1			18.0
	B	16.4			17.0
	C	11.9			15.8
6.		Target			
	Table VIII	1	2	3	4
	A (Day)	13.9	16.2	8.8	13.7
	B (Night)	24.1	17.7	11.4	14.5
7.		Target			
	Company	1	2	3	4
	A	16.3	16.7	10.2	14.9
	B	22.2	18.8	11.4	14.4
	C	18.5	15.3	8.6	13.0



(17) Analysis of the UPA Battalion.

(a) Table 9-P-1 presents the Summary of Gunnery Performance Measures for the P Battalion. The statistics are based on data from a total N of 48 tank crews: 16 in A Company, 15 in B Company, and 17 in C Company. Data from the first 15 crews in each company, a total N of 45 crews were used in the two analysis of variance. The Tables factor had to be eliminated from the analytical design because there were an unequal number of engagements; 6 on Table VIII A (Day), and 4 on Table VIII B (Night). Furthermore, none of the engagement conditions were comparable across Table VIII A (Day) and B (Night) so it was more appropriate to treat each target as being a different treatment condition. The change resulted in a 3 x 10 factorial design with 3 companys and 10 targets.

(b) Table 9-P-2 presents the results of the analysis of variance of first round  $\bar{P}_h$  scores. Significant effects were Companys ( $F=5.63$ ,  $p < .01$ ), and Targets ( $F=4.15$ ,  $p < .005$ ). The Companys means, presented in Table 9-P-3, were compared in a Tukey's (HSD) Test. The results revealed that the first round  $\bar{P}_h$  scores for A and B Companys were significantly higher ( $p < .05$  and  $p < .01$ , respectively) than C Company's. The target means, plotted in figure 9-P-1, were also compared in a Tukey's (HSD) Test. The meaningful comparisons were limited to targets within Table VIII A (Day) and B (Night) and not between tables. On the Table VIII A (Day) targets, the first round  $\bar{P}_h$  scores on Targets 4, 5, and 6, which comprised a multiple engagement target, were significantly higher ( $p < .01$ ) than the  $\bar{P}_h$  scores on Targets 1, 2, and 3. On the Table VIII B (Night) targets, the first round  $\bar{P}_h$  scores on Targets 7 and 8 were significantly higher ( $p < .05$ ) than the  $\bar{P}_h$  score on Target 9.

(c) Table 9-P-4 presents the results of the analysis of variance of first round mean firing time. There was one significant effect which was Targets ( $F=18.04$ ,  $p < .001$ ). The Target means, presented in table 9-P-5 and plotted in figure 9-P-2, were compared in a Tukey's (HSD) Test. On Table VIII A (Day), mean firing time on Targets 4, 5, and 6, the multiple engagement targets, was significantly faster ( $p < .01$ ) than on Targets 2 and 3. On Table VIII B (Night), mean firing time on Target 7 was significantly faster ( $p < .01$ ) than on Targets 9 and 10.

(d) Three interesting findings emerged from the analysis. One, there was a difference between Companys on  $\bar{P}_h$  performance. C Company did not perform as well as A and B Companys. Two, performance on the multiple-target engagement was superior both in  $\bar{P}_h$  scores and mean firing times to the individual target engagements on Table VIII A (Day). Three,  $\bar{P}_h$  performance on the battlesight engagement on Table VIII B (Night) Target 9, was relatively poor compared with the  $\bar{P}_h$  performance on the two precision engagements using HEAT ammo, Targets 7 and 8.

TABLE 9-P-1

GUNNERY PERFORMANCE MEASURES

UNIT: DPA

ROUND: 1

GUNNERY RANGE: 1

TABLE VIII	TARGET CHARACTERISTICS						MEASURES							
	TARGET QUANTITY	RANGE (METERS)	Engagement Method	No. ROUNDS AMMO	TARGET	Illumination	NO. OF CREWS	NO. OF HITS	NO. OF MISSES	p	σ <sub>M</sub>	MEAN FIRING TIME	S.D.	rpb
A	2	1610	P	2	HEAT-T Hull	A	48	24	24	.50	.07	10.73	3.31	.08
A	3	1020	P	2	HEP-TPT Stationary panel	A	48	27	21	.56	.07	13.58	5.64	.04
A	6	1940	P	2	DS-T Moving Panel	A	48	22	26	.46	.07	14.42	9.82	.08
A	7	1150	B	2	DS-T Stationary panel	A	48	40	8	.83	.05	7.07	2.99	.19
A	7	1200	B	2	DS-T Stationary panel	A	48	35	13	.73	.07	8.24	4.92	.00
A	7	1340	B	2	DS-T Stationary panel	A	48	40	8	.83	.05	7.47	4.04	.05
B	2	888	P	2	HEAT-T Hull	I	48	30	17	.64	.07	10.24	4.27	.21
B	3	1050	P	2	HEAT-TPT Moving Panel	W	48	28	19	.60	.07	12.87	4.05	.19
B	6	800	B	2	HEAT-TPT Stationary panel	W	48	23	24	.49	.07	16.82	9.38	.10
B	7	1300	P	2	HEP-T Stationary panel	W	48	25	22	.53	.07	16.24	6.50	.08

\* Engagement Method

\*\* Illumination

B = Gunner: Daylight Battlesight  
 C = TC, Gunner: Rangecard  
 I = Gunner: IR Battlesight  
 P = Gunner: Daylight Precision  
 R = Gunner: IR Precision  
 S = TC: Daylight Battlesight  
 T = TC: Daylight Precision  
 X = TC: IR 50 Cal. Sight

A = Ambient Light  
 W = Artificial White Light  
 I = Infrared Light

\*\*\* Multiple Engagement

TABLE 9-P-2  
 TABLE VIII A and B  
 ANALYSIS OF VARIANCE SUMMARY

SOURCE OF VARIATION	d. f.	MEAN SQUARE	F	P
A - Companys	2	14155.550	5.63	< .01
C - Targets	9	8977.762	4.15	< .005
N(A) - Error	42	2514.259		
AC - Companys X Targets	18	2451.813	1.13	N.S.
NC(A) - Error	378	2161.454		

P Values of F

N.S. = F value is not statistically significant.

<.05, <.01, <.005, <.001 = F value is significant at less than the percent value indicated.

TABLE 9-P-3  
FIRST ROUND MEAN VALUES  
UNIT UP A PERFORMANCE MEASURE Ph

1. Overall Mean = 60.4	UNIT UP A										
	Co. A	Co. B	Co. C	PERFORMANCE MEASURE Ph							
2. Company's	64.7	67.3	49.3	3	4	5	6	7	8	9	10
3. Target	48.9	82.2	73.3	82.2	82.2	82.2	82.2	60.0	60.0	44.4	48.9
4.	TARGET										
Company	1	2	3	4	5	6	7	8	9	10	
A	53.3	66.7	66.7	86.7	86.7	100.0	66.7	46.7	33.3	40.0	
B	46.7	53.3	53.3	86.7	73.3	73.3	80.0	73.3	60.0	73.3	
C	46.7	46.7	26.7	73.3	60.0	73.3	33.3	60.0	40.0	33.3	



TABLE 9-P-4

TABLE VIII A and B

## ANALYSIS OF VARIANCE SUMMARY

SOURCE OF VARIATION	d.f.	MEAN SQUARE	F	P
A - Companys	2	19.696	----	N.S.
C - Targets	9	567.610	18.04	< .001
N(A) - Error	42	69.794		
AC - Companys X Targets	18	38.595	1.23	N.S.
NC(A) - Error	378	31.467		

## P-Values of F

N.S. = F value is not statistically significant.

<.05, <.01, <.005, <.001 = F value is significant at less than the percent value indicated.

TABLE 9-P-5  
FIRST ROUND MEAN VALUES

UNIT UPA PERFORMANCE MEASURE Firing Time

1. Overall Mean = 11.8

2. Company Co. A Co. B Co. C  
11.5 12.2 11.6

3. Target 1 2 3 4 5 6 7 8 9 10  
10.7 13.6 14.4 7.1 8.2 7.5 10.2 12.9 16.8 16.2

TARGET

4. Company 1 2 3 4 5 6 7 8 9 10  
A 9.7 11.2 12.5 6.7 9.3 7.2 10.1 11.9 20.3 16.5  
B 12.5 15.2 15.1 6.7 8.6 7.5 10.3 12.8 15.7 17.5  
C 10.0 14.3 15.7 7.8 6.9 7.7 10.4 13.9 14.5 14.7

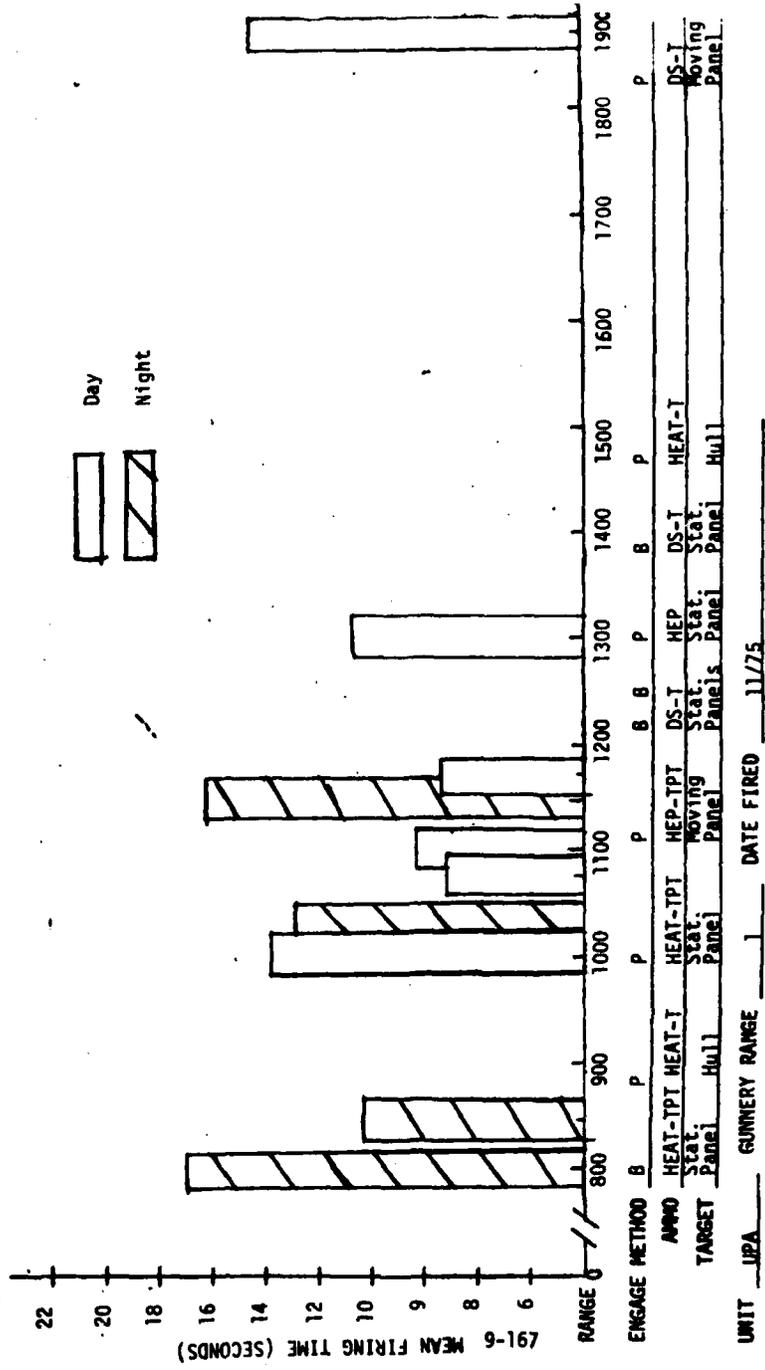


Figure 9-p-2 First Round Mean Firing Time on Table VIII Main Gun Targets

d. Evaluation of the General Influence of Factors in the Analyses of Variance.

(1) The analyses of the individual battalions provide appraisals of how the three independent factors (Companies, Tables, and Targets) influenced first round mean  $P_h$  scores and firing time within each battalion. However, each battalion analysis is independent of the others and they are not integrated in any way such that taken together they contribute toward an overall appreciation of how the factors affected performance across all battalions. In order to describe how the factors influenced performance generally, it is necessary to make a comparison of the effects of the factors across all the battalions. This comparison is presented in table 9-16.

(2) Table 9-16 contains tabulations of all the significant effects of the factors and their interactions for every battalion. An X in a cell indicates a significant effect at the .05 level of confidence or less. An empty cell indicated the effect was not statistically significant. Observing the number of significant effects for each factor by scanning across each row provides an understanding of how frequently that factor was a significant effect in all the battalions. The last column (F) presents the frequency number of significant effects for each factor.

(3) Examination of the frequencies indicates that the factor of Targets was a significant effect in 16 out of 15 analyses of  $P_h$  scores and in all 15 analyses of mean firing time. Obviously, differences in target characteristics were the factors that consistently influenced performance in all battalions. The second most frequent effect for both performance measures was the Tables X Targets interaction. It was significant in 8 of 15 analyses of  $P_h$  scores and in 9 of 15 analysis of mean firing time. The Tables X Targets interaction is closely related to the targets factors in that day/night effects can be considered in the same class as other target characteristics. The third most frequent effect for both performance measures was Tables. It was significant in 4 out of 15 analyses of  $P_h$  scores and in 8 out of 15 analyses of mean firing time. The Tables factor can also be viewed in the same class as the previous factors; fundamentally as a target characteristic. Interestingly, the significant tables effects for the  $P_h$  measure were not distributed equally among the USAREUR and CONUS battalions. Four of the 5 significant effects occurred in the CONUS battalions. Furthermore, all 4  $P_h$  scores on Table VIII B (Night) were significantly higher than on Table VIII A (Day), while the reverse was true for the one significant effect in the USAREUR battalions. Overall, the sum of significant effects due to target characteristics: Targets, Targets X Tables, and Tables, accounted for 25 of the 37 effects for the  $P_h$  measures, 67 percent, and 32 of the 46 effects for the firing time measures, 70 percent. Thus approximately two-thirds of the significant effects in the analyses were due to the influence of target characteristics of one kind or another.



(4) The remaining one-third of the significant effects were divided equally among the other main effect and interaction-effects. These effects involved the Companys factor. Examination of the frequencies of significant effects for these factors shows that none were greater than 5 or one-third of the total number of battalions involved. On the Companys factor, there were 3 significant effects from analyses of the  $P_h$  scores and 5 significant effects from analyses of the mean firing time scores. The former all came from CONUS battalions. There were no significant effects due to Company difference in  $P_h$  scores from the USAREUR battalions. These results may provide some evidence to indicate that main-gun marksmanship may be more consistent among the Companys in USAREUR battalions than it is in CONUS battalions. The Companys X Targets factor produced 5 significant effects from the analyses of  $P_h$  scores and 2 significant effects from analyses of mean firing time scores. These results may suggest perhaps that the differences occurred due to specific differences in gunnery training within the Companys of certain battalions. In the other two interactions, Companys X Tables and Companys X Tables X Targets, the frequencies of significant effects were relatively small and it does not appear that the effects were consistent enough to warrant drawing generalizations from them.

e. Findings and Conclusions. The results from the analyses of individual battalions indicate that target characteristics are the primary factors affecting first round accuracy and firing time. In the analyses of variance, the effects of Targets, Tables, and Targets X Tables accounted for about two-thirds of the statistically significant effects. From these findings, the following conclusions are drawn.

(1) The main factors influencing first round accuracy and firing time are target characteristics including day/night conditions, range, ammunition, engagement method, target motion, and target type.

(2) In four CONUS battalions main-gun accuracy was significantly better on Table VIII B (Night) than on Table VIII A (Day). This difference did not occur with any USAREUR battalions.

(3) There was little difference in main-gun accuracy performance between the companys within the battalions. There were no significant differences between any of the companys in the USAREUR battalions and only three such differences in the CONUS battalions. However, significant differences between companys in mean firing time performance did occur in five of the battalions.

(4) In five battalions, one-third of the sample, there was a significant Companys X Targets interaction indicating that some companys did better or worse than the others on certain targets. These results suggest that perhaps there are differences in training programs at the company level which are reflected in differences in gunnery performance on different types of target engagements.

9.5. One Battalion's Case Study of Firing Experience.

- a. Data were collected on the firing proficiency of one CONUS battalion (UAM) over a period of one year. The firing data includes:
  - (1) Table VIII fired at the completion of a formal gunnery training program in February and March 1975.
  - (2) Main gun firings collected during October 1975 as a part of the Tank Degradation Test (FN325).
  - (3) Table VIII fired without preliminary training in late January 1976.
  - (4) Table VIII fired at the completion of a formal gunnery training program in early March 1976.
- b. The battalion experienced a good deal of turbulence throughout the period; however, its experience is similar to that of the other CONUS battalions. Of the crews that fired in February and March of 1975, none retained all four members in the same positions to fire in October. Of those firing in October, none remained precisely the same for the January firing. And of those firing in January, only seven remained intact for the final firing six weeks later. Parenthetically, an examination of the performance of those seven crews revealed that their increase in performance was approximately equal to that of the remainder of the battalion crews that experienced turbulence.
- c. The ranges used during the documented firings differed. The March 1975 Table VIII, Tank Degradation and Off-Season Table VIII were conducted on Crittenberger Range; the March 1976 Table VIII was conducted on Tank Table VIII North (range descriptions are in Chapter 8). In similar fashion, the scoring was performed by different sets of AI/Safety Officer teams. All Table VIII firings were scored by Division Gunnery Assistance Teams while Tank Degradation was scored by MASSTER evaluators. All scoring suffered the hinderance of dust and smoke obscuration. In all cases of unresolved hit determination the crew was given the benefit of the doubt. Table 9-17 displays the percentage of hits obtained during the various firings. The Tank Degradation and Off-Season Table VIII scores are combined since both were fired without the benefit of formal gunnery program and the percentage of hits obtained were similar between the two. As can be seen, the percentages for the two Table VIII's fired at the end of formal gunnery training are similar while those fired without gunnery



training are lower. There is one exception, second round night, in which the Off-Season percentage of hits is higher than the March 76 firing. This is due primarily to the relatively poor performance of the battalion when firing the second round at night with HEF-1 ammunition. (See breakout of ammunition types in tables 9-17 through 9-20).

- d. An examination of the firing times shows a marked difference between the firings. The Off-Season Table VIII times are considerably higher than the remainder. For example, the overall mean first round firing time for all day targets in January was 19.5 seconds. Six weeks later, it was 11.0. At night, the overall means were 20.4 and 12.6 respectively. The means fired for each of the ranges is shown in Table 9-21.
- e. Another meaningful comparison is shown in Table 9-22. A study of the table reveals that the formal gunnery training program improved performance in terms of hits and firing times, when comparisons of like conditions of ammunition, range, target type and firing mode are made.
- f. Findings and Conclusions.

A significant increase in hit percentages and decrease in firing times on Table VIII will occur if preceded by a formal gunnery program.

TABLE 3-16 HEAT-TP-T FIRINGS.

	DAY			NIGHT			OVERALL		
	1	2	Subtotal	1	2	Subtotal	1	2	
	Subtotal	Subtotal	Subtotal	Subtotal	Subtotal	Subtotal	Subtotal	Subtotal	
Yards fired	—	—	—	31/53 (58)	41/53 (77)	72/106 (68)	31/53 (58)	41/53 (77)	72/106 (68)
Deprecation and off-season	79/133 (59)	28/74 (38)	106/207 (51)	52/125 (50)	30/75 (40)	92/200 (46)	140/258 (54)	53/149 (39)	198/407 (49)
Yards fired	116/157 (74)	27/51 (53)	143/208 (69)	52/78 (79)	19/45 (42)	81/123 (66)	178/235 (76)	46/96 (48)	224/331 (68)

Subtotal - 100% of Firing Percentage

Table 3-19 HEAT-T Firing

	DAY		THREAT				OVERALL		
	1	2	Subtotal	1	2	Subtotal	1	2	
	Subtotal	Subtotal	Subtotal	Subtotal	Subtotal	Subtotal	Subtotal	Subtotal	
March 75 Table 3-19	67/107 (63)	76/106 (72)	143/213 (67)	93/107 (87)	90/107 (84)	183/214 (86)	160/214 (75)	166/213 (78)	326/427 (76)
Target Deactivation and Off-Season	43/80 (54)	35/67 (52)	78/147 (53)	48/74 (65)	44/70 (63)	92/144 (64)	91/159 (57)	79/137 (58)	170/295 (58)
March 76 Table 3-19	24/39 (62)	12/19 (63)	36/58 (62)	33/39 (85)	11/17 (65)	44/56 (79)	57/78 (73)	23/36 (64)	80/114 (70)

Format: Hits/Bounds Fired  
(Percentage)



TABLE 9-21 MEAN 1st ROUND FIRING TIMES (SECONDS).

Range (Meters)	Table VIII Annual March 1975		Table Degradation (open) October 1975		Tank Degradation (closed) October 1975		Table VIII Off-Season January 1976		Table VIII Annual March 1976	
	D	N	D	N	D	N	D	N	D	N
770-810 <sup>1</sup>								20.2	7.3	13.3
820	12.2	11.0								
838			15.0	14.1	12.6	12.5				
1024			13.0	11.6	9.6	9.3	17.8	16.0		-
1000	7.6									
1100		9.3	16.4	13.6	12.1	15.3				
1200							16.6	20.7		12.4
1250										
1300			14.3	10.8	18.8	7.7	23.0	24.9		
1435									11.0	
1450										11.9
1495	15.1	15.2								
1500									14.5	12.4
1600									16.2	
1610			18.1	9.8	11.3	13.8	21.5	19.9	12.5	
1700									10.2	10.4
1720	7.7	10.6								
1997									13.2	13.9
1994	12.5		11.6	11.2	16.3	10.4	19.0			

<sup>1</sup> Three targets fired in sequence from one position March 1976 Table VIII (day).

TABLE 9-22

COMPARISON OF PERFORMANCE, JANUARY 76 (OFF-SEASON) AND MARCH 76 TABLE VIII.

		Range (Meters)	Type Target	Mode	1st Rd Opening Time	1st Rd % Hits	N. targets
H E A T I T I P T	D A Y	770-810	S	B	7.3	86	119
		(1024)	M	B	(17.8)	(75)	32
		(1230)	S	P	(16.6)	(68)	31
		1610	M	P	12.1	37	32
		(1894)	S	P	(19.0)	(27)	30
H E A T I T I P T	N I G H T	800-810	S	B	13.3	87	37
		(800)	S	B	(20.8)	(45)	29
		(1024)	M	B	(16.0)	(62)	29
		(1200)	S	P	(20.7)	(59)	29
		1250	M	P	12.4	72	19
H E A T I T I P T	D A Y	(1300)	S	P	(23.0)	(23)	31
		1435	S	P	11.9	50	8
		1500	S	P	14.5	21	14
		1600	S	P	16.2	38	13
		(1610)	S	P	(21.5)	(10)	31
H E A T I T I P T	H I G H T	(1300)	S	P	(24.9)	(52)	27
		1450	S	P	12.5	69	13
		1500	S	P	13.5	62	26
		(1610)	S	P	(19.9)	(57)	28

Note: S=Stationary M=Moving P=Precision B=Battlesight  
( )=January Off-Season

#### 9-6. Between-Battalion Analyses of Selected Battalions.

a. This section presents analyses which compare different battalions with each other to ascertain if there are differences in gunnery performance at the battalion level. The previous analyses of individual battalions revealed that at the company level gunnery performance was usually similar for all the companies within the battalions. Attention is now focused on investigating how gunnery performance varies between battalions.

#### b. Battalion Selection.

(1) In order to make meaningful comparisons between battalions, it was necessary to reduce the confounding influence of uncontrolled variables as much as possible. This was accomplished mainly by requiring that the battalions included in all comparisons must have taken the same tank crew qualification test and were tested on the same Table VIII gunnery range. Tank crew qualification tests are not standardized due to training preferences at division level and differences in range facilities, and can vary to a considerable degree even among battalions in the same division. Thus the prerequisites eliminated the possibility of any comparison of battalions from different divisions. All comparisons would be restricted to battalions within the same division.

(2) The selection of battalions to be included in a comparison were made by comparing the specifications of target characteristics on main gun targets listed on the summary tables of gunnery performance measures presented in Section 9-4, Individual Analyses of the Sample Tank Battalions. The examination uncovered three sets of battalions with similar main-gun target characteristics on Table VIII. Each set of battalions came from a different division: two USAREUR divisions, the B and G divisions; and one CONUS division, the C division. The battalions comprising each set are listed below:

#### B Division Battalions

EBB  
ECB  
EOB  
EEB

#### G Division Battalions

LHG  
EOG

#### C Division Battalions

UFC  
UIC  
UGC

The gunnery measures from each set of battalions were analyzed separately to discover any differences in performance between them.

c. Between-Battalion Analyses

(1) Analysis of the B Division Battalions.

(a) Gunnery data were collected from a total N of 140 tank crews: 34 from the EBB Battalion, 32 from the ECB Battalion, 39 from the EDB Battalion, and 35 from the EEB Battalion. The statistics produced from the following analyses of variance were based on data from a total N of 120 tank crews, the first 30 from each battalion.

(b) Table 9-23 presents the results of the analysis of variance of first round  $\bar{P}_h$  scores. Significant main effects were Battalions ( $F=4.89$ ,  $p < .01$ ), and Targets ( $F=84.21$ ,  $p < .001$ ). A significant interaction effect was Battalions X Targets ( $F=4.48$ ,  $p < .005$ ). The battalion means, presented in Table 9-24, were compared for differences in a Tukey's (HSD) Test. The results indicated that the  $\bar{P}_h$  score of the EDB Battalion was significantly higher ( $< .01$ ) than that of the EBB and EEB battalions. Comparison of the target means in a Tukey's (HSD) Test indicated that  $\bar{P}_h$  scores on Target 1, 2, and 5 were significantly higher ( $p < .01$ ) than on targets 3 and 4. The means for the Battalions X Targets interaction, plotted in Figure 9-15, were examined and indicate that the EEB Battalion had the highest  $\bar{P}_h$  score on Target 2 and very low scores on all the other targets. Likewise, the EBB Battalion had the highest  $\bar{P}_h$  score on Target 3 and comparatively low scores on the other Targets.

(c) Table 9-25 presents the results of the analysis of variance of first round firing time. Significant main effects were Battalions ( $F=6.40$ ,  $p < .005$ ), Tables ( $F=11.94$ ,  $p < .005$ ), and Targets ( $F=92.33$ ,  $p < .001$ ). Significant interaction effects were Battalions X Tables ( $F=9.20$ ,  $p < .005$ ), Battalions X Targets ( $F=2.82$ ,  $p < .01$ ), Battalions X Companies X Targets ( $F=1.85$ ,  $p < .01$ ), and Tables X Targets ( $F=2.41$ ,  $p < .05$ ). The means for the Battalions main effect, presented in Table 9-26, were analyzed for differences in a Tukey's (HSD) Test. The results indicated that the EEB Battalion's mean firing time was significantly slower than that of the EBB and ECB battalions,  $p < .05$  and  $p < .01$  respectively, while the EDB Battalion's mean firing time was significantly slower ( $p < .05$ ) than the ECB Battalions. Examination of the means for the Battalions X Tables interaction showed that the EBB Battalion had a faster mean firing time on Table VIII B (Night) than on Table VIII A (Day) while the reverse was true for the other battalions. The means for the Battalions X Targets interaction, plotted in Figure 9-16, show that the EBB Battalion had the fastest mean firing time on targets 1, 2, and 5 and the slowest on target 3.

(d) The results revealed four pertinent findings. One, the significant Battalions main effect indicated that there exist absolute differences in

Table 9-23. Table VIII A and B Analysis of Variance Summary, Comparison of the Battalions in the B Division

Source of Variation	df	MS	Gunnery Measure: 1st Round P <sub>h</sub> (Percent)		
			F	P	
D - Battalions	3	12988.89	4.89	< .01	
A - Companies	2	6408.33	2.41	N.S.	
DA - Bn X Co	6	3797.21	1.43	N.S.	
W(DA) - Error	108	2653.62			
B - Tables (Tb)	1	2700.00	1.21	N.S.	
DB - Bn X Tb	3	1211.11	---	N.S.	
AB - Co X Tb	2	924.99	---	N.S.	
DAB - Bn X Co X Tb	6	2736.10	1.22	N.S.	
WB(DA) - Error	108	2234.98			
C - Targets (Tgt)	4	144687.40	84.21	< .001	
DC - Bn X Tgt	12	7704.11	4.48	< .005	
AC - Co X Tgt	8	1949.95	1.13	N.S.	
DAC - Bn X Co X Tgt	24	2450.00	1.43	N.S.	
WC(DA) - Error	432	1778.25			
BC - Tb X Tgt	4	3304.13	1.90	N.S.	
DBC - Bn X Tb X Tgt	12	1954.05	1.12	N.S.	
ABC - Co X Tb X Tgt	8	1966.49	1.13	N.S.	
DABC - Bn X Co X Tb X Tgt	24	2416.67	1.39	N.S.	
WBC(DA) - Error	432	1742.89			

**Table 9-24. First Round Mean Values**

Battalions		Performance Measure				
EBB, ECB, EDB, and EEB		First Round P <sub>h</sub> (Percent)				
1. Overall Mean = 45.83						
2.						
Battalion						
	EBB	ECB	EDB	EEB		
	40.67	48.33	54.00	40.33		
3.						
Target						
	1	2	3	4	5	
	60.83	67.92	21.67	16.67	62.08	
4.						
Target						
Battalion	1	2	3	4	5	
EBB	51.67	50.00	36.67	11.67	53.33	
ECB	63.33	65.00	20.00	25.00	68.33	
EDB	83.33	76.67	20.00	16.67	73.33	
EEB	45.00	80.00	10.00	13.33	53.33	

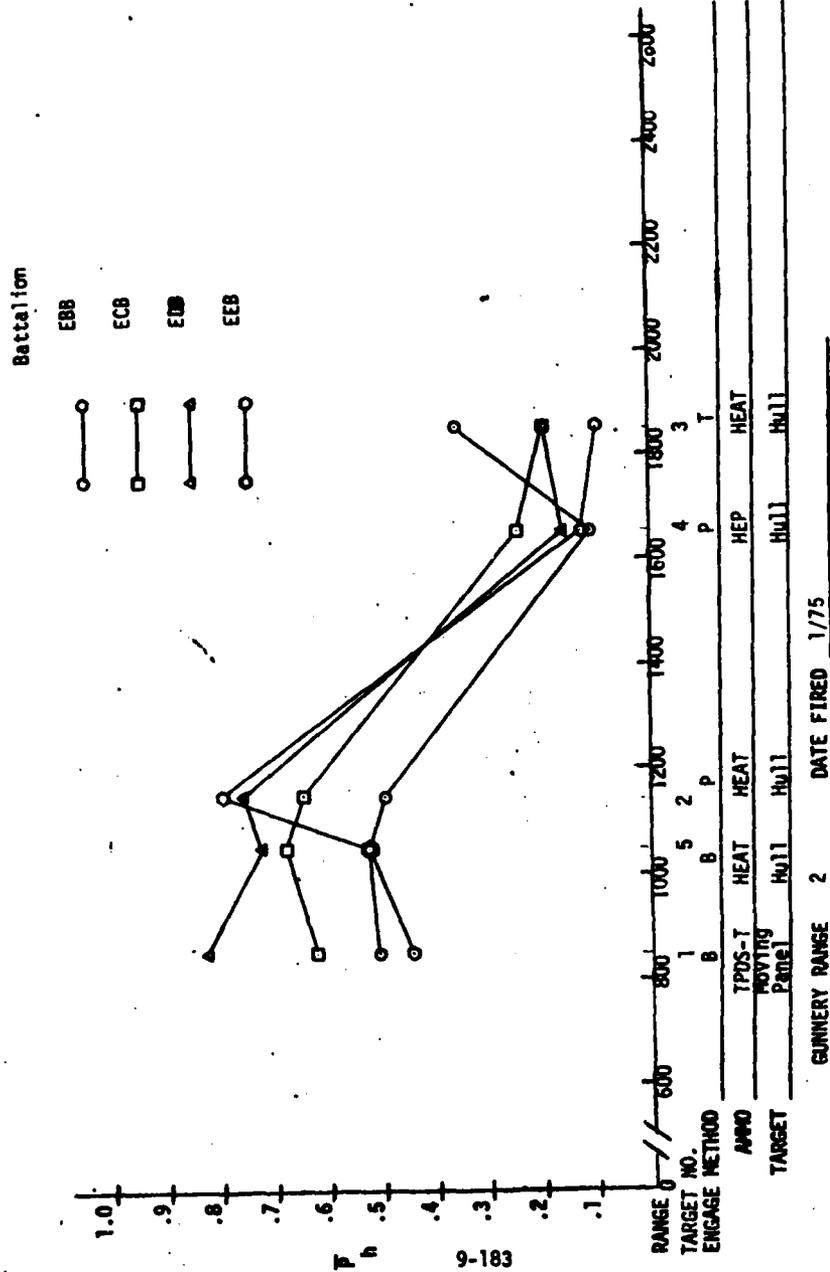


Figure 9-15. Mean First Round Hit Probability ( $P_h$ ) Performance on Table VIII Main Gun Targets.

Table 9-25. Table VIII A and B Analysis of Variance Summary, Comparison of the Battalions in the B Division

Source of Variation	df	MS	F	P
Battalions: EBB, ECB, EDB, and EEB      Summary Measure: 1st Round Firing Time				
D - Battalions	3	269.82	6.40	<.005
A - Companies	2	128.52	3.05	N.S.
DA - Bn. X Co.	6	57.01	1.35	N.S.
M(DA) - Error	108	42.17		
B - Tables (Tb)	1	346.69	11.94	<.005
DB - Bn X Tb	3	267.08	9.20	<.005
AB - Co. X Tb	2	17.52	---	N.S.
DAB - Bn X Co. X Tb	6	105.15	3.62	<.01
MB(DA) - Error	108	29.04		
C - Targets (Tgt.)	4	2304.65	92.33	<.001
DC - Bn X Tgt	12	70.40	2.82	<.01
AC - Co X Tgt	8	23.55	---	N.S.
DAC - Bn X Co. X Tgt	24	46.27	1.85	<.01
MC(DA) - Error	432	24.96		
BC - Tb X Tgt	4	54.99	2.41	<.05
DBC - Bn X Tb X Tgt	12	59.39	1.73	N.S.
ABC - Co. X Tb X Tgt	8	24.65	1.08	N.S.
DABC - Bn X Co X Tb X Tgt	24	26.55	1.16	N.S.
MBC(DA) - Error	432	22.83		

Table 9-26. First Round Mean Values

Battalions		Performance Measure			
EEB, ECB, EDB, and EEB		1st Round Firing Time			
1. Overall Mean = 12.04					
2. Day = 11.50		Night = 12.58			
3.					
Battalion					
	EBB	ECB	EDB	EEB	
	11.48	11.01	12.68	13.00	
4.					
Target					
	1	2	3	4	5
	9.24	11.03	16.06	14.53	9.35
5.					
	Battalion		Day		Night
	EBB		12.06		10.91
	ECB		10.61		11.41
	EDB		12.07		13.28
	EEB		11.27		14.72
6.					
Target					
Battalion	1	2	3	4	5
EBB	8.52	8.70	17.10	15.10	8.00
ECB	8.80	10.15	13.90	13.03	9.15
EDB	10.08	11.98	17.03	14.25	10.03
EEB	9.57	13.28	16.20	15.72	10.22

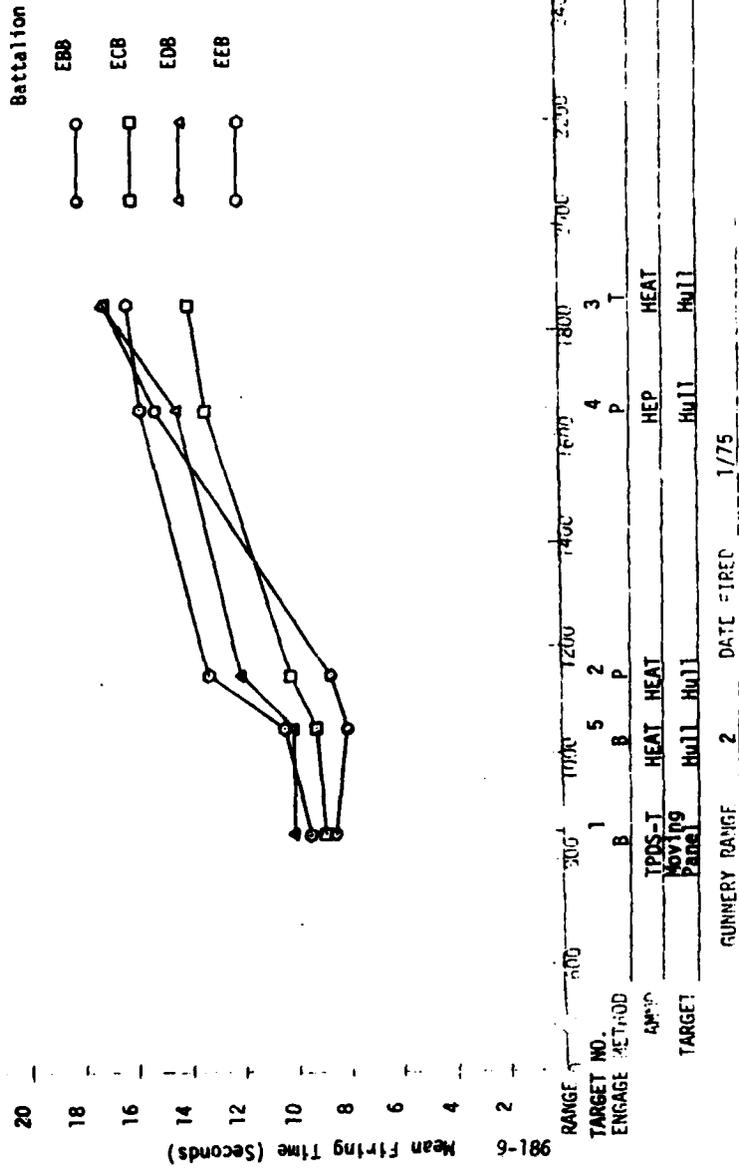


Figure 9-16. First Round Mean Firing Time on Table VIII Main Gun Targets.

gunnery proficiency between some battalions. These differences may be normally distributed resulting in superior, average and inferior battalion proficiency. In the present case, the EDB Battalion was relatively superior to the EBB and EEB Battalions, whereas the ECB Battalion did not differ significantly from any of the other battalions. The range of the  $\bar{P}_h$  difference between the highest and lowest scoring battalions was about 14 percent which appears to be large enough to be of some practical significance in terms of battlefield performance.

(1) Two, comparing the  $\bar{P}_h$  scores in Figure 9-15 shows that the four battalions maintained relative performance differences among one another across targets except for two deviations from the two lowest scoring battalions. The constancy in pattern perhaps suggests that the crews from the high scoring battalions came from training programs which were similar in content and emphasis. The EEB and EBB Battalions deviated from the pattern on two different targets. The EEB Battalion excelled on Target 2, which used HEAT ammo and the precision engagement method. It performed relatively poorly on the other engagements. Superficially, this might indicate that the battalion concentrated on training on one type of engagement and neglected training for the other types. Likewise, on target 3 the EBB Battalion achieved a relatively high  $\bar{P}_h$  score combined with a relatively slow mean firing time, see Figure 9-16, compared with its performance on the other targets. Target 3 was the only TC engagement in the test which suggests that the gunnery skills of the Tank Commanders in the battalion differed from those in the other battalions. In any case, these examples provide evidence that fundamental differences in gunnery skills exist to some extent between battalions.

(2) Three, the significant Battalions main effect in the analysis of firing time revealed that there also exist absolute differences between battalions in first round firing speed. On the average, some battalions fire faster than others. Also, in general, they tend to maintain the same differences in relative firing speed across different types of engagements.

(3) Four, comparing performance on both gunnery measures revealed that the EEB Battalion had the lowest  $\bar{P}_h$  score and slowest mean firing time of the four battalions. This finding provides additional evidence of the extent of the difference in gunnery proficiency existing between battalions.

## 2. Analysis of the G Division Battalions.

(a) Gunnery data were collected from a total  $N$  of 99 tank crews: 51 from the LNG Battalion, and 48 from the EOG Battalion. The statistics produced from the following analyses of variance were based on data from a total  $N$  of 96 tank crews, the first 48 from each battalion.

(b) Table 9-27 presents the results of the analysis of variance of

of first round  $\bar{P}_h$  scores. Significant main effects were Battalions ( $F=4.80, p < .05$ ), Companies ( $F=4.50, p < .05$ ), and Targets ( $F=27.57, p < .001$ ). Significant interaction effects were Tables X Targets ( $F=3.69, p < .01$ ), and Battalions X Companies X Targets ( $F=2.21, p < .05$ ). The battalion means, presented in Table 9-28, indicate that the  $\bar{P}_h$  score of the EOG battalion was significantly higher ( $p < .05$ ) than that of the ENG Battalion. The Companies main effect is not a meaningful factor in this statistical design and will not be considered. The appropriate test for companies effects is the Battalions X Companies interaction which was not statistically significant. Comparison of the target means in a Tukey's (HSD) Test indicated that the  $\bar{P}_h$  score on Target 3 was significantly higher ( $p < .01$ ) than the scores for the other targets, while the  $\bar{P}_h$  score on Target 2 was significantly lower than the other targets ( $p < .05$  for targets 1 and 5, and  $p < .01$  for targets 3 and 4). Examination of the means for the Tables X Targets interaction indicated that on targets 1 and 2  $\bar{P}_h$  performance was much lower during the day than at night, while the reverse was true for target 5. The means for the Battalions X Companies X Targets interaction indicated that the  $\bar{P}_h$  scores of the companies in both battalions varied across the targets.

(c) Table 9-29 presents the results of the analysis of variance of first round mean firing times. There were 10 significant effects. The most important ones were: Battalions ( $F=7.13, p < .01$ ), and Battalions X Tables X Targets ( $F=12.99, p < .005$ ). Examination of the mean firing time scores for the two battalions, presented in Table 9-30, showed that the first round mean firing time for the EOG Battalion was significantly faster ( $p < .01$ ) than the ENG Battalion's. The means for the Battalions X Tables X Targets interaction showed that on target 5 mean firing time varied considerably between battalions on Table VIII A (Day). The mean firing time for the EOG Battalion was extremely fast while the mean firing time for the ENG Battalion was relatively slow.

(d) Two important findings emerged from this analysis. One, the results showed that the EOG Battalion performed significantly better than the ENG Battalion in terms of both first round accuracy and firing time. The mean difference in  $\bar{P}_h$  and firing time was 7 percent and 1.42 seconds, respectively. Neither difference appears to be impressive when considered alone, but when considered in combination the performance difference becomes more apparent. Small differences in gunnery proficiency along two performance dimensions may possibly produce a larger difference in battlefield effectiveness. An adversary who can shoot a little quicker and more accurately than his opponent may enjoy a distinct advantage when considering that in war all capabilities are relative.

(1) Two, comparing  $\bar{P}_h$  performance across targets, illustrated in Figure 9-17, shows that battalion performance differed mainly on target 3, a battlesight engagement of a moving target. The EOG Battalion achieved an exceedingly high  $\bar{P}_h$  score of 79 percent on this engagement, while the ENG

Table 9-27. Table VIII A and B Analysis of Variance Summary, Comparison of the Battalions in the 6 Division

Source of Variation	Battalions: ENG and EOG		Gunnery Measure: First Round P <sub>h</sub>	
	df	MS	F	F
D - Battalions	1	12041.66	4.80	<.05
A - Companies	2	11281.25	4.50	<.05
DA - Bn X Co	2	135.42	---	N.S.
R(DA) - Error	90	2506.89		
B - Tables (Tb)	1	4166.66	1.29	N.S.
DB - Bn X Tb	1	1041.67	---	N.S.
AB - Co X Tb	2	2510.41	---	N.S.
DAB - Bn X Co X Tb	2	2572.89	---	N.S.
MB(DA) - Error	90	3228.97		
C - Targets (Tgt)	4	54229.09	27.57	<.001
DC - Bn X Tgt	4	4541.69	2.31	N.S.
AC - Co X Tgt	8	2244.81	1.14	N.S.
DAC - Bn X Co X Tgt	8	4354.10	2.21	<.05
MC(DA) - Error	360	1966.82		
BC - Tb X Tgt	4	7083.27	3.69	<.01
DBC - Bn X Tb X Tgt	4	1979.22	1.03	N.S.
ABC - Co X Tb X Tgt	8	2927.06	1.53	N.S.
DABC - Bn X Co X Tb X Tgt	8	1713.44	---	
NBC(DA) - Error	360	1917.09		

**Table 9-23. First Round Mean Values**

Battalions		Performance Measure				
ENG and EOG		First Round P <sub>h</sub> (Percent)				
1. Overall Mean = 41.25						
2. Day = 39.17		Night = 43.33				
3. Battalion						
		ENG	EOG			
		37.71	44.79			
4. Target						
	1	2	3	4	5	
	36.46	22.92	68.75	40.63	37.50	
5. Target						
		1	2	3	4	5
ENG		32.29	22.92	58.33	42.71	32.29
EOG		40.63	22.92	79.17	38.54	42.71
6. Target						
		1	2	3	4	5
Day		29.17	13.54	69.79	40.63	42.71
Night		43.75	32.29	67.71	40.63	32.29

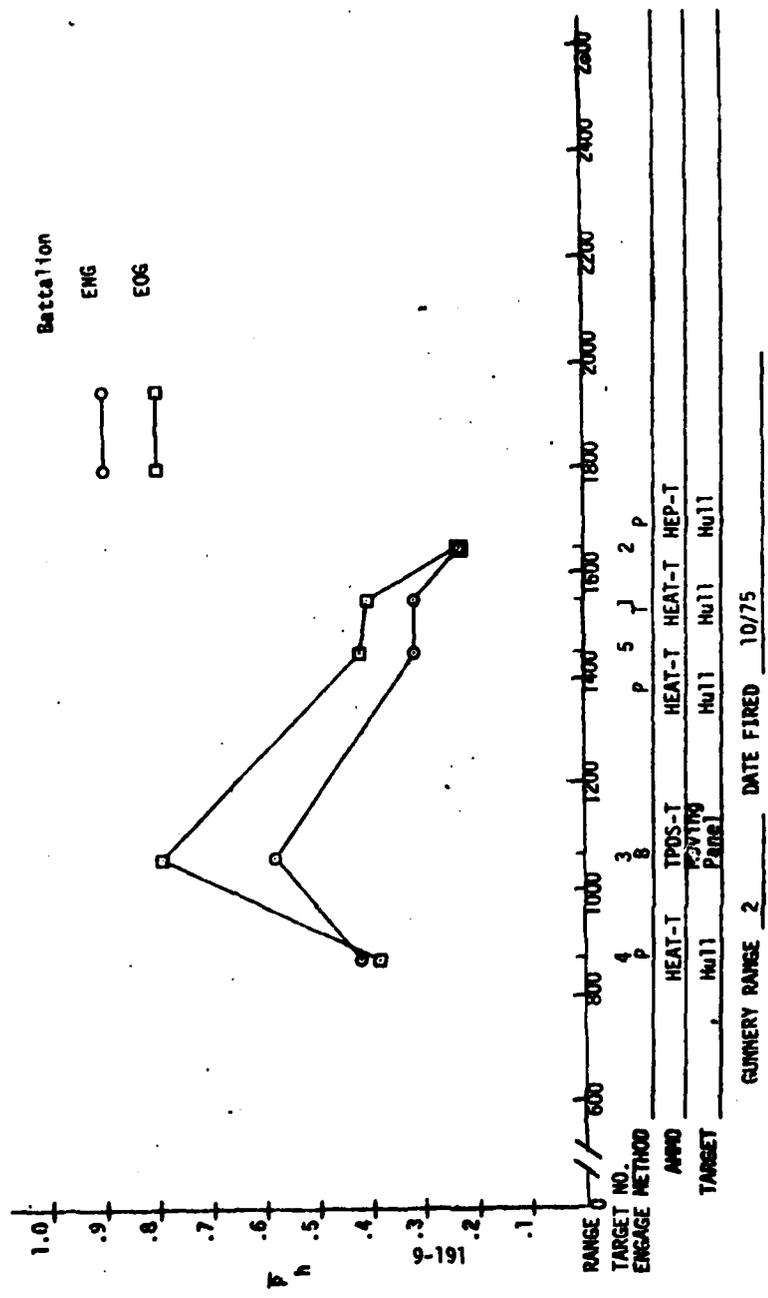


Figure 9-17. Mean First Round Hit Probability ( $P_h$ ) Performance on Table VIII Main Gun Targets.

Table 9-29. Table VIII A and B Analysis of Variance Summary, Comparison of the Battalions in the 6 Division

Source of Variation	df	MS	Gunnery Measure: First Round Firing Time		
			F	P	
D - Battalions	1	478.84	7.13	<.01	
A - Companies	2	319.59	4.76	<.05	
DA - Bn X Co	2	85.89	1.28	N.S.	
M(DA) - Error	90	67.15			
B - Tables (Tb)	1	30.82	---	N.S.	
DB - Bn X Tb	1	540.00	7.00	<.01	
AB - Co X Tb	2	332.18	4.31	<.05	
DAB - Bn X Co X Tb	2	65.73	---	N.S.	
MB(DA) - Error	90	77.15			
C - Targets (Tgt)	4	1558.33	44.70	<.001	
DC - Bn X Tgt	4	325.54	9.34	<.005	
AC - Co X Tgt	8	129.64	3.72	<.005	
DAC - Bn X Co X Tgt	8	133.81	3.84	<.005	
MC(DA) - Error	360	34.86			
BC - Tb X Tgt	4	58.65	1.62	N.S.	
DBC - Bn X Tb X Tgt	4	470.49	12.99	<.005	
ABC - Co X Tb X Tgt	8	110.26	3.05	<.005	
DABC - Bn X Co X Tb X Tgt	8	69.82	1.93	N.S.	
NBC(DA) - Error	360	36.21			

Table 9-30. First Round Mean Values

Battalions		Performance Measure				
ENG and LOG		First Round Firing Time				
1. Overall Mean =	12.61	Day = 12.79		Night = 12.43		
2.	Battalion					
		ENG	EOG			
		13.32	11.90			
3.	Target					
	1	2	3	4	5	
	15.59	14.05	8.51	10.93	13.97	
4.	Target					
Battalion	Table	1	2	3	4	5
ENG	Day	16.96	14.90	8.63	10.85	19.88
	Night	14.52	14.35	8.98	10.13	13.94
EOG	Day	16.17	13.79	8.92	10.73	7.04
	Night	14.73	13.10	7.50	12.00	15.02

Battalion's score of 58 percent was comparatively low. The AMSAA value for the engagement range fell about half-way between the two battalion means at approximately 68 percent. The results suggest that a real difference in gunnery proficiency exists between the battalions under the specific engagement conditions of target 3.

(2) Analysis of the C Division Battalions.

(a) Gunnery data were collected from a total N of 153 tank crews: 51 each from the UFC, UIC and UGC Battalions. The statistics produced from the following analysis of variance included the data from all 153 tank crews.

(b) Table 9-31 presents the results of the analysis of variance of first round  $\bar{P}_h$  scores. There were 9 significant effects. The most important ones were: Battalions ( $F=4.46$ ,  $p < .05$ ), Targets ( $F=95.50$ ,  $p < .001$ ), and Battalions X Targets ( $F=2.42$ ,  $p < .05$ ). The battalion means, presented in Table 9-32, were compared for differences in a Tukey's (HSD) Test. The results indicated that the  $\bar{P}_h$  score of the UGC Battalion was significantly higher ( $p < .05$ ) than the  $\bar{P}_h$  score of the UFC Battalion. Comparison of the Targets means in a Tukey's (HSD) Test indicated that the  $\bar{P}_h$  scores of targets 3 and 4 were significantly higher ( $p < .01$ ) than those for targets 1 and 2. Examination of the means for the Battalions X Targets X Targets interaction indicated that the UFC Battalion had the lowest  $\bar{P}_h$  scores on Table VIII A (Day) on all targets, and the highest  $\bar{P}_h$  scores on targets 1 and 2 on Table VIII B (Night).

(c) Table 9-33 presents the results of the analysis of variance of first round mean firing times. Pertinent significant effects were Battalions ( $F=6.72$ ,  $p < .005$ ), and Targets ( $F=181.54$ ,  $p < .001$ ). The battalion means, presented in Table 9-34, were compared for differences in a Tukey's (HSD) Test. The results indicated that the first round mean firing times of the UGC and UFC Battalions were significantly faster ( $p < .01$ ) than the UIC Battalion's. Comparison of the targets means in a Tukey's (HSD) Test showed that the mean firing times for all four targets differed significantly ( $p < .01$ ) from one another.

(d) The main finding which resulted from this analysis was that the UGC Battalion had the highest  $\bar{P}_h$  score and fastest mean firing time among the three battalions in the analysis. It achieved this superiority by scoring higher on three of the four targets and firing a little faster on all the targets. Taking each engagement separately, the UGC Battalion clearly outperformed the other battalions on only one engagement, and that was a ranged card problem involving indirect fire techniques which are of secondary importance in tank gunnery. Thus, the improved proficiency was attained by consistently good performance on all engagements which had the cumulative effect of raising the measures of overall performance.

d. Discussion.

(1) The results of this analysis have produced evidence which indicates

Table 9-31 Table VIII A and B Analysis of Variance Summary, Comparison of the Battalions in the C Division

Source of Variation	Battalions: UFC, UIC and U6C		Gunnery Measure: 1st Round P <sub>H</sub> (Percent)	
	df	MS	F	P
D - Battalions	2	9836.64	4.46	<.05
A - Companies	2	17508.17	7.93	<.005
DA - Bn X Co	4	1748.32	---	N.S.
N(DA) - Error	144	2206.82		
B - Tables (Tb)	1	115694.40	62.71	<.001
DB - Bn X Tb	2	11797.34	6.39	<.005
AB - Co X Tb	2	2115.91	7.15	N.S.
DAB - Bn X Co X Tb	4	498.48	---	N.S.
NB(DA) - Error	144	1845.06		
C - Targets (Tgt)	3	154300.10	95.50	<.001
DC - Bn X Tgt	6	2625.19	1.62	N.S.
AC - Co X Tgt	6	6963.41	4.31	<.005
DAC - Bn X Co X Tgt	12	3769.02	2.33	<.01
NC(DA) - Error	432	1615.67		
BC - Tb X Tgt	3	33929.64	21.11	<.001
DBC - Bn X Tb X Tgt	6	3888.56	2.42	<.05
ABC - Co X Tb X Tgt	6	677.94	---	N.S.
DABC - Bn X Co X Tb X Tgt	12	809.10	---	N.S.
NBC(DA) - Error	432	1607.02		

Table 9-32. First Round Mean Values

Battalions		Performance Measure			
UFC, UIC and UGC		First Round P <sub>h</sub> (Percent)			
1. Overall Mean = 61.85					
2. Day = 52.12			Night = 71.57		
3. Battalion					
	UFC	UIC	UGC		
	58.09	60.05	67.40		
4. Target					
	1	2	3	4	
	40.20	44.77	82.35	80.07	
5. Battalion					
		Day		Night	
	UFC	42.16		74.10	
	UIC	53.43		66.67	
	UGC	60.78		74.10	
6. Target					
Battalion	Table	1	2	3	4
UFC	Day	2.0	33.3	76.5	56.9
	Night	76.5	47.1	86.3	86.3
UIC	Day	25.5	51.0	76.5	60.8
	Night	49.2	45.1	82.4	90.2
UGC	Day	21.6	49.0	84.3	88.2
	Night	66.7	43.1	88.2	98.0

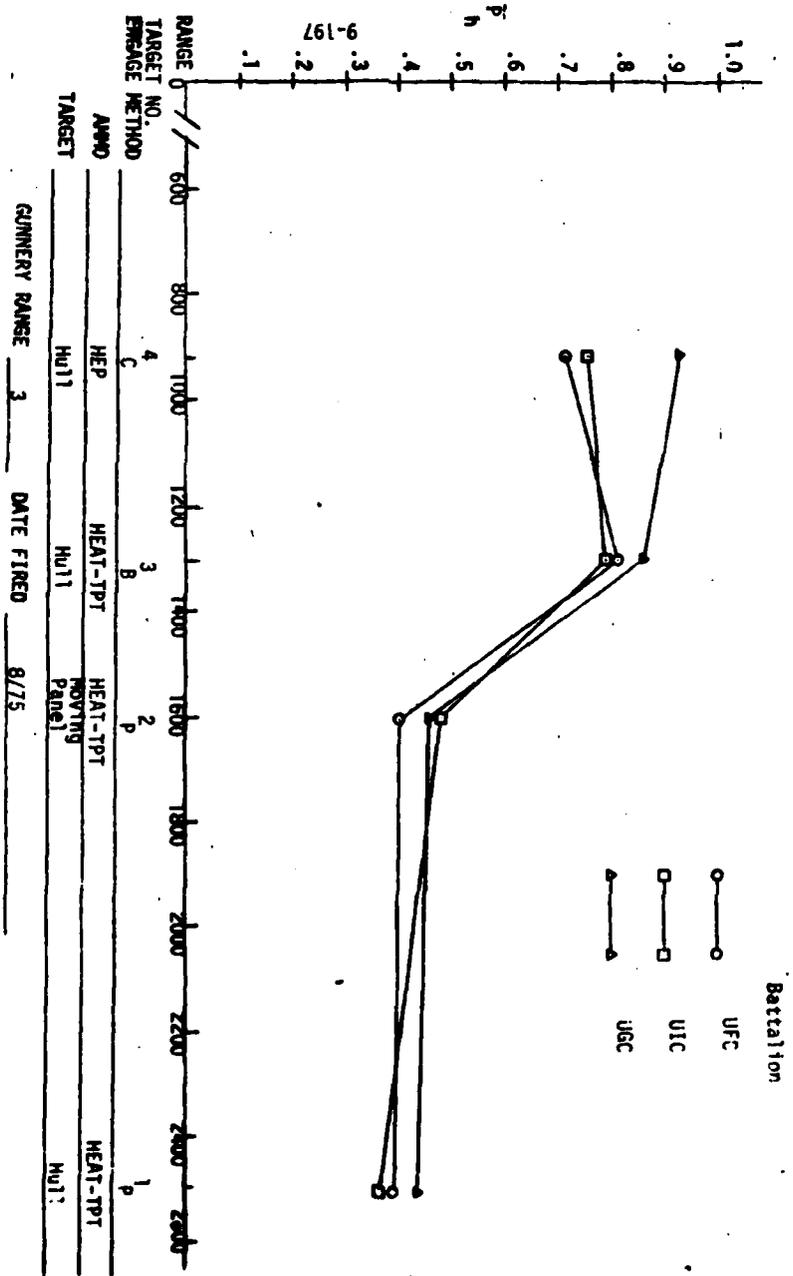


Figure 9-18 Mean First Round Hit Probability ( $P_h$ ) Performance on Table VIII Main Gun Targets.

TARGET	AMMO	HEAT-TPT	HEAT-TPT	HEAT-TPT
4	HEP	3	2	1
C	HU11	HU11	MOVING Panel	HU11

GUNNERY RANGE 3 DATE FIRED 8/75

Table 9-33 Table VIII A and B Analysis of Variance Summary, Comparison of the Battalions in the C Division

Source of Variation	df	MS	F	P
Battalions: UFC, UIC and UGC				
D - Battalions	2	1784.59	6.72	<.005
A - Companies	2	310.90	1.17	N.S.
DA - Bn X Co	4	99.27	---	N.S.
N(DA) - Error	144	265.53		
B - Tables (Tb)				
DB - Bn X Tb	1	124.90	---	N.S.
AB - Co X Tb	2	33.45	---	N.S.
DAB - Bn X Co X Tb	4	442.17	2.30	N.S.
NB(DA) - Error	144	180.52	---	N.S.
C - Targets (Tgt)				
DC - Bn X Tgt	3	32764.46	181.54	<.001
AC - Co X Tgt	6	359.23	1.99	N.S.
DAC - Bn X Co X Tgt	12	42.02	---	N.S.
NC(DA) - Error	432	194.13	1.08	N.S.
BC - Tb X Tgt				
DBC - Bn X Tb X Tgt	3	1695.88	12.09	<.005
ABC - Co X Tb X Tgt	6	237.17	1.69	N.S.
DABC - Bn X Co X Tb X Tgt	12	621.92	4.44	<.005
NBC(DA) - Error	432	179.40	1.28	N.S.
		140.22		

Table 9.34. First Round Mean Values

Battalions		Performance Measure			
UFC, UIC and UGC		First Round Firing Time			
1. Overall Mean =	23.82	Day =	23.50	Night =	24.14
2.		Battalion			
	UFC	UIC	UGC		
	23.00	26.19	22.25		
3.		Target			
	1	2	3	4	
	24.56	21.77	11.91	37.03	
4.		Target			
Battalion	1	2	3	4	
UFC	22.36	21.53	12.60	35.53	
UIC	29.42	22.86	12.06	40.43	
UGC	21.90	20.91	11.07	35.14	

that differences in gunnery proficiency frequently exist at the battalion level between units assigned to the same division. The outcome was somewhat unexpected in light of the previous discovery that within most battalions performance differences among their companies were not statistically significant. It is not immediately apparent why differences in gunnery proficiency occur more frequently at the battalion level than at the company level, but part of the difference may be due to the properties of the statistical tests used and not due to any change in the magnitude of mean differences that were observed at the two levels of organization. Examination of mean differences at both company level and battalion level seem to show that they are about of the same magnitude; around ten to fifteen percent. However, the variability in scores seems to be less at battalion level. The difference in variability could account for the difference in results. In any case, the results show unequivocally that there are real differences in gunnery proficiency between battalions.

(2) The performance differences occurred in terms of both accuracy measures and firing time. They were positively correlated. The superior battalions tended to attain significantly higher mean accuracy scores and significantly faster mean firing times in comparison with the inferior battalions. This demonstration of higher proficiency on both performance measures provides additional evidence showing that between-battalion differences are broadly based. This strengthens confidence in the judgement that the differences are reliable and meaningful.

(3) Mean differences in accuracy measures between battalions can differ in terms of either specific engagement conditions or in overall performance. Type of difference is important because it has implications for how interpretations are formulated explaining the cause of the differences. If the differences are specific to engagement conditions, it can be argued that they result from differences in emphasis on specific subjects in gunnery training and not due to any real difference in general proficiency. The problem could be corrected by merely changing the emphasis in training to conform more closely with test requirements. On the other hand, if the difference is in overall performance the interpretation is straightforward. The level of proficiency should be viewed as substandard in all gunnery subjects. Remedial training would involve upgrading technical skills in all areas of gunnery, a more demanding requirement.

(4) Between-battalion differences in mean firing time tend to differ more on overall performance than on specific engagements although there are a few instances of the latter occurring. It appears that increasing firing speed tends to generalize to all types of engagements. Thus differences appear to show more uniformity. Some battalions fire at a faster rate than others.

#### e. Findings and Conclusions.

(1) Significant differences frequently occur in measures of gunnery proficiency between battalions assigned to the same division.

(2) The higher scoring battalions tend to demonstrate superior proficiency in terms of both increased  $\bar{P}_h$  scores and faster mean firing times.

(3) Between-battalion differences in  $\bar{P}_h$  scores differ in terms of specific engagement conditions and in overall performance.

(4) Between-battalion differences in firing time appear to differ mainly in terms of overall performance.

## 9-7. The Effects of Target Engagement Variables on Tank Gunnery Error.

This study was concerned with analyzing tank gunnery error data to identify their main characteristics, the target engagement variables that contribute to their occurrence, and to describe the functional relations that exist between them. The analysis was restricted to considering the influence of target engagement factors and did not include any direct assessment of relevant equipment and operator variables that could have contributed to gunnery error. Examples of these latter variables are: inaccurate boresighting and synchronizing of the main gun, and poor alignment of the gunner's eyes with the line-of-sight in the optical aiming device. If such factors produced gunnery errors, it is assumed that they operated randomly and therefore, did not bias the results in any direction. The gunnery data used in the analysis came from the Tank Crew Qualification Test data (called Table VIII Scores) reported in Annex A to Net Assessment of U.S. and Soviet Tank Crew Training, TCATA report, April 1976.

### a. Types of Tank Gunnery Errors.

(1) Generally speaking, gunnery errors are described in terms of two dimensions; range and angle. Weapon ballistic characteristics determine the proportions of errors that will fall within each dimension. High velocity, direct fire, tank guns produce a large proportion of errors in the range dimension and relatively few in angle. Thus most tank gunnery errors occur with the line of flight of the round in correct alignment with the target, but err at point of impact with the round either passing over it or striking short of it. The two errors are designated as Over Line (OL) and Short Line (SL), respectively.

(2) Angle errors usually occur in conjunction with moving targets as a result of applying incorrect lead angle. Even so, the magnitude of error is usually small when it does occur and observers experience some difficulty in sensing the miss. Thus they designate these errors as either Doubtful Right (DR) or Doubtful Left (DL). These four error types comprise the main categories and account for well over 90 percent of tank gunnery errors. There are other error categories, but they cover miscellaneous events that occur infrequently. This analysis was limited to evaluating the four main error categories. Miscellaneous error types were not considered.

### b. Comparison of USAREUR and CONUS Gunnery Data.

The previous analysis of gunnery data reported in Annex A of the Net Assessment Study concluded that the quality of scoring varied greatly between USAREUR and CONUS battalions. USAREUR scoring appeared to be accurate and reliable, while CONUS scoring showed evidence of large inaccuracies and unreliability in much of its scoring. This difference in

scoring quality was encountered in the present analysis. The results from the analysis of the data from the USAREUR battalions were consistent, orderly and open to straight forward interpretation. The results from the analysis of the CONUS data, on the other hand, showed inconsistencies and were difficult to interpret. It was felt that the differences in results reflected the differences in scoring quality. Therefore, it was decided to base the analysis on the USAREUR data exclusively, since there was a lack of confidence in the validity and reliability of the CONUS data.

c. Analysis of USAREUR Error Data. Table 9-35 presents a tabulation of frequencies and percentages of the four error categories according to range intervals. The grand total amounts to 1,090 errors out of the USAREUR sample total of 1,169, indicating that 93.3 percent of the errors were accounted for. The missing 6.7 percent, 79 rounds, fell into the miscellaneous category; a comparatively small proportion. Furthermore, when the frequency proportions of the four error types are examined, it is found that 87 percent were concentrated in the OL and SL categories. Obviously, OL and SL errors are the primary tank gunnery errors observed on Table VIII. Since ranging errors were preponderant, emphasis was given to their analysis which is presented first followed by the analysis of angle errors.

(1) Analysis of Over Line and Short Line Errors.

(a) The percentage data in Table 9-35 is presented graphically in Figure 9-19. The two linear curves in Figure 9-19 show clearly the functional relation that exists between target range and type of ranging error. They describe the classic X-form relationship that occurs between two variables that interact strongly with one another. They show that type of ranging error depends upon target range. At short ranges OL errors predominate and SL errors are minimal. There is a constant error to overestimate target range. As target range increases OL errors decrease while SL errors increase proportionally. The trends continue in this manner until at long ranges OL errors are minimal and SL errors predominate; a complete reversal of the relation at short range. Now, there is a constant error to underestimate target range. Thus target range determines the relative frequency of the type of ranging error. The percentage data were tested in an analysis of variance. The range X error interaction was highly significant,  $F(6,14) = 13.37$ ,  $p < .005$ , confirming the foregoing interpretation. The main effects of range and error were not statistically significant.

(b) An important feature of the interaction is the point at which the two curves intersect. This is the range at which OL and SL errors are equally likely. By inference, it is also the range that is estimated most accurately since the OL and SL errors bracket the target, that is, from a probabilistic point of view. At this range there is not constant error in range estimation. Figures 9-20 and 9-21 present graphs of the interaction for Table VIII A (day) and B (night) respectively. Examination of the intersect points in the two figures indicates that it shifts to a longer

Table 9-35. USAREUR ICOC Round 1 Gunnery Errors Table VIII A and B Combined Overall Engagement Conditions

RANGE		ERROR				TOTAL
600 - 800	OL	SL	DR	DL		
	N	7	1	0	2	10
	%	70	10	0	20	100
800 - 1000	N	187	124	17	54	382
	%	49	32	5	14	100
1000 - 1200	N	47	32	11	12	102
	%	46	31	11	12	100
1200 - 1400	N	11	24	3	2	40
	%	28	60	8	4	100
1400 - 1600	N	37	128	1	10	226
	%	38	57	1	4	100
1600 - 1800	N	55	152	8	13	228
	%	24	67	3	6	100
1800 - 2000	N	30	63	2	7	102
	%	29	62	2	7	100
TOTAL	N	424	524	42	100	1090
	%	39	48	4	9	100

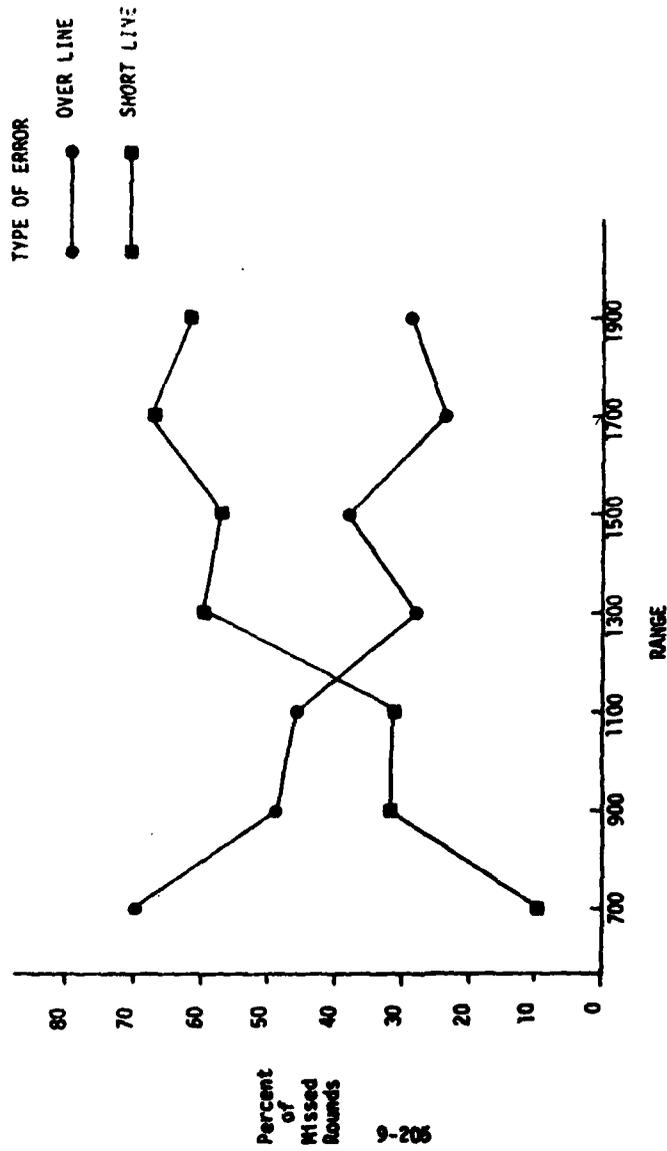


Figure 9-19. USAREUR Overall Engagement Conditions for Table VIII A and B (Day and Night) Combined.

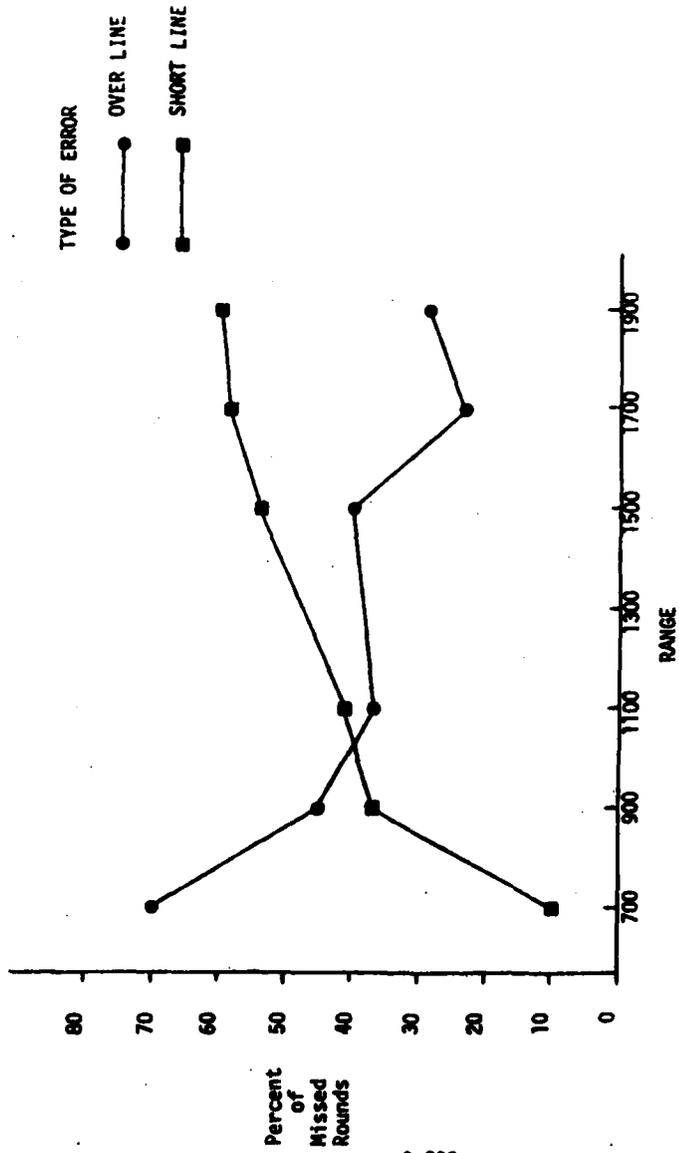


Figure 9-20. USAREUR Overall Engagement Conditions for Table VIII A (Day).

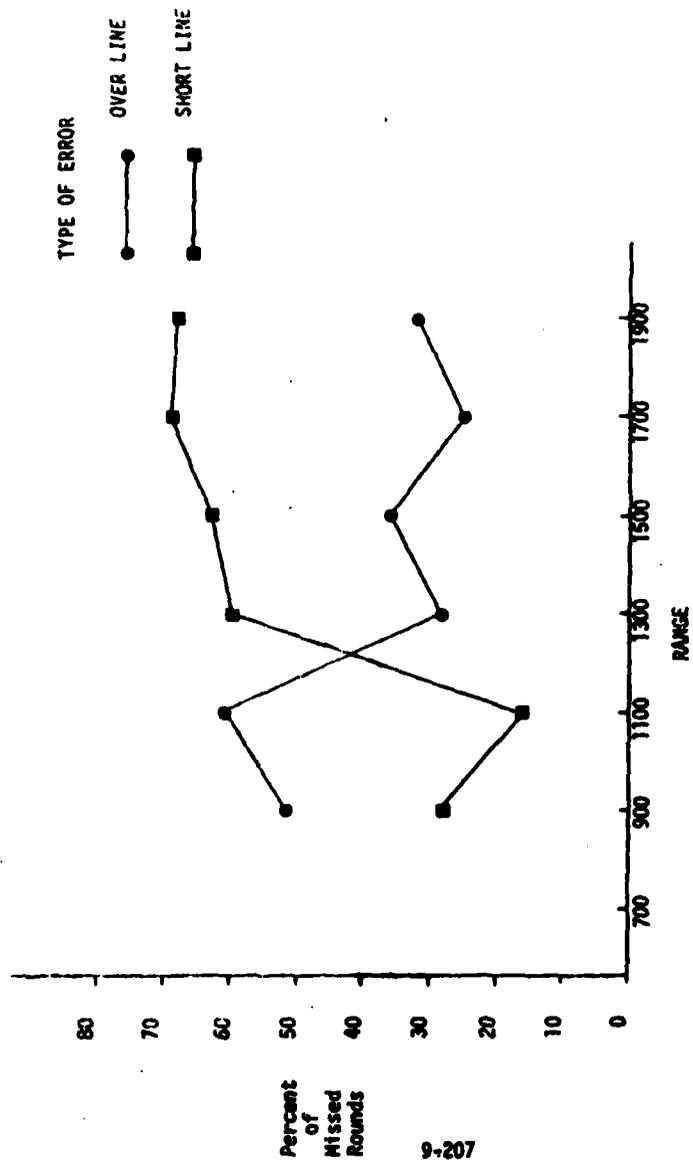


Figure 9-21. USAREUR Overall Engagement Conditions for Table VIII B (Night).

range from day to night. On Table VIII A (day) the point falls at 1030 meters, while on Table VIII B (night) it falls at 1220 meters; an increase of approximately 200 meters in range. Since range estimations are performed by means of daylight and low light optical and electro-optical range finders, explanations of the shift of the intercept will involve analysis of the relations between human visual characteristics for day and night vision and the properties of the range finders.

(2) Analysis of Doubtful Right and Doubtful Left Errors.

(a) The gunnery data on moving targets in the sample is limited to one target on Range 80 at Grafenwoehr Training Area. This was Target Number 8 whose characteristics are given below:

Table 9-36. Target Number 8 - Moving Target

Range	Type	Attitude	Direction of Movements
800-1000	12' x 6' OD Tank Silhouette	Flank	Left to Right

Speed: 12 MPH over 220 Meters

Tabulation of the four gunnery errors on Target 8 are presented in Table 9-37.

Table 9-37. USAREUR TCQC Round and Gunnery Errors, Target Number 8, TPDS-T Battlesight, Moving Target

Table VIII		Gunnery Errors				TOTAL
		OL	SL	DR	DL	
Day	N	46	49	2	27	124
	%	37	40	1	22	100
Night	N	47	25	1	15	88
	%	53	28	2	17	100
Day & Night	N	93	74	3	42	212
	%	44	35	1	20	100

(b) The results in Table 9-37 were derived from one target engagement and therefore are limited to the conditions from which they were obtained. Nevertheless, two findings emerged which may prove to be fundamental to moving target engagements as a class. One, the proportion of gunnery errors due to angle error becomes substantial and can account for as much as 20 percent of the overall error. Two, an insufficient amount of lead

angle was entered into the aiming solution resulting in 42 of 45 (93 percent) angle errors passing behind the moving target. It is interesting to note that TPDS-T high velocity ammo was used on this engagement. This means that at a range of 1000 meters the rounds should have reached the target in about 0.3 second. At 12 MPH the target should have moved 5.28 feet in that time; say 6 feet for sake of argument. The target was 12 feet wide. If the aiming point was at the center of the target, there would be 6 feet of target on either side at the time of firing. Since the target moved 6 feet before the round arrived, it could pass behind the target only if the aiming point was at the target center and no lead angle had been entered into the aiming solution. It follows that DL errors resulted because gunners aimed at the center of the target when they should have been aiming at its leading edge. This interpretation is a rational deduction and may not be true. However, it does suggest the possibility that a substantial number of gunners apply little or no lead angle to moving targets when firing battlesights with the non-ballistic retical and using TPDS-T ammo.

#### 9-8 Summary of Findings

- Table VIII data from the sample USAREUR battalions appears to be more valid and reliable than data from CONUS battalions.

- Both USAREUR and CONUS tank crews fire more accurately at middle ranges of from approximately 1000-1800 meters. First round accuracy at the short ranges from 600-1000 meters is relatively poor.

- There was no practical difference in main gun accuracy performance between Table VIII A (day) and Table VIII B (night).

- There is no difference in first round accuracy between precision and battlesight engagement methods in the battlesight range band (600-1800 meters).

- There is little difference in first round accuracy and firing time when engaging either stationary or moving targets.

- There is not a strong linear correlation between first round accuracy and firing time.