Research Problem Review 77-13

FACTORS AFFECTING EFFICIENCY OF BORESIGHTING AND ZEROING PERFORMANCES IN THE M60A1 TANK

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Research Problem Review 77-13

FACTORS AFFECTING EFFICIENCY OF BORESIGHTING AND ZEROING PERFORMANCES IN THE M60A1 TANK

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FOREWORD

The ARI Field Unit at Fort Knox, Kentucky, is concerned primarily with the development and evaluation of training directed toward enhancing crew and unit proficiency in various Armor systems. The present research deals with an investigation of factors influencing the efficiency of boresighting and zeroing performances on the M60A1 tank weapon system. The work was conducted in support of the US Army Armor School's training effectiveness analysis of the M60A1/AOS tank. Recommendations based on the results of the study have a potential impact on improved cost effectiveness in tank gunnery training as well as on enhanced system performance and unit readiness. The research is part of a larger effort responsive to the Army Training and Doctrine Command (TRADOC), as well as Army Project 2Q763743A773, "Combat Unit Training."

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Technical Director

FACTORS AFFECTING EFFICIENCY OF BORESIGHTING AND ZEROING PERFORMANCES IN THE M60A1 TANK

BRIEF

Requirement:

In support of the US Army Armor School's training effectiveness analysis of the M60A1 tank, to identify factors in standard Armor training that may influence the number of rounds used to zero the tank main gun. Rounds to zero is a measure of efficiency in boresighting (visually aligning gun tube and sight) and in zeroing (correcting the aiming point by observation of actual hits).

Procedure:

In a scheduled field exercise, 34 M60A1 tank crews filled in questionnaires on their knowledge of the principles and procedures of boresighting and zeroing, their perceptions of gunnery outcomes, and their experience. Afterward, data collectors observed and recorded the boresighting and zeroing exercises and results.

Five factors were assessed in relation to number of rounds to zero: gun tube life, as determined from the tank logbooks; and the tank commanders' and gunners' experience, knowledge of procedures, knowledge of principles, and expectations of results.

Findings:

The crews averaged 6.36 rounds to zero, including the warm-up round. Fewer than 60% hit the target panel on the first round after warm-up, and only 75% of all rounds hit the panel. In general, the crews that hit the panel most often needed significantly fewer rounds to zero.

Neither gun tube life nor crew experience were related to rounds to zero in this research.

Data collectors noted few errors during the exercises, but reported that only about half the commanders physically verified crewmen's boresighting alignments. Two thirds of the crews did not know their tank's established zero, and none used it. While no major procedural errors were noted during the conduct of boresighting and zeroing, 70% of tank commanders and gunners missed over half of all knowledge items pertaining to boresighting and zeroing. Performances were generally poorer on items calling for the application of knowledge than on items requiring only the identification of a principle. In many instances, responses indicate a failure to clearly differentiate procedurally between boresighting and zeroing as well as between the separate functions served by each. Overall, gunners' total knowledge scores correlated significantly with number of rounds to zero.

Crews did not consider boresighting and zeroing to be precision tasks. Attitudes survey responses were not related to number of rounds to zero.

Use of a larger target panel, combined with increased emphasis in training on the separate functions of boresighting and zeroing are recommended.

Utilization of Findings:

Recommendations as to ways to achieve greater cost effectiveness in the area of zeroing as well as greater overall system effectiveness for the M60A1 tank have been presented to: Commandant, US Army Armor School, (USAARMS); Chief, Directorate of Training Developments, (USAARMS); Director, Weapons Department, (USAARMS); Chief, Gunnery Division, (USAARMS); Annual Armor Up-Date Conference, Ft Knox; and to Division Commander, Battalion and Company officers of participating unit. Potential cost savings are estimated to be .4 million dollars or more annually. Recording and use of established zero will result in improved state of readiness of armor force.

FACTORS AFFECTING EFFICIENCY OF BORESIGHTING AND ZEROING PERFORMANCES IN THE M60A1 TANK

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FACTORS AFFECTING EFFICIENCY OF BORESIGHTING AND ZEROING PERFORMANCES IN THE M60A1 TANK

INTRODUCTION

Because boresighting and zeroing represent tasks of primary importance in maintaining the tank's first-round hit capability and, in turn, its overall system effectiveness, questions about crew proficiency in these tasks prompted the research reported here of a typical FORSCOM armor battalion. Data were collected during a regularly scheduled off-season tank gunnery training exercise approximately three months after the unit's annual tank crew qualification exercises.

The study was performed in conjunction with the US Army Armor School's training effectiveness analysis (TEA) of the M60A1 series tank, and with associated work areas of the Army Research Institute's Ft Knox Field Unit dealing with the development of training effectiveness methodology and with the improvement of tank crew training in general.

An important measure of training effectiveness as well as cost effectiveness in the areas of boresighting and zeroing is the number of rounds used to zero. Five factors were studied for their possible relation to this variable. These factors were (1) gun tube life, (2) experience of the tank commander and gunner, (3) knowledge and performance of basic procedures, (4) knowledge of tank gunnery principles underlying boresighting and zeroing, and (5) expectations of performance outcomes associated with the execution of proper boresighting and zeroing procedures.

Recommendations based on the relations of these variables to the amount of ammunition expended during zeroing impacted on training (e.g., in the areas of tank commander supervisory responsibilities during boresighting and zeroing; level of feedback associated with training given in boresighting; emphasis given to the requirement for precision inherent in the task) as well as on anticipated cost savings and overall weapon system effectiveness.

Basic Procedures of Boresighting and Zeroing the 105mm Gun. An effective first-round hit capability for any direct-fire weapon system is based on a reliable relation between the gunner's point of aim and the point where rounds actually strike the target. To establish this relation, two procedurally independent but functionally interrelated tasks must be performed, as outlined in Army Field Manual FM 17-12, "Tank Gunnery."[1] The first task, called boresighting, aligns the center axis of the gun tube with the firer's line of sight at a predetermined range. The second, called zeroing, corrects for the difference between the gunner's line of sight and the actual point where rounds strike the target. This deviation is referred to as "fixed jump"[2,3] and is viewed as the net result of an unknown combination of errors which are present at all firings and are relatively constant for a particular vehicle, gun, and ammunition lot. It is usually assumed that this error is fully corrected by zeroing.

Procedurally, boresighting the tank main gun first involves aligning the gun tube on the upper left corner of the rectangular boresight panel. Alignment is accomplished through the use of a two-point reference system. One reference point is at the intersection of two threads placed across the muzzle of the gun at right angles to one another. The other reference point is at the breech end of the gun tube, where a crewmember, sighting through the firing pen well with the non-ballistic portion of the binoculars, instructs the gunner to manually traverse and elevate the gun until the intersection point at the muzzle is laid on the upper left corner of the boresight panel. The gunner, looking through his sight, then aligns the sight reticle on the same point by physically moving the sight reticle with the boresight knobs for elevation and deflection. With both the gun and the sights looking at the same point, the gunner "slips" the boresight knobs for elevation and deflection to established reference points prescribed in the operator's manual. The gunner follows a similar procedure for the other sights, as does the tank commander for the rangefinder at his position.

Although the tank main gun and sights are now "boresighted," rounds fired at the zero panel will not necessarily strike within two feet of the gunner's aiming point (the criterion for being "zeroed"). The deviation of rounds from the gunner's point of aim is due to factors (e.g., curvature of the gun tube) generally not detectable by the crew because of limitations of the field boresight method. To establish with reasonable confidence the extent of this deviation (jump relationship), a three-round shot group is fired at the zero panel and then the aiming point of gunner's sight is

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[1] US Army Armor School. Tank Gunnery, FM 17-12, Ft Knox, KY, November 1972.

[2] Bryla, E. A. Reduce your budget, yet buy more. Armor Magazine, 15, November-December 1976.

[3] Shiflett, J. Tank gunnery boresight and zero. US Army Armor and Engineer Board, Ft Knox, KY, 1976.

referred to the center of this shot group (using the boresight adjustment knobs). The rationale for this procedure, called zeroing, lies in the mathematical demonstration that a three-round shot group in a panel 1200 meters away has a probability near unity that the center of that shot group will be within two feet of the "true" center (true center being defined as the center of a hypothetical 2000 shot group). In principle, then, after the sights are referred to the new aiming point, most subsequent rounds should strike within two feet of the aiming point at 1200 meters.

The scale readings on the boresight knobs now become the "established zero" for that gun tube for that particular ammunition. The established zero is essentially an angular measure (in mils) of the jump relationship. The relationship is between the gun tube and the path taken by projectiles when leaving the gun tube, and as such is independent of the optics of the sighting system. To the extent that this jump relationship remains relatively constant over time, the gun crew can reboresight and reapply the established zero. To go through the entire zeroing exercise again, in principle, merely reconfirms the previously identified jump relationship contained in the established zero settings.

Current Indicators of Performance Deficiencies in Boresighting and Zeroing. Pilot work by ARI in developing simulated performance tests for the Armor Advanced Individual Training (AIT) end-of-cycle exam[4] suggested that boresighting and zeroing tasks may not be adequately taught. Of the Armor AIT graduates tested, 20% to 50% missed items dealing with boresighting and zeroing (e.g., what is the correct aimpoint when boresighting; to what point do you refer the sight reticle after firing the shot group). The percentage of persons passing/failing an item was a function of whether the test items were presented as pencil and paper items or by video tape.

Other data questioned the extent to which these skills were retained once the individual was graduated from AIT and assigned to a unit. Of 20 tank crews undergoing an initial skills test on M60A1 procedures before participating in an Armor Board project, 14 out of 20 of the tank commanders and gunners tested failed the station on boresighting.[5]

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[4] Cockrell, J. T. Television as stimulus input in synthetic performance testing: Experiment I. Ppaer given at Military Testing Association Conference, Gulf Shores, Alabama, October 1976.

[5] After Action Report: M60A1E3 Training Program. Weapons Department, US Army Armor School, Ft Knox, KY, November 1975.

Although all individuals succeeded in passing the station after minimal refresher training, the high rate of initial failures points to a potential problem in the retention of these skills over time.

Th se data draw attention to a problem in the areas of boresighting and zeroing but do not make clear the exact locus of the problem (i.e., whether in training, retention, or motivation). It is clear, however, that a direct consequence of poor performance in these areas may be the unnecessary expenditure of main gun ammunication in zeroing, and more important, poor system effectiveness.

METHOD

SUBJECTS

Subjects consisted of the members of 34 M60A1 tank crews of a FORSCOM tank battalion. Primary attention was directed toward tank commanders and gunners. The tank commanders and gunners of the battalion studied were significantly less experienced in terms of time in service, time in crew position, and time in crew than their counterparts sampled by the "Assessment of US Tank Crew Training".[6] For the present sample, measures of time in service, time in crew position, and time in crew are given in Table 1 by company.

The inexperience of crewmen in the present sample must be viewed in light of personnel factors operating in conjunction with the unit's planned move from CONUS to USAREUR status. All tank commanders had, however, participated in the unit's annual tank crew qualification exercises conducted three months before the present data were collected, although fewer than 20 percent had served with the present gunner prior to this time.

PROCEDURE

The data in the present research were collected during a scheduled off-season tank gunnery training exercise involving boresighting and zeroing. The exercises were conducted on one company at a time over the period of approximately 6 days (2 days/company) and followed the battalion's annual tank crew qualification exercises by approximately 3 months.

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6 Lawson, J., Earl, W., and Henson, V. Assessment of US tank crew training. TRADOC Combined Arms Test Activity, Ft Hood, TX. Report Number FM 331, July 1976.

Table 1

EXPERIENCE MEASURES FOR TANK COMMANDERS AND GUNNERS

	Tank Commander		
	Time in Service	Experience in Position	Experience in Crew
Co A	4 yr 4 mo	8 mo	3 mo
Co B	5 yr	7 mo	1 mo
Co C	1 yr 8 mo	4 mo	2 mo
NET Asses.	8 yr 6 mo	12.4 mo	6 mo

	Tank Gunner		
	Time in Service	Experience in Position	Experience in Crew
Co A	1 yr 5 mo.	6 mo	1 mo
Co B	1 yr 10 mo	6 mo	2.5 mo
Co C	1 yr 1 mo	5 mo	.5 mo
NET Asses.	5 yr 7 mo	8.9 mo	6 mo

First, a briefing described the purpose of the data collection as determining factors related to the amount of ammunition used to zero. Next, tank commanders and gunners filled out the gunnery knowledge questionnaire (Appendix A) and performance outcome survey (Appendix B) in the immediate area of their tank, with the instruction that they were to work independently. Both the outcome survey and the gunnery knowledge questionnaire were constructed by ARI. Neither should be considered "valid" in the sense of bearing known empirical relations to tank gunnery performance. In no instance should performances on either instrument be taken as the basis for prediction or selection.

Background information was collected and/or verified by data collectors before the crews began to boresight. Data collectors consisted of one ARI researcher, ARI operations sergeant, and two Master Gunners assigned to the battalion. The background data and observations were recorded on the form shown in Appendix C. Rounds fired for zeroing were sensed by the battalion's support platoon leader using a BC scope situated to the left rear of the firing line. Zeroing was accomplished one tank at a time with confirmation of sensings provided by nonfiring tanks' crews. Information as to gun tube life was provided by the support platoon leader on the basis of a personal inspection of data found in each tank's logbook.

RESULTS

Following a brief description of the hit performances and their relation to the number of rounds to zero, the relation between each of the five classes of variables and the number of rounds are presented.

HIT PERFORMANCES

The mean number of rounds used to zero by the 34 tanks was 6.36 rounds per tank (includes warm-up round). The distribution of rounds to zero is given in Figure 1 by company and for the battalion as a whole. Counting all rounds fired during the zeroing exercise (including warm-up), only 75 percent of all rounds actually struck the 8x8 ft zero panel. With respect to the first round fired at the panel following the warm-up round, only 56 percent actually hit the panel. In terms of the proximity of the initial shot group to the point of aim, only 1 of 34 tanks obtained an initial shot group having a center within 2 feet of the aiming point.

Figure 2 shows the mean number of rounds used to zero as a function of the time of day when zeroing was conducted. The vertical bars indicate the range of rounds used during each time period. No significant linear

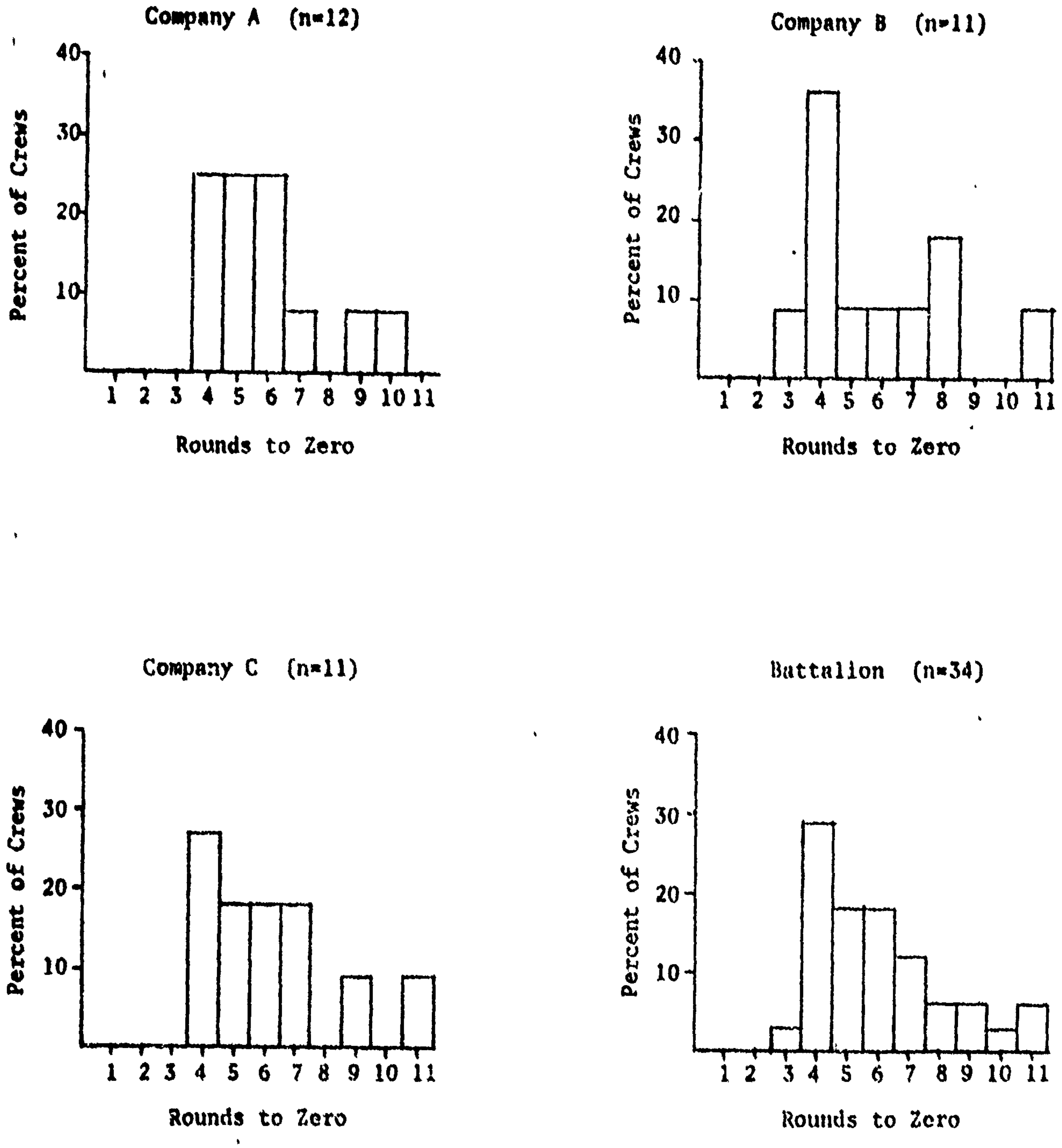

Figure 1. Distribution of Rounds to Zero

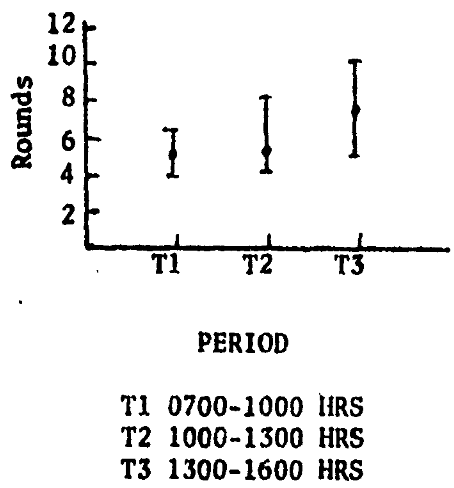

Figure 2. Rounds to Zero as a Function of Period of Day when Firing Was Conducted.

relation was found between the number of rounds used and time of day ($r = .337$, $df = 30$, $p > .05$). A one-way analysis of variance was performed on the data by identifying performances as to whether they occurred during the following 3-hour periods: 0700-1000 hrs; 1000-1300 hrs; 1300-1600 hrs. No significant main effect was found ($F = 2.2128$, $df = 2,29$, $p > .05$).

When correlating measures of hit performance with the number of rounds used to zero, it was found that the percent overall hits correlated significantly with the number of rounds used to zero ($r = -.34$, $df = 32$, $p < .05$). Those tanks achieving a high percentage of hits, in general, used fewer rounds to zero. Of all variables studied, overall percent hits have the clearest relation to the number of rounds used to zero.

GUN TUBE LIFE

Measures of gun tube life for the 34 tanks studied ranged from 920 to 280 remaining rounds, with a mean of 560. No systematic relation was observed between the number of remaining rounds and the number of rounds used to zero ($r = -.09$, $df = 32$, $p > .05$). The recognized importance of gun tube life as a factor in tank gunner is not questioned by this result, for the present result is interpreted only in the context of a limited range of gun tube life.

TANK COMMANDER AND GUNNER EXPERIENCE

For neither the tank commander nor the gunner was a systematic relation observed between experience (time in service and time in MOS), and the number of rounds used to zero. Interpretation of this finding must take into account the narrow range of experience represented in the present sample of tank commanders and gunners and by no means should be generalized to the point of negating the effect of experience as a variable in tank gunnery performance. The present result simply says that if some aspect of experience had anything to do with the present results, that aspect was not measured by time in service or time in MOS.

PROCEDURES

Two aspects of procedure were addressed. First, tank commander's and gunners' knowledge of specific procedures were assessed through a paper and pencil questionnaire (see Appendix A, Part B, Items 1-15). Second, procedures were assessed through direct observation of their execution during the boresighting and zeroing exercise (Appendix C).

Knowledge of Procedures. Table 2 shows the percent of tank commanders and gunners giving each response alternative on the paper and pencil items. Of particular concern are those items where fewer than 70 percent of either group answered the item correctly (see items 7, 8, 10, 12, 14). Strictly speaking, item 8 is not a procedural item. Of the remaining errors, items 10, 12, and 14 are the most serious, both

Table 2

RESPONSES (PERCENT) OF TANK COMMANDERS AND GUNNERS TO PROCEDURE ITEMS (PART B)

TANK COMMANDERS

Item	a	b	c	d	NR	Correct Response
	Response Catagory					
1	6	3	91	0	0	C
2	6	3	91	0	0	C
3	0	0	0	100	0	D
4	81	12	6	0	0	A
5	28	78	6	0	0	B
6	41	3	53	0	0	C
7	16	9	38	38	0	D
8	19	81	0	0	0	B
9	0	0	100	0	0	C
10	66	6	0	28	0	A
11	3	75	6	16	0	B
12	69	16	6	9	0	A
13	9	91	0	0	0	B
14	31	3	56	6	0	C
15*	41	78	25	16	0	B

GUNNERS

Item	a	b	c	d	NR	Correct Response
	Response Catagory					
1	0	3	94	0	3	C
2	6	0	91	0	3	C
3	3	0	3	91	3	D
4	84	9	3	0	3	A
5	12	81	3	0	3	B
6	19	6	72	0	3	C
7	12	9	44	28	6	D
8	28	69	0	0	3	B
9	0	0	97	0	3	C
10	53	19	0	25	3	A
11	0	75	12	3	9	B
12	53	16	19	6	6	A
13	12	78	3	3	3	B
14	38	0	47	9	6	C
15*	38	69	28	12	3	B

* Percentages totalling more than 100% reflect that more than one answer was allowable.

from the standpoint of ammunition conservation during zeroing and for tank gunnery performance in general. The distribution of responses to item 10 indicates that the actions taken by the crew following a miss are not well standardized. In light of the observation that fewer than 60 percent of rounds fired immediately following the warm-up round hit the panel, the question indicates that actions taken at this frequently occurring choice point are not well understood.

Actual observations of the actions taken by crews under these conditions revealed that a frequent response (and one not represented by the lettered alternatives) is to refer one's sights to what is essentially a one-round shot group. What is gained by such a manipulation is doubtful inasmuch as one can say with relative certainty only that on the basis of one round, the true center of the shot group is somewhere within four feet of the point of impact of the round.

Item 12, dealing with the setting of the established zero on the boresight knobs, indicates that the manner for performing this operation is poorly understood. Sixteen percent of both groups thought that the slip-scales themselves were moved, an operation which would result in no movement of the sight reticle. Implications of the improper application of the established zero are discussed later.

A more serious error is implied in the responses given by tank commanders and gunners to item 14, where 31 percent of tank commanders and 38 percent of gunners reported that all superelevation was removed from the main gun during zeroing. Although this response may indicate a failure to distinguish between the procedures involved in boresighting and those involved in zeroing, if the error correlates with actual performance the consequences will be great and will depend both on the ammunition used for zeroing and that used when firing for effect.

For instance, when zeroing with TPDS and then firing with TPDS, the superelevation error of approximately 3 mils, while causing the round to go over the target, will not be so great as when TPDS is fired following zeroing with HEAT. Under these conditions, a superelevation error of approximately 16 mils would be introduced. With the high muzzle velocity of TPDS, such an error would cause the round to miss by such an extent as to probably result in a sensing of "LOST".

Execution of Procedures. With the exception of 10 percent or fewer of the gunners using the 1200 meter aiming point of the telescope reticle rather than the boresight cross for boresighting, no major procedural errors were committed in the execution of boresighting and zeroing. Nevertheless, several aspects of procedure, not labeled as "errors" per se, were noted.

The first was a general lack of supervision on the part of the tank commander in verifying both the lay of the gun and the gunner's sights for a precise lay on the boresight panel. Only 60 percent of the tank commanders were observed to physically check the sight picture obtained by the crew-member sighting through the breech with the binoculars and only 40 percent checked the sight picture obtained by the gunner. Although "checking" or "not checking" was not shown to be statistically correlated with the number of rounds used to zero, the observations were taken as representing a general lack of responsiveness on the part of the tank commander to the precision elements of the boresighting task.

Verifying the lay of the main gun seems to be warranted on the basis of the difficulty observed on the part of the crew member using the binoculars to sight through the breech. Partly because of the crouched position one must assume to perform this task and partly because of the absence of a firm seating for the binoculars to rest in, the sight picture may vary excessively due to movement of the binoculars.

A second aspect of procedure, although not itself a procedural error, was the failure to use the opportunity for confirming and/or refining an established zero instead of as an opportunity for repeating the entire zeroing exercise. Although the battalion had participated in its annual tank gunnery qualification exercise only three months prior to this particular exercise, two thirds of the crews did not know their tank's established zero. Taken in conjunction with the responses to the question-naire item regarding the manner in which the established zero was actually applied, the observation indicates not only a lack of attention at the unit level given to this aspect of tank gunnery but also a lack of understanding at the level of the individual tank crewman in the performance of the task.

KNOWLEDGE OF TANK GUNNERY PRINCIPLES

Part A of the paper and pencil test (Appendix A, Part A) administered to tank commanders and gunners contained 14 scored items dealing with basic principles relevant to boresighting and zeroing. Items 1, 2, 5, 6, 8, 9 and items 10-14 were phrased in such a way as to assess an individual's knowledge of the principle as well as its application in the following areas: effects of cross wind (1, 2), cant (5, 6), dispersion (10-14), and the relation between boresight and the path of the projectile (8, 9).

Table 3 presents the responses of tank commanders and gunners. Items 1-2 deal with the effects of cross wind; although 59% of TCs and 46% of gunners correctly identified the principle contained in item 2, only 9% of each were able to correctly apply the principle in item 1.

Table 3

RESPONSES (PERCENT) OF TANK COMMANDERS AND GUNNERS TO PRINCIPLES KNOWLEDGE ITEMS (PART A)

TANK COMMANDER

Item	a	b	c	d	NR	Correct Response
1	9	19	66	6	0	A
2	16	59	6	9	9	B
3	3	12	3	78	0	D
4	6	72	12	9	0	B
5	9	6	62	22	0	C
6	6	3	75	12	3	C
7	28	0	59	9	3	C
8	0	34	44	3	3	B
9	25	25	16	22	12	B
10	31	50	9	16	9	B
11	19	3	38	31	9	C
12	12	22	6	50	9	D
13*						
14	72	9	9	6	3	A

GUNNERS

Item	a	b	c	d	NR	Correct Response
1	9	28	56	3	3	A
2	25	46	9	12	6	B
3	6	16	0	78	0	D
4	6	69	9	16	0	B
5	19	6	41	28	6	C
6	9	6	75	6	3	C
7	31	3	50	12	3	C
8	0	34	50	0	16	B
9	9	16	25	38	12	B
10	25	44	6	19	6	B
11	19	3	38	31	6	C
12	9	22	3	56	6	D
13*						
14	88	3	0	3	6	A

NOTE: Item 13 scored in terms of percentage of persons identifying increasing dispersion pattern in items 10-12. 56% of gunners and 53% of Tank Commanders correctly identified increasing pattern.

Note that 16% of the TCs and 25% of gunners indicated that it did not matter whether or not the wind was blowing during zeroing (answer A) and that another 9% and 12%, respectively, indicated that once a tank is zeroed, wind no longer affected the path of the projectile (answer D).

In items 5 and 6 dealing with the effects of cant, recognition of the principle was again superior to its application. The same pattern was also observed in items 10-14 dealing with dispersion. Whereas 72% of tank commanders and 88% of the gunners correctly identified the relation between dispersion pattern and range in item 1A, only 53% and 56%, respectively, correctly indicated such a pattern (item 13) in their choice of responses to items 10-12. Item 13 was not an item presented in the test but rather a measure based on items 10-12.

Item 7 represents the only other substantial disagreement as to the proper action to take. The item required the tank commander and gunner to indicate what action should be taken if the first round fired at the zero panel was a miss. Twenty-eight percent of the tank commanders and 31% of the gunners reported they would refer their sights to the point of impact of the round. Only 59% of the TCs and 50% of the gunners indicated they would relay and fire a second round.

Based on scores covering all 29 items (knowledge, Part A, plus procedural items, Part B), it was found that gunners' scores correlated significantly with the number of rounds used to zero ($r = -.3624$, $df = 32$, $p < .05$). A significant correlation with tank commander's scores was not found. These results do not represent an intended validation of the items on the paper and pencil test. Scores on the knowledge test are <u>in no case</u> intended as a potential selection variable for gunners.

SURVEY OF PERCEIVED OUTCOMES

Table 4 presents the means and standard deviations for each of the 21 items in the survey. Where t-tests revealed no significant differences between the responses of tank commanders and gunners, the responses of the two groups were combined.

The responses were studied first from the point of vew of determining the relative importance attached to experience (items 16, 20), equipment-related factors (items 18, 19), and external factors (items 14, 15, 17). Greatest importance was attached to the influence of experience, whereas the least was attached to the effects of external variables such as wind, cant, and solar radiation. An intermediate degree of emphasis was assigned to gun tube wear and to ammunication dispersion. Because of the wide range of individual variation, however, this order can not be considered statistically significant.

Table 4

SURVEY OF PERCEIVED TANK GUNNERY OUTCOMES

"Never" 0% of the time	"Rarely" less than 20% of the time	"Seldom" between 20% and 40% of the time	"Sometimes" between 40% and 60% of the time	"Often" between 60% and 80% of the time	"Almost Always" more than 80% of the time	"Always" 100% of the time
1	2	3	4	5	6	7

	Question	Mean	Standard Deviation
1.	When using the standard FM 17-12 method for boresighting, after firing a warm-up round, how frequently can you expect the first round of your 3-round shot group to hit the zero panel?	5.1486	1.0813
2.	After boresighting, how frequently would you expect the center of your 3-round shot group to be within two feet of the aiming point before referring your sights?	4.0945	1.0490
3.	When zeroing and boresighting with the standard FM 17-12 method, how frequently do you expect your check round to hit within two feet of the aiming point after referring your sight?	5.2837	1.2221
4.	When firing a check round to confirm your established zero, how frequently do you expect it to strike within two feet of the aiming point on the zero panel?	5.1891	1.0556
5.	How frequently do you think that difficulty in zeroing is due to gunner error?	3.5945	1.0588
6.	How frequently do you think that failure to remain zeroed is due to gunner error?	3.1351	0.9975
7.	How frequently do you think that the average tank crew makes procedural errors in boresighting?	4.0405	0.8826
8.	How frequently do you think that you, yourself, make procedural errors in boresighting?	3.6216 3.0540(1)	1.1631 0.9984(1)
9.	How frequently do you think that the average tank crew makes procedural errors in zeroing?	3.9459 3.4594(1)	0.9702 0.8025(1)

		Mean	Standard Deviation
10.	How frequently do you think that you, yourself, make procedural errors in zeroing?	3.2027	1.0595
11.	How frequently do you think that the care taken by the crew to properly boresight leads to more accurate firing?	5.[illegible]104	0.9224
12.	How frequently would you expect to hit a stationary target at 1200 meters if all you had done was to boresight and then apply your established zero?	5.0945	1.1124
13.	How frequently would you expect to hit a stationary tartet at 2500 meters if all you had done was to boresight and then apply your established zero?	4.0945	1.1487
14.	How frequently do you think that rounds miss the target because of crosswind?	3.5270	0.8947
15.	How frequently do you think that rounds miss the target because the tank is canted (that is, not on level ground when firing)?	3.5270	1.0627
16.	How frequently do you think that rounds miss the target because of tank commander ranging error?	4.2702	1.0108
17.	How frequently do you think that rounds miss the target because of tube-bending (droop) due to solar radiation?	2.9729	1.1583
18.	How frequently do you think that rounds miss the target because of bad ammunition?	3.6486	1.0908
19.	How frequently do you think that rounds miss the target because of the amount of wear on the gun tube?	4.0684	2.2443
20.	How frequently do you think that poor hit performance in tank gunnery is due to a lack of experience of the gunner?	4.0000	1.0598
21.	How frequently do you think that poor hit performance in tank gunnery is due to a lack of experience of the tank commander?	4.1081	1.0542

(1) Where group differences were present, data for each group is reported separately. The first number in each pair is for the tank commander; the second for the gunner.

With regard to how capable the crews perceived themselves in performing boresighting and zeroing tasks, a comparison of items 7 and 8 and items 9 and 10 indicates a perceived feeling of superiority in relation to the "average" tank crew. This finding probably does not accurately reflect the level of actual proficiency, but rather a halo effect. From a training standpoint, however, the perception of oneself as being better than average should probably serve as a warning that a need for additional training is not felt at the crew level.

Attempts to relate statistically the individual response patterns of tank commanders and gunners failed to identify any degree of association between responses on the survey and the number of rounds used to zero. The responses taken as a whole, however, do give an indication of the importance attached to these factors by crews in the field as well as an indication of the degree to which these tasks are perceived as precision tasks with predictable outcomes (see items 1-3). The low perceived influence of such variables as cant, crosswind, solar radiation, etc. may also present a training problem insofar as advanced fire control systems may require correction for these factors.

DISCUSSION

Although the immediate focus of the present research has been on the identification of factors correlated with the number of rounds used to zero, the more critical issue is tank gunnery training effectiveness. Despite the fact that a known relati. . exists between the reduction in system error acheived through zeroing and subsequent first-round hit probability, zeroing continues to be one of the "most neglected aspects of our tank gunnery training".[7] Although current literature on boresighting and zeroing[8] stresses the improvement in system effectiveness to be expected through the adoption of alternative means for boresighting (e.g., the Pye-Watson Muzzle Boresight), the present data suggested that regardless of the particular method used, armor crewmen possess an extremely poor understanding of the basic principles underlying these tasks.

The emphasis given to developing an understanding of the principles and rationale behind boresighting and zeroing and their relation to tank gunnery proficiency is reflected in the present data by the fact that

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[7] Bryla, CPT Edward A. Reduce your budget, yet buy more. Armor Magazine, 15, Nov-Dec 1976.

[8] Shiflett, J. Tank Gunnery Boresight and Zero. US Army Armor and Engineer Board, Ft Knox, KY, 1976.

70 percent or more of the tank commanders and gunners tested missed over half of all items covering basic boresighting and zeroing principles. Even in those instances where principles were correctly identified a clear indication was given that recognition of the principle was superior to its application. Although direct observation of armor crewmen in the process of boresighting and zeroing identified no major procedural errors, the crewmen were unable, in many instances, to differentiate between the two sets of procedures when questioned. It would appear that for a large number of crewmen the tasks are performed as if they were a single functional task rather than as two separate but interdependent tasks.

The failure to differentiate boresighting tasks from zeroing tasks probably arises from the fact that current practices in tank gunnery training treat them as a single task. Rarely if ever is boresighting performed that zeroing does not follow. Armor crewmen do not understand the function served by boresighting independently of zeroing. Rather than viewing boresighting as a procedure for identifying the line of sight reference from which the established zero (jump angle relationship) is applied, boresighting is perceived only as serving to obtain an approximate correspondence between the "where the gun is looking" and where the gunner's sight is looking. Evidence that crewmen do not perceive this as being a precise manipulation is given by the fact that the average crewman expects the first round fired at the zero panel after boresighting to hit the panel only between 60 and 80% of the time, and for his shot group to be within two feet of the aiming point less than 50% of the time. Such expectations are partly confirmed by their performances; only 56% of the time did crews' first round strike the panel and only 1 of 34 crews' shot groups was within two feet of the aiming point.

Evidence that boresighting is not viewed as a precision task is also given by the tank commander's general lack of supervision in terms of verifying sight pictures obtained by the loader and gunnery through the breech and primary sight. The lack of emphasis on precision in boresighting can be traced back to the individual's introduction to tank gunnery in Armor AIT. Here the individual is taught that the proper sight picture for boresighting consists of the crosshairs on the upper left corner of the boresight panel. That the point is well taught is reflected in the few errors committed in the field in this aspect of the procedure. The training most poorly applied in the field is in the use of the established zero, where fewer than a third of the tanks observed had an established zero recorded.

The failure to have an established zero recorded means that if these tanks were to be called into combat without opportunity to zero and were thereby required to shoot from boresight, fewer than 60% of these tanks could be expected to achieve a first-round hit on a target at 1200 meters, and that about 25% of all rounds fired at a target of that size at 1200 meters would completely miss the target. Inasmuch as we must be prepared to be greatly outnumbered by threat forces, we must be able to engage targets at extended ranges and certainly with some degree of first round hit capability beyond that demonstrated here.

The extent to which firing from an extablished zero would have improved such performances cannot be directly determined from these data, because even those tanks having established zeros did not employ them for this exercise. What can be determined from these data, by a comparison of the responses of tank commanders and gunners to questions 1 and 12 on the survey of perceived outcomes, is that crewmen do not perceive the established zero as providing any significant advantage over firing directly from boresight. The extent to which such perceptions are paralleled by actual experience is doubtful, given (1) the infrequency with which crewmen currently use the established zero in lieu of rezeroing with live ammunition and (2) the lack of understanding demonstrated on the knowledge items regarding the function of zeroing.

Recommendations which seem to be warranted fall into two areas. The first concerns achieving greater cost effectiveness in zeroing. The second concerns achieving greater weapon system effectiveness.

RECOMMENDATIONS FOR GREATER COST EFFECTIVENESS IN ZEROING

1. Eliminate frequent zeroing. To the extent that the primary function of zeroing is to establish the jump relation for a particular gun tube and to the extent that this relation remains relatively unchanged over the life of the gun, rezeroing serves only to reconfirm the relation contained in the tank's established zero.

2. Stress compliance with the 12x12 foot zero panel. To the extent that the variable having the clearest relation to the number of rounds to zero in the present research was the percentage of rounds hitting the panel, an effort must be made to use target panels of sufficient size for capturing most rounds fired. Because of the known difficulty of sensing the point at which rounds pass by the panel,[9,10] and the known difficulty due to obscuration, rounds which miss the panel contribute little if any to the accurate determination of a shot group.

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9 Fried, C. and Ivey, L. A Human Engineering Evaluation of spotted Rounds with Respect to Fire Direction Capabilities. Human Engineering Laboratory, Tech Memorandum 4-59, June 1959.

10 Glucksberg, S. and Klein, H. The Effectiveness of Various Spotting Techniques in Fire Control: A Pilot Study. Human Engineering Laboratory, Tech Memorandum 9-61, June 1961

3. Place greater emphasis on boresighting as a precision task. Precision in boresighting should be stressed along several dimensions. First, given that the jump relation for most tanks will not be so great as to produce a total miss with a 12x12 panel at 1200 meters, reinforce, as part of the scoring, first-round hits on the zero panel following boresighting. Along the same line, scoring may also be used to differentially reinforce the proximity of shot groups to the aiming point.

4. Reinforce "efficient" zeroing. Reinforce ammunition conservation in zeroing through the application of scoring contingencies which differentially reinforce crews in terms of the number of rounds used to zero.

RECOMMENDATIONS FOR GREATER SYSTEM EFFECTIVENESS

1. Ensure that tank commanders and gunners understand the use of the established zero as an alternative to frequent rezeroing with live ammunition.

2. Throughout training (both institutional and unit), reinforce and test for consistency in boresighting (i.e., reducing variation in boresighting from occasion to occasion) rather than solely the selection of the correct sight picture. To the extent that the established zero is applied to a line of reference established through boresighting, it is important that variation in this base reference due to human error be minimized.

3. In training, insure that the level of feedback (i.e. variation in azimuth and elevation) given in boresighting is consistent with the level of precision of the task.

4. Develop a responsiveness on the part of the tank commander to the quality control aspects of tank gunnery, and insure that adequate supervision of crew duties is given in these areas.

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US Army Armor School. Tank Gunnery, FM 17-12, Ft Knox, KY, November 1972.

APPENDIX A

Knowledge of Boresight/Zero
Principles and Procedures

APPENDIX A

DEPARTMENT OF THE ARMY
U.S. ARMY RESEARCH INSTITUTE FOR THE BEHAVIORAL AND SOCIAL SCIENCES
FORT KNOX FIELD UNIT
FORT KNOX, KENTUCKY 40121

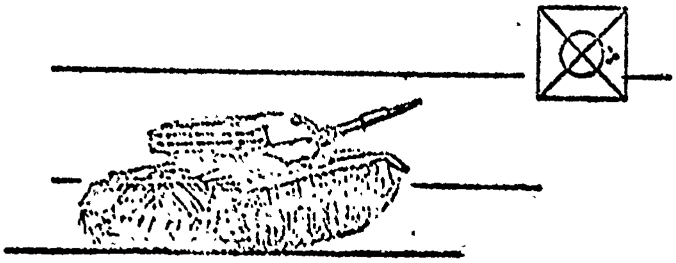
PERI-IK

READ THIS FIRST

The Army Research Institute at Ft Knox is currently conducting research to find out to what extent a tank crewman needs to understand the basic principles behind boresighting and zeroing in order to perform these tasks well. We would appreciate your help in this research.

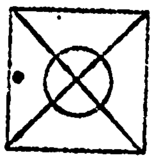
Read each of the following items carefully, indicating your answer to an item by drawing a circle around the letter you think is correct. Not knowing the answer to some of the items does not mean necessarily that you yourself do not perform these tasks well. No one is expected to get all items correct. In no way will your answers be viewed by persons other than those at ARI directly connected with this project.

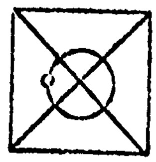
You may turn the page and begin.

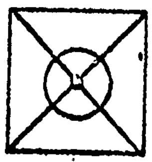


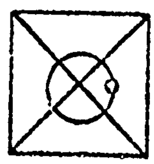
The 3-round shot group was fired by this tank with HEAT-TP ammunition with a 10 mph crosswind blowing from left to right. The gunner then referred his sights to the center of the shot group, relayed on the aiming point and fired a confirmation round. The round hit 3-inches from the aiming point and the tank was declared zeroed. The target panel was a standard zero panel at 1200 meters.

Item 1.
QUESTION: If the wind were now to change direction so as to be blowing from right to left at 10 mph, what would be the most likely point of impact of a round fired at the same target panel? Circle either A, B, C, or D.

A 

 C

B 

 D

QUESTION (Item 2)

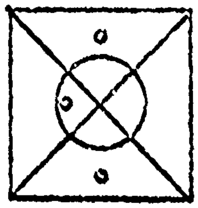
The above example demonstrates that: (Circle your answer)

A. it does not matter whether or not the wind is blowing when you are zeroing

B. zeroing with a crosswind blowing will correct for the effects of wind so long as the wind continues to blow at the same speed and from the same direction.

C. by zeroing with a crosswind blowing, subsequent rounds will not be affected by crosswind regardless of the speed or direction.

D. once a tank is zeroed, external factors such as wind no longer affect the path of the projectile.



Itom 3

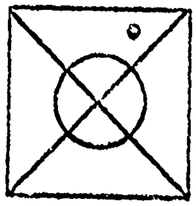
The 3-round shot group pattorn shown above would most likely be due to:

A. Gunner indoxed wrong ammunition

B. Characteristic pattorn of the individual gun tube.

C. Crosswind blowing from right to left.

D. Gunner failed to lay gun in same direction (low to high) each time.



Item 4

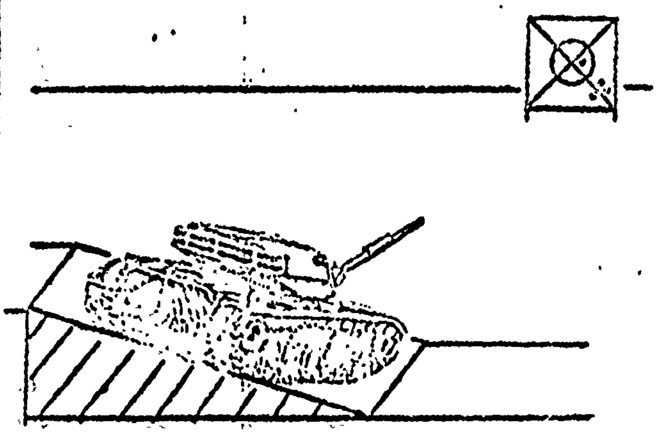
You decide to verify your present zero by firing a warm-up round followed by a check round at a standard zero panel located at 1200 meters from your tank. The check round strikes the panel at the point shown above. Your action at this point would be:

A. To accopt your prosont zoro and mako no furthor corroction to sights.

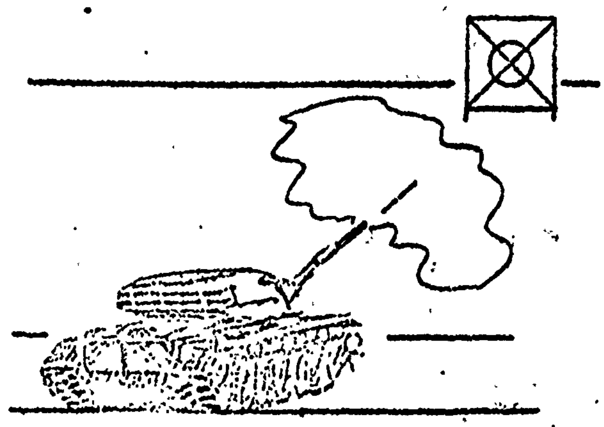
B. To fire a socond round.

C. Using the M32 borosight knobs, refor tho aiming point of tho sight reticle to the point where tho round hit the target.

D. Apply burst-on-target.



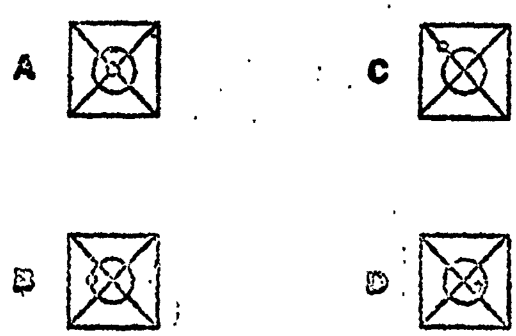
The tank shown above was boresighted and zeroed in this position. The panel is at 1200 meters.



The tank then moved t. this position and fired at the panel (the panel is at the same range).

Item 5

QUESTION: Where is the round most likely to strike the target panel? Circle your answer below.



QUESTION (Item 6)

The above example demonstrates that: (Circle your answer below)

A. cant has no effect upon the flight of the round.

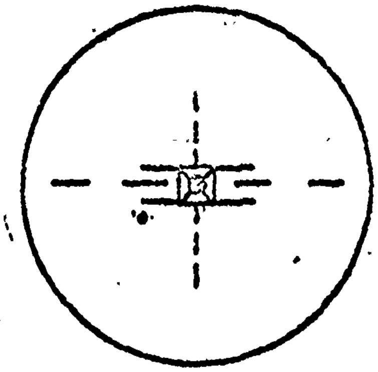
B. the terrain upon which the tank is zeroed is unimportant.

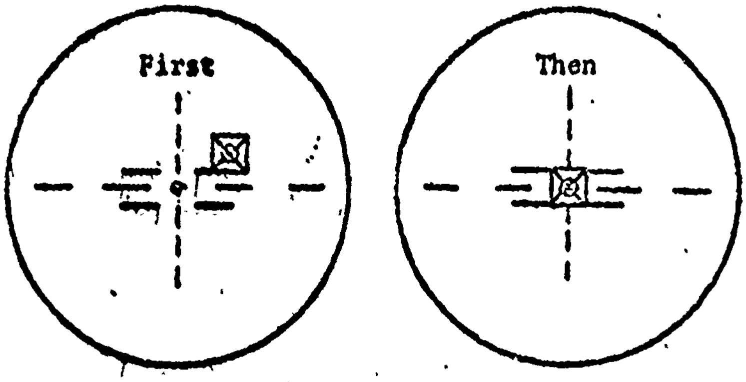
C. zeroing at a cant introduces a directional firing error when firing on level terrain.

D. the M60A1 tank automatically corrects for cant.

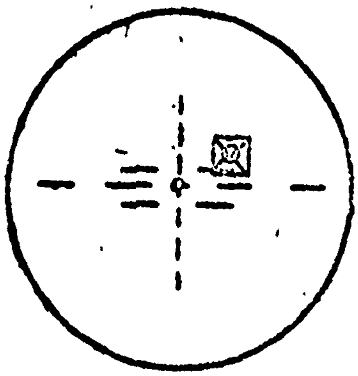
Item 7

You are attempting to establish a 3-round shot group. You have already fired a warm-up round. The next round that you fire misses the zero panel as shown to the right. What action would you as gunner take before firing your next round?

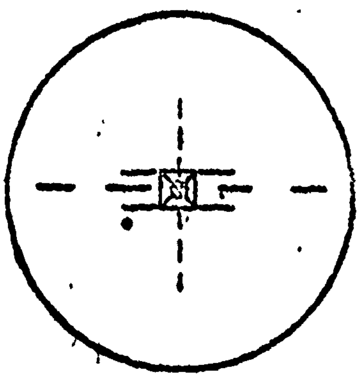




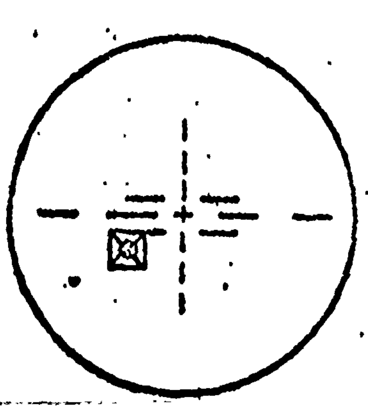
A First, using your boresight knobs refer sights to point of impact. Then relay on center of zero panel.



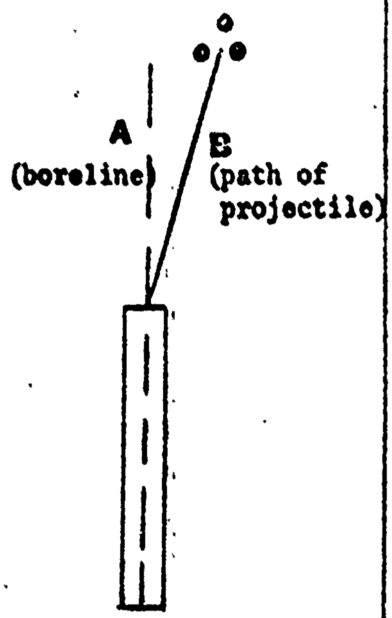
B Aim at point of impact and fire second round.

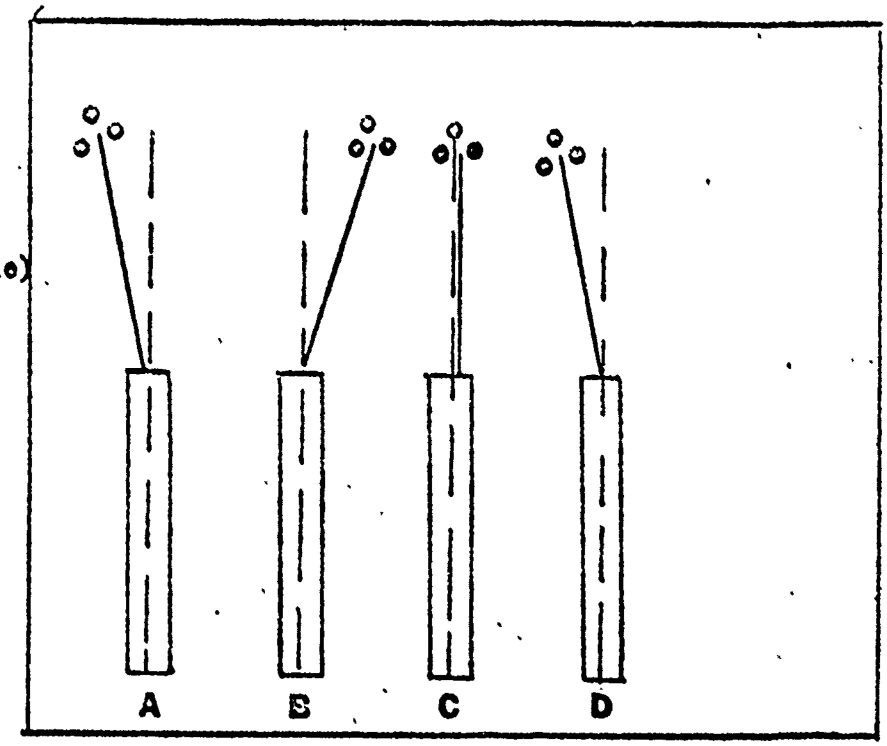


C Relay on center of zero panel and fire second round.



D Apply burst-on-target and fire second round.





QUESTION: (Item 8)

In the figure to the left above, line A represents the boreline of the gun tube and line B represents the path of the projectile. If, after the gunner has referred his sights to the center of the shot group, fired a check round, and been declared "zeroed" he were then to fire a <u>second</u> 3-round shot group, which figure to the right would represent the relation between the boreline of the gun and the path of the projectile? Circle your choice from the four alternatives shown above.

QUESTION: (Item 9)

The above example demonstrates that: (Circle your answer below)

A. zeroing corrects for the deviation of the shot group from the point of aim.

B. the relation between the boreline and the path of the projectile is not affected by zeroing.

C. zeroing cannot be conducted unless the boreline of the gun and the path of the projectile are the same.

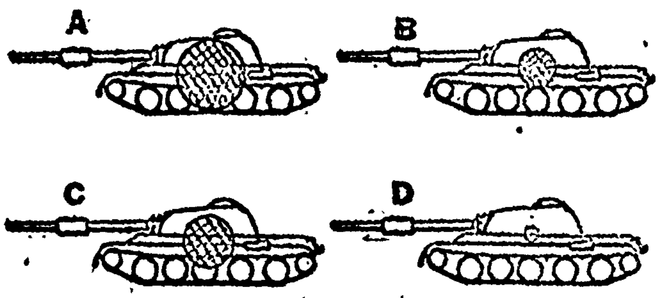
D. boresighting involves aligning the sights with the center of impact of the shot group.

QUESTION

If you were able to fire an unlimited number of rounds at a Russian T-62 tank at 1000, 2000, and 3000 meters, which picture in each block below would show the area on the target where approximately 90 percent of the rounds would hit? In each block, circle either A, B, C, or D.

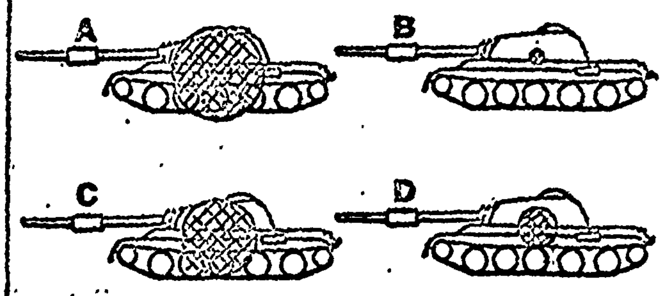
Item 10

T-62 Tank at 1000 Meters



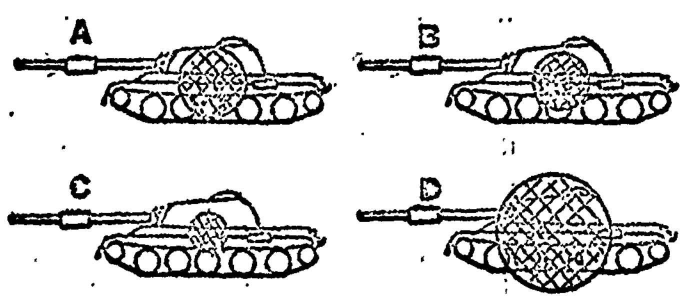
Item 11

T-62 Tank at 2000 Meters



Item 12

T-62 Tank at 3000 Meters



QUESTION (Item 14)

The above example demonstrates that: (Circle your answer below)

A. the dispersion pattern becomes larger with increases in range.

B. the dispersion pattern becomes smaller with increases in range.

C. range has no effect upon the amount of dispersion

D. dispersion decreases accuracy at close ranges more than at long ranges.

PART B
PROCEDURAL QUESTIONS

1. On what point of the target panel do you place the aiming cross of the periscope reticle (M32) when boresighting the main gun?

   a. upper right-hand corner
   b. center
   c. upper left-hand corner
   d. any place on the panel

2. When sighting through the main gun tube with the binoculars to boresight, what point on the target panel do you use as the aiming point?

   a. upper right-hand corner
   b. center
   c. upper left-hand corner
   d. anywhere on the panel

3. When boresighting, which of the following do you use to move the main gun on to the aiming point of the target panel?

   a. power control handles
   b. boresight knobs
   c. zeroing knobs
   d. manual traversing and elevating handles

4. After adjusting the boresight knobs and locking the handles, on what numbers should you put the slipscale settings for the non-ballistic reticle (M32)?

   a. 4 and 4
   b. 3 and 3
   c. 4 and 3
   d. 2 and 3

5. After adjusting the boresight knobs and locking the handles, on what numbers should you put the slipscale settings for the telescope reticle?

   a. 4 and 4
   b. 3 and 3
   c. 4 and 3
   d. 2 and 3

6. After turning the computer switch on the rangefinder to the off position, the next step in boresighting is to:

   a. rotate the range knob of the rangefinder to set the known tank-to-target range on the range scale
   b. rotate slip scale on zeroing knobs
   c. set superelevation to zero
   d. move tank to level terrain

7. After aligning the main gun on the aiming point, the occluder knob on the rangefinder should be placed in what position?

   a. M position
   b. L position
   c. C position
   d. R position

8. The gun is considered zeroed if a confirming round strikes the target within what distance of the aiming point?

   a. 12 inches
   b. 24 inches
   c. 1 meter
   d. 5 feet

9. In boresighting or zeroing, what is the preferable target range?

   a. 800 meters
   b. 1000 meters
   c. 1200 meters
   d. 1300 meters

10. When zeroing, if the first round misses the entire target:

   a. relay the reticle on the original aiming point and fire a second round
   b. reboresight
   c. rotate the slip scales on the boresight knobs to the next highest number
   d. none of the above

11. During boresighting, which of the following do you move to align the non-ballistic reticle (M32) with the main gun?

   a. power control handles
   b. boresight knobs
   c. zeroing knobs
   d. manual traversing and elevating handles

12. When rezeroing a gun with a previously established zero:

   a. the boresight knobs should be adjusted to the established zero setting
   b. the boresight slipscales should be adjusted to the established zero setting, without turning the boresight knob
   c. no adjustments should be made to a gun with an established zero
   d. none of the above

13. The 105mm gun of the M60A1 tank is boresighted with the computer in the

a. on position
b. off position
c. either position
d. none of the above

14. When zeroing the 105mm gun of the M60A1 tank,

a. all superelevation is removed from the gun
b. computer is placed in off position
c. computer is placed in on position
d. computer is on but all superelevation is removed from the gun

15. It is necessary to repeat the complete zeroing exercise whenever

(Circle one or more)

a. a direct fire sight is changed
b. the gun tube is replaced
c. a check round falls outside the 24" aiming circle
d. verifying an established zero

APPENDIX B

Survey of Perceived
Tank Gunnery Outcomes

PRECEDING PAGE BLANK

APPENDIX B

Survey of Perceived Tank Gunnery Outcomes

Name ______________________________ Crew Position ______________ Date Assigned to Crew __________
Last, First, M.I.

Primary MOS ______________ Time in PMOS ______(yrs)______(mo)

INSTRUCTIONS:

The Army Research Institute is interested in finding out how you perceive the relationship between boresighting, zeroing, and tank gunnery. Each item asks you to rate how frequently some event or action occurs, or how frequently you expect it to occur. There are no right or wrong answers. Each persons' answers will be affected by his own personal experience. While there is no time limit, work promptly, putting down your first impression. Your answers will be used for research purposes only. In no way will your response to any item be viewed by persons other than ARI research personnel associated with this project.

Before you begin, consider the following example:

How frequently do you think that the round misses the target because the gunner indexed the wrong ammunition?

"Never" 0% of the time	"Rarely" less than 20% of the time	"Seldom" between 20% and 40% of the time	"Sometimes" between 40% and 60% of the time	"Often" between 60% and 80% of the time	"Almost Always" more than 80% of the time	"Always" 100 % of the time
1	2	(3)	4	5	6	7

If you think that 3 is the most appropriate answer based upon your experience, circle 3 on the response scale as shown above.

---

1. When using the standard FM 17-12 method for boresighting, after firing a warm-up round, how frequently can you expect the first round of your 3-round shot group to hit the zero panel?

Never	Rarely	Seldom	Sometimes	Often	Almost always	Always
1	2	3	4	5	6	7

2. After boresighting, how frequently would you expect the center of your 3-round shot group to be within two feet of the aiming point before referring your sights?

Never	Rarely	Seldom	Sometimes	Often	Almost always	Always
1	2	3	4	5	6	7

3. When zeroing and boresighting with the standard FM 17-12 method, how frequently do you expect your check round to hit within two feet of the aiming point after referring your sights?

Never	Rarely	Seldom	Sometimes	Often	Almost always	Always
1	2	3	4	5	6	7

4. When firing a check round to confirm your established zero, how frequently do you expect it to strike within two feet of the aiming point on the zero panel?

Never	Rarely	Seldom	Sometimes	Often	Almost always	Always
1	2	3	4	5	6	7

5. How frequently do you think that difficulty in zeroing is due to gunner error?

Never	Rarely	Seldom	Sometimes	Often	Almost always	Always
1	2	3	4	5	6	7

6. How frequently do you think that failure to remain zeroed is due to gunner error?

Never	Rarely	Seldom	Sometimes	Often	Almost always	Always
1	2	3	4	5	6	7

7. How frequently do you think that the average tank crew makes procedural errors in boreisghting?

Never	Rarely	Seldom	Sometimes	Often	Almost always	Always
1	2	3	4	5	6	7

8. How frequently do you think that you, yourself, make procedural errors in boresighting?

Never	Rarely	Seldom	Sometimes	Often	Almost always	Always
1	2	3	4	5	6	7

9. How frequently do you think that the average tank crew makes procedural errors in zeroing?

Never	Rarely	Seldom	Sometimes	Often	Almost always	Always
1	2	3	4	5	6	7

10. How frequently do you think that you, yourself, make procedural errors in zeroing?

Never	Rarely	Seldom	Sometimes	Often	Almost always	Always
1	2	3	4	5	6	7

11. How frequently do you think that the care taken by the crew to properly boresight leads to more accurate firing?

Never	Rarely	Seldom	Sometimes	Often	Almost always	Always
1	2	3	4	5	6	7

12. How frequently would you expect to hit a stationary target at 1200 meters if all you had done was to boresight and then apply your established zero?

Never	Rarely	Seldom	Sometimes	Often	Almost always	Always
1	2	3	4	5	6	7

13. How frequently would you expect to hit a stationary target at 2500 meters if all you had done was to boresight and then apply your established zero?

Never	Rarely	Seldom	Sometimes	Often	Almost always	Always
1	2	3	4	5	6	7

14. How frequently do you think that rounds miss the target because of crosswind?

Never	Rarely	Seldom	Sometimes	Often	Almost always	Always
1	2	3	4	5	6	7

15. How frequently do you think that rounds miss the target because the tank is canted (that is, not on level ground when firing)?

Never	Rarely	Seldom	Sometimes	Often	Almost always	Always
1	2	3	4	5	6	7

16. How frequently do you think that rounds miss the target because of tank commander ranging error?

Never	Rarely	Seldom	Sometimes	Often	Almost always	Always
1	2	3	4	5	6	7

17. How frequently do you think that rounds miss the target because of tube-bending (droop) due to solar radiation?

Never	Rarely	Seldom	Sometimes	Often	Almost always	Always
1	2	3	4	5	6	7

18. How frequently do you think that rounds miss the target because of bad ammunition?

Never	Rarely	Seldom	Sometimes	Often	Almost always	Always
1	2	3	4	5	6	7

19. How frequently do you think that rounds miss the target because of the amount of wear on the gun tube?

Never	Rarely	Seldom	Sometimes	Often	Almost always	Always
1	2	3	4	5	6	7

20. How frequently do you think that poor hit performance in tank gunnery is due to a lack of experience of the gunner?

Never	Rarely	Seldom	Sometimes	Often	Almost always	Always
1	2	3	4	5	6	7

21. How frequently do you think that poor hit performance in tank gunnery is due to a lack of experience of the tank commander?

Never	Rarely	Seldom	Sometimes	Often	Almost always	Always
1	2	3	4	5	6	7

APPENDIX C

Boresight/Zero Procedures
Checklist

APPENDIX C

CREW NUMBER__________________ TANK FIRED__________________

A. INFORMATION ON THE TANK COMMANDER

1. Name__________________ (last) (first) MI Rank________ PMOS________

2. Time in service _____yrs _____mo

3. Time in primary MOS _____yrs _____mo

4. Time in present crew position _____yrs _____mo

5. Time in this crew _____yrs _____mo

6. Time in this crew as Tank Commander _____yrs _____mo

7. On last Table VIII, did your crew qualify?_____; qualify distinguished? _____; or not qualify? _____.

B. INFORMATION ON THE GUNNER

1. Name__________________ (last) (first) MI Rank________ PMOS________

2. Time in service _____yrs _____mo

3. Time in primary MOS _____yrs _____mo

4. Time in present duty position _____yrs _____mo

5. Time in this crew _____yrs _____mo

6. Time in this crew as gunner _____yrs _____mo

7. On last Table VIII, did your crew qualify? _____; qualify distinguished? _____; or not qualify? _____.

C. INFORMATION ON THE TANK

1. Date this tank was last boresighted and zeroed ______________.

2. Is established zero recorded in tank? YES (verify)_____ NO_____

   a. For which sights? Primary___/___ (EL AZ); Telescope___/___ (EL AZ); Range Finder___/___ (EL AZ)

   b. For which ammo? APDS-T_____; HEAT-TP_____; HEP_____

3. How frequently is zero verified?

   Weekly_____ Monthly_____ Quarterly_____ Annually_____

4. Total rounds fired through gun (EFC factor) prior to this firing?_____

BORESIGHTING

CHECK THE TIME!!

__________(hr) Time boresighting exercise begins (record time from when thread is attached to muzzle of gun)

__________(hr) Time when boresighting of main gun is completed (record time when all sights have been laid on aiming point and slipscales set)

COMPUTER, RANGE, AND SUPERELEVATION

1. During boresighting, computer was in ON_____position or OFF_____ position.
2. What tank-to-target range was indexed on range scale? _____meters
3. How many mils were recorded on superelevation counter? ______mils

PLACEMENT OF THREAD (Check the time)

1. Which crewmember placed the thread on the muzzle? TC G D L
2. Where was thread obtained? (explain)______________________________
3. With what was the thread held in place? (explain)______________________
4. Did another crewmember verify the placement of the thread? YES____ NO____

   Who? TC G D L

SIGHTING THROUGH BREECH

1. Which crewmember sighted through breech? TC G D L
2. Were binoculars used? YES____ NO____
3. Which sight picture was identified by person performing task as being correct (show crewman picture of main gun sight picture on next page and ask him to point to correct sight picture). Record his answer.

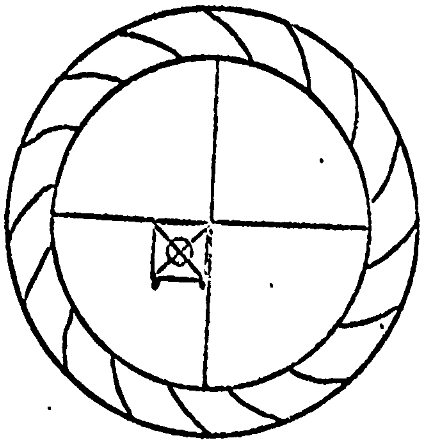
   A B C D E

4. Was sight picture through breech verified by another crewman? YES____ NO____

   Who? TC G D L

MAIN GUN

A



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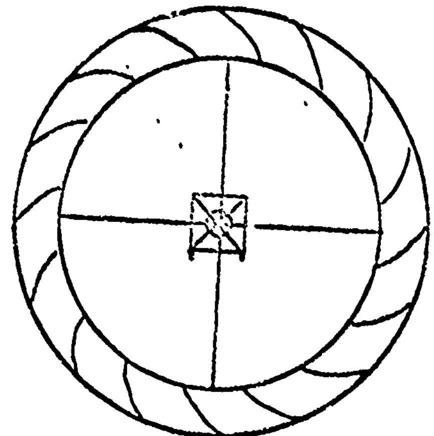

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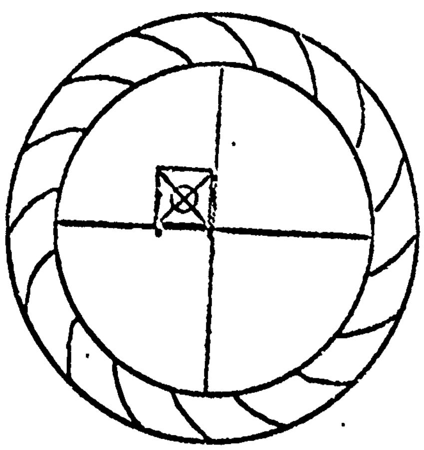

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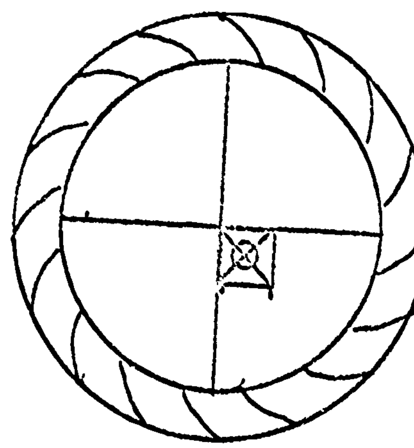

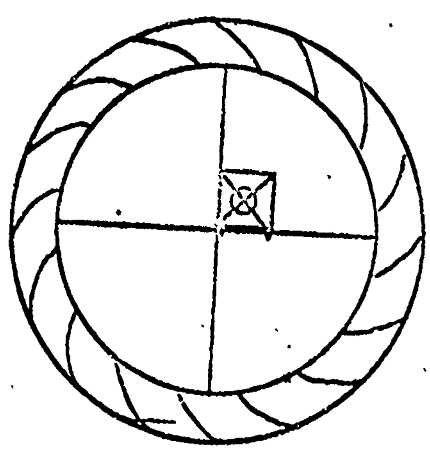

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BORESIGHTING

PERISCOPE (M32)

1. Who boresighted M32 Periscope? TC G D L
2. Which sight picture (next page) was identified by this person as correct?

   A B C D E
3. Did another crewmember verify sight picture? TC G D L
4. What settings were indexed on boresight knobs? ___/___ EL AZ

TELESCOPE

1. Who boresighted the telescope? TC G D L
2. Which telescope sight picture was identified as correct? A B C D E
3. Did another crewmember verify the sight picture? TC G D L

What settings were indexed on boresight knobs? ___/___ EL AZ

RANGEFINDER

1. Who boresighted the rangefinder? TC G D L
2. Did another crewmember verify the sight picture? YES___ NO___

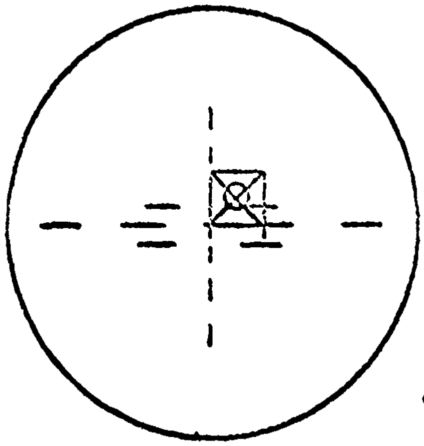
   If so, who? TC G D L
3. What settings were indexed on boresight knobs? ___/___ EL AZ
4. What range finder sight picture was identified as correct? A B C D E

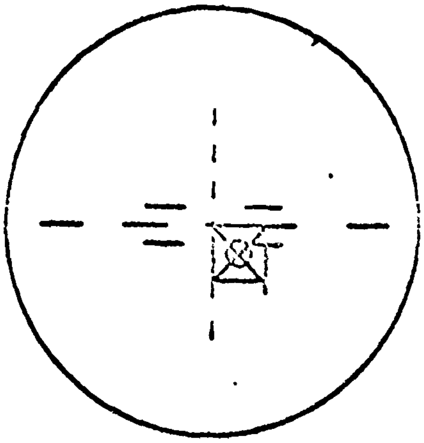
CHECK THE TIME!!

Record time when last sight is laid on aiming point and slipscale set.

PRIMARY SIGHT AND RANGEFINDER SIGHT

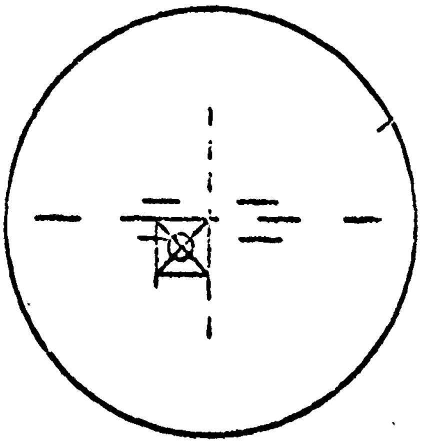
A

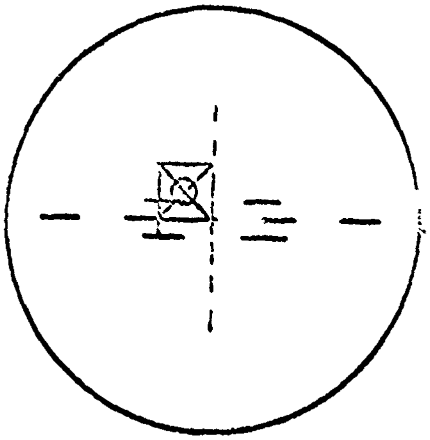




C

B





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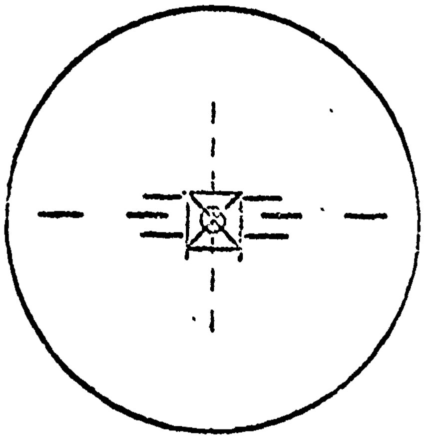
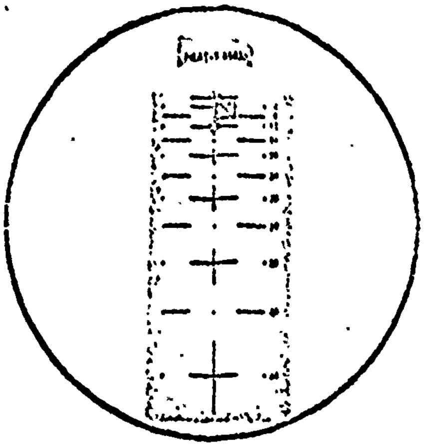
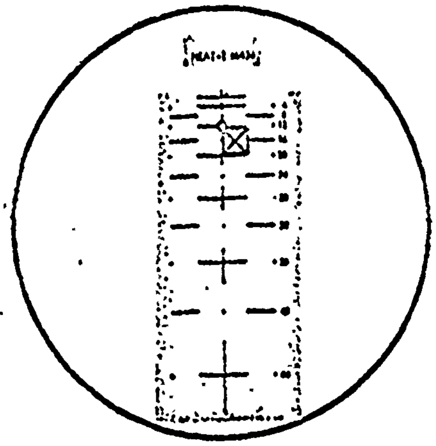


TELESCOPE

A





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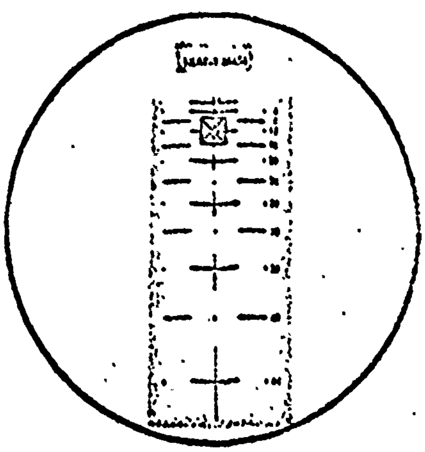

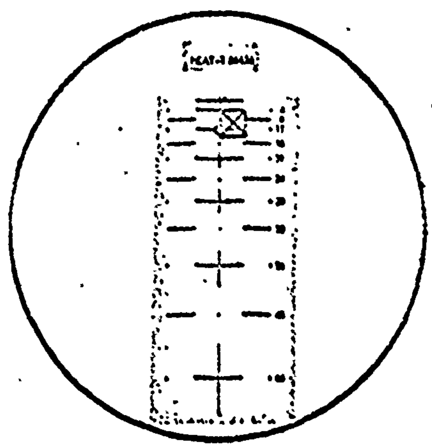

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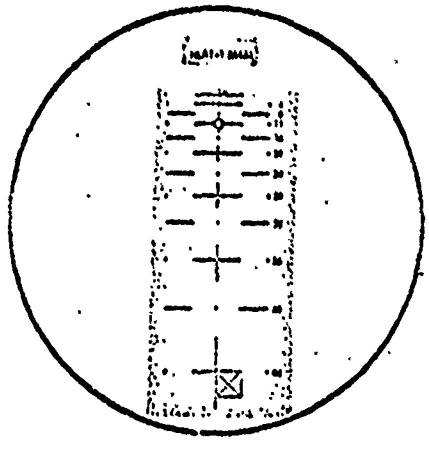
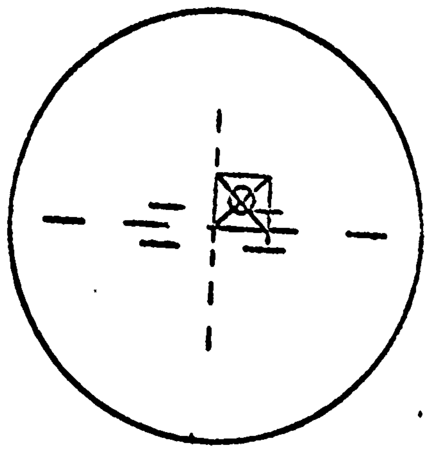
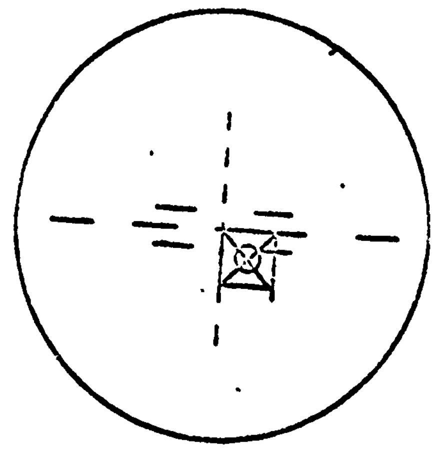


PRIMARY SIGHT AND RANGEFINDER SIGHT

A





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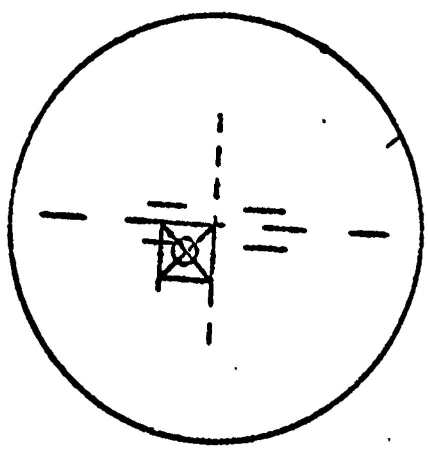

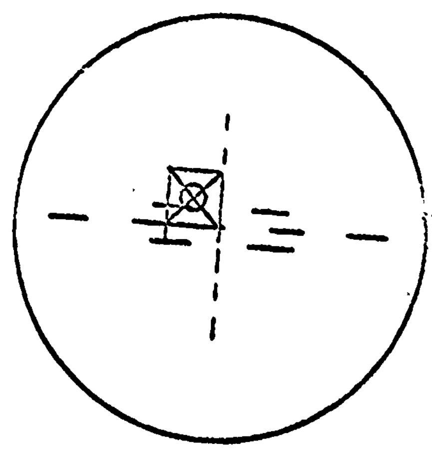

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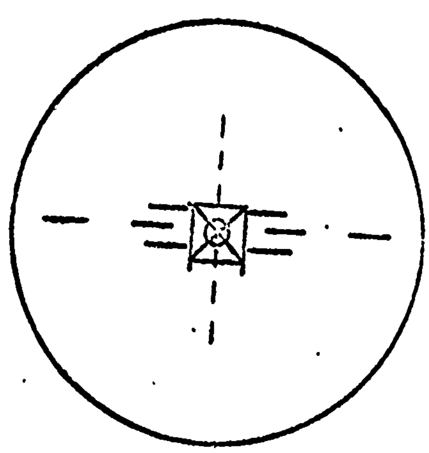

E

ZEROING THE 105MM MAIN GUN

CHECK THE TIME!!

______________ Start Time (time when 1st warm-up round is fired)

______________ Stop Time (time when last confirmation round is fired)

What were M32 boresight knob readings prior to firing? ____/____ (EL / AZ)

What were M32 boresight knob readings after zeroing was completed? ____/____ (EL / AZ)

COMPUTER, SUPERELEVATION, RANGE CORRECTION, AMMUNITION

1. What ammunition was indexed in computer? ______________
2. What superelevation reading was showing in computer window? ______mils
3. What was setting on range correction knob? ______________
4. Was computer "on" or "off" during zeroing? ON____ OFF____

WARM-UP ROUNDS (Record location on recording sheet - last page)

1. What time was 1st warm-up round fired? ____________
2. At what was warm-up round fired? zero panel_____ other (explain)_________
3. How many warm up rounds were fired? __________
4. What ammunition was used for the warm-up round/s? ___________
5. What actions were taken after firing warm-up round/s?
   a. Sight reticle referred
   b. No change made
   c. Reboresighted

ZEROING

1ST ZERO ROUND AFTER WARM-UP ROUND (Plot on recording sheet)

1. Was the round sensed from the tank? YES____ NO____

2. Could gunner see point of impact through M32? YES____ NO____

3. What was the sensing of the round?

   TGT Over Line Short Line Doubtful Left Doubtful Right

4. What action was taken by the gunner?

   a. referred sights using boresight knobs to point of impact
   b. applied burst on target
   c. relayed on original aiming point and prepared to fire second round
   d. other (explain)____

2ND ZERO ROUND AFTER WARM-UP ROUND (Plot on recording sheet)

1. Was the round sensed from the tank? YES____ NO____

2. Could the gunner see the point of impact through M32? YES____ NO____

3. What was the point of impact of the round?

   TGT Over Line Short Line Doubtful Left Doubtful Right

4. What action was taken by the gunner?

   a. refereed sights using boresight knobs to new point of impact
   b. applied burst on target
   c. relayed on original aiming point and prepared to fire another round
   d. other (explain)____

3RD ZERO ROUND AFTER WARM-UP ROUND (Plot on recording sheet)

1. Was the round sensed from the tank? YES____ NO____

2. Could the gunner see the point of impact through M32? YES____ NO____

3. What was the point of impact of the round?

   TGT Over Line Short Line Doubtful Left Doubtful Right

4. What action was taken by the gunner?

   a. referred sights using boresight knobs to new point of impact
   b. applied burst on target
   c. relayed on original aiming point and prepared to fire another round
   d. other (explain)____

Was 3-round shot group established at this point? YES___ NO___

Was center of shot group within 24" circle? YES___ NO___

IF MORE THAN THREE ROUNDS ARE NEEDED TO ESTABLISH SHOT GROUP, CONTINUE TO RECORD USING SHEETS AT END, AND CONTINUE TO PLOT THE LOCATION OF EACH ROUND ON THE RECORDING SHEET.

CHECK ROUND (Plot on recording sheet)

1. Was first check round within the 24" circle? YES___ NO___

   If no, what action was taken by gunner?

   a. refer sights to point of impact of check round
   b. relay on center of target panel and fire a second check round
   c. apply burst on target
   d. other (explain)___________________________________

2. If second check round was fired, did it hit within the 24" circle?

   YES___ NO___

3. If not within 24" what action was taken by gunner?

   a. referred sight to center of 2-round shot group
   b. relayed fired 3rd check round
   c. other___________________________________

ZEROING CONTINUATION PAGE

ROUND#_____ AFTER WARM-UP ROUND (Plot on recording sheet)

1. Was the round sensed from the tank? YES____ NO____

2. Could gunner see point of impact through M32? YES____ NO____

3. What was the sensing of the round?

   TGT   Over Line   Short Line   Doubtful Left   Doubtful Right

4. What action was taken by the gunner?

   a. referred sights using boresight knobs to point of impact
   b. applied burst on target
   c. relayed on original aiming point and prepared to fire second round
   d. other (explain)____

ROUND#_____ AFTER WARM-UP ROUND (Plot on recording sheet)

1. Was the round sensed from the tank? YES____ NO____

2. Could the gunner see the point of impact through M32? YES____ NO____

3. What was the point of impact of the round?

   TGT   Over Line   Short Line   Doubtful Left   Doubtful Right

4. What action was taken by the gunner?

   a. refereed sights using boresight knobs to new point of impact
   b. applied burst on target
   c. relayed on original aiming point and prepared to fire another round
   d. other (explain)____

ROUND#_____ AFTER WARM-UP ROUND (Plot on recording sheet)

1. Was the round sensed from the tank? YES____ NO____

2. Could the gunner see the point of impact through M32? YES____ NO____

3. What was the point of impact of the round?

   TGT   Over Line   Short Line   Doubtful Left   Doubtful Right

4. What action was taken by the gunner?

   a. referred sights using boresight knobs to new point of impact
   b. applied burst on target
   c. relayed on original aiming point and prepared to fire another round
   d. other (explain)____

DATA COLLECTION SHEET

INSTRUCTIONS: Record the points of impact of all rounds fired as part of zero exercise.

Specific Instructions:

1. Use a number instead of a dot to identify each round.
2. Count the first warm-up round as number 1.
3. Draw a circle around each warm-up round.
4. Number all rounds.
5. Which numbers identify the 3-round shot group? ______/______/______
6. Circle the number of each check round.

CREW NUMBER __________