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Comparison of the Stereoscopic Range Finder, M12 With the Coincidence Range Finder, T43 (U)

by

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Under the Technical Supervision of

The George Washington University
HUMAN RESOURCES RESEARCH OFFICE
operating under contract with
THE DEPARTMENT OF THE ARMY

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Task FIREPOWER I

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The work which was the basis of this report was done with the technical assistance of Melvin A. Schmitz, Leland J. Thune, James W. Grubb, and Alan M. Rochlin.

This study was conducted while Dr. T.R. Vallance was Director of Research at Human Research Unit Nr 1, CONARC (now the U.S. Army Armor Human Research Unit).

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COMPARISON OF THE STEREOSCOPIC RANGE FINDER, M12 WITH THE COINCIDENCE RANGE FINDER, T43 (U)

SUMMARY AND CONCLUSIONS

THE MILITARY PROBLEM

One of the greatest needs in Armor operations is a reliable method of determining target distance (range). Two kinds of optical ranging devices are available, one using the stereoscopic principle, the other the coincidence principle. The stereoscopic device contains two reticles which may be fused and made to appear to recede or to approach the observer, the target image remaining stationary. The coincidence device shows the observer two target images which he tries to superimpose by mechanical means.

Both of these devices have been widely used or suggested for use in military training and operations. In 1952 the Army adopted the stereoscopic range finder for use in Armor. Since then, the effort to make further improvements in optical ranging procedures has produced a new model of the coincidence range finder. In 1955 the Army conducted extensive tests which involved comparing improved models of both devices. The tests were carried out by The Armor School, Human Research Unit Nr 1, and Board Nr 2, CONARC. The assignment of the Unit was to make a controlled comparison between the two devices with respect to the operator's rate of learning and the final level of proficiency he reaches.

THE RESEARCH PROBLEM

The two ranging instruments employ two different optical principles to do exactly the same job. The two range finders are comparable in base length and magnification power. But the coincidence instrument, the T43 range finder, uses a full field superimposed example of the coincidence principle, and the stereoscopic instrument, the M12 range finder, is a wandermark device, the stereo-reticle being adjusted until it is judged to be at target distance.

Neither instrument fulfills all the military requirements for the use of a ranging device in combat, for the effectiveness of both depends partly on target characteristics and operator capabilities. The research was designed to compare the effectiveness of these instruments in relation to their use by representative Armor personnel in determining the distance to the kinds of targets met with in combat.

THE RESEARCH METHOD

The personnel used in conducting the research were 38 Armor trainees who had finished basic training and had been ordered to Armor branch training. They were randomly assigned to two groups, the coincidence (T43) group, and the stereoscopic (M12) group, hereafter called Group C and Group S respectively. Before the men were given range finder training, they were given a series of vision tests and their aptitude scores were recorded.

Four coincidence and four stereoscopic range finders were used in the study; two of each, mounted in M47 tanks, were used for about half the training and all the final testing, and two of each, mounted in a converted barracks, were used for the rest of the training. The tank-mounted instruments were used for ranging on targets and at distances judged to be typical in combat, and the floor-mounted instruments were used for ranging on panel targets and buildings.

SUMMARY AND CONCLUSIONS

Before the training began, The Armor School gave all the men two hours of classroom instruction on tank equipment, and each group four hours of instruction on the operation and use of the range finder the group was to use. Each man then made 2,165 practice rangings. At the end of each day's practice, each man took a test, ranging 10 times on a panel target at about 1,500 yards.

After the training period, the men were given a proficiency test, using a target area unfamiliar to them, and two combat targets of each of five types: building, fortification, parked vehicle, anti-tank emplacement, and moving vehicle. Each type of target was shown twice, once at a range of less than 1,400 yards and once at a range between 1,400 and 2,200 yards.

The final test furnished data for four measures of range finder effectiveness (besides the variability measure obtained from the daily test): target identification time, ranging time, ranging bias, and operator spread.

FINDINGS

(1) As measured in this study, Group C (coincidence instrument) made rangings 4.1 seconds faster on the average than did Group S (stereoscopic instrument).

(2) The groups did not differ significantly in the time it took the men to identify the final test targets.

(3) The results of the daily tests showed that Group C acquired ranging skill much faster than Group S, but the groups did not differ significantly in median variability scores after 245 practice rangings. But the variability scores themselves were significantly more variable for Group S than they were for Group C on eight of the 16 periodic tests. This difference appears to dissipate with practice and is evident on only two of seven comparisons made after 1,000 practice rangings.

(4) When operator consistency is computed for each group on each target, there is a significant difference between group medians on four of the 10 targets. Three of these differences favor Group S, which therefore seems to be more consistent. But variability tended to increase with target distance in about the same way for both groups.

(5) The Internal Correction System for both range finders was calibrated at 1,500 yards, one ICS adjustment serving for all the men in Group C whereas every man in Group S had to make his own ICS adjustment. Because of the nature of the ICS on the stereoscopic instrument, the bias for Group S increased with range, especially at 2,000 yards and beyond. The ICS for Group C held for every distance, but bias for the group deviated sharply on two indistinct targets.

(6) According to one scoring system (Frankford Arsenal graphs), nine men in Group S and 13 in Group C qualified on a target at about 1,000 yards; the difference is not statistically significant, and on the average over 50 per cent of operators would qualify at this distance on either instrument. On two targets at about 2,000 yards, 15 and nine men in Group C and one and two in Group S qualified. The differences here are significant; they probably reflect both bias error and target characteristics.

(7) The relationship between ranging proficiency and the aptitude measures was found to be low. One vision characteristic (for vertical phoria) was significantly related to the performance of both groups, and two others (stereopsis and near vertical phoria) to that of Group S. Three men in Group S had vision characteristics that prevented their using the stereoscopic range finder effectively.

RECOMMENDATIONS

In comparing the military effectiveness of the two instruments, the findings listed below should be considered in relation to the importance of reducing bias error, the value of ease of training and speed of operation, the probability of meeting various kinds of targets in combat, and the percentage of men who can be expected to be capable of using the instrument:

(1) The bias error of the stereoscopic range finder at greater ranges is so large that an engineering study is needed.

(2) Ease of training and speed of operation favor the coincidence over the stereoscopic instrument.

(3) There is a suggestion that the coincidence range finder is comparatively weak on ill-defined and indistinct targets.

(4) All the men in the coincidence range finder group were capable of using their ranging device, but three men (about 15%) in the stereoscopic group were unable to use their ranging device.

These findings should be carefully weighed, along with those reported by Board Nr 2, CONARC,[1] in making long-range plans with regard to Armor equipment.

[1] Report of Board Nr 2, Project Nr 1872, Test of Range Finder, T68 (U), (DA Project Nr 5[illegible]-[illegible]), 31 August 1956 (CONFIDENTIAL).

THE PROBLEM

In response to a need for a reliable method of determining target distance (range), the Army in 1952 adopted the stereoscopic range finder, which employs one optical principle. The coincidence range finder, which employs another optical principle, was well known at the time, and had often been used or recommended for use in the military setting.

The present coincidence instrument, T43, uses a full field superimposed example of the coincidence principle; whereas the current stereoscopic instrument, M12, may be classed as a wandermark device because the stereo-reticle is adjusted until it is judged to be at the distance of the target. The two instruments are, however, the same or comparable in base length (60 inches) and in power magnification (7.5 and 7.0, respectively). And though they employ different optical principles, they were designed to do exactly the same job.

According to optical theory, differences between the two principles lead to differences between the two instruments in the effectiveness with which target distances can be determined. Further, the effectiveness of optical range finders depends in part on operator capabilities or target characteristics. It is apparent, then, that neither principle, when employed in ranging equipment, fulfills all the military requirements for tactical operation.

METHOD OF CONDUCTING THE RESEARCH

This study was planned as a field comparison of the two types of optical principles as embodied in two ranging instruments. Since the experiment was conducted in the field, the results must be interpreted as applying only to the two optical principles when they are an integral part of a weapons system which is designated to be used on a specific type of target.

The research was developed to provide the best answer on the relative effectiveness of these instruments when they are tank-mounted and used by a group of Armor personnel in determining distances to a representative sample of combat targets. The word effectiveness may need additional definition. Here, it is intended to include such factors as cost of training time, cost of manpower (where special abilities may be required), combat restrictions associated with the equipment itself, operating time for its normal functioning, and finally, reliability in performing the designated task.

In order to meet these requirements, and to obtain results which would give the military user valid answers to a specific problem, the following experimental controls were exercised.

Subjects

The 38 subjects used in the experiment were part of the normal flow of personnel from basic training. They were selected by the Department of the Army, Personnel Section, as being representative of the trainees supplied to Fort Knox during the summer of 1955. Since these men were to be further ordered to Armor Branch Individual Training, it must be assumed that they met the requirements for Armor Branch trainees, as the Army perceives this classification. Their average Aptitude Area CO-A was 92.74, and their average Aptitude Area CO-B was 94.26. The percentage of Negroes, 52.6 per cent, was higher than the Army-wide average.

When these 38 men reported for duty at Fort Knox, they were randomly assigned to two groups, Group C (coincidence range finder) and Group S (stereoscopic range finder).

Before their training began, the men were tested on the Armed Forces Vision Tester.[1] In addition, Aptitude Area CO-A, CO-B, GM, and MM scores for each man were obtained from his Form 20. Significance tests of the differences in average scores of the two groups on these variables were computed. Only one significant difference[2] was found between the groups and this may be attributed to chance: For right eye acuity at a distance, Group C was significantly better than Group S. However, this difference did not enter into the comparison for, on either instrument, deficiencies in operator acuity are correctable by proper diopter adjustment. (The comparison of groups on aptitude and the vision test is shown in Appendix A.)

Equipment and Targets

The four stereoscopic instruments used were M12 (T41E3) models which had been thoroughly checked by a specialist from Frankford Arsenal. Two M12's were mounted in M47 Tanks, and about half the training and all the final testing for Group S were conducted on these two instruments. The other two M12's were floor-mounted in a frame building, with two of the coincidence (T43) instruments. The other two T43's were tank-mounted in M47's, and were used for about half the training and all the final proficiency testing for Group C.

During the training periods, the tank-mounted instruments were used for ranging on combat-type targets (such as another tank, or a machine gun emplacement) located in a range area judged by experienced officers as typical of combat terrain.

Two ranging areas were visible from the site where the floor-mounted instruments were used. One M12 and one T43 faced across an airfield; within the bounds of the airfield and beyond, there were several 7.5-foot square white panel targets. The other two instruments (an M12 and a T43) faced toward the Civic Center at Fort Knox. This area

[1] This tester, patterned after the Ortho-Rater, has target tests for near lateral phoria, near vertical phoria, near acuity right eye, near acuity left eye, stereopsis, far lateral phoria, far vertical phoria, far acuity right eye, and far acuity left eye.

[2] Throughout this report the .05 level will be accepted as statistically significant.

offered targets which might be representative of buildings in a small village. (A description of the training targets is given in Table I.)

Table I

TARGETS USED FOR TRAINING AND FINAL TEST

Targets	Range (yards)
Training Targets	
(Floor-mounted instruments used)	
Civic Center	
Cupola Post chapel	2,287
R.R. switch box, white	848
Smoke stack	3,325
Cupola atop main PX	1,892
Steeple on chapel	917
Sign atop Post library—ICS	1,420
Godman Army Air Field	
White panel	2,130
White panel	2,220
White panel	2,040
White panel	1,750
Air strip wind sack	970
White panel—ICS	1,660
(Tank-mounted instruments used)	
Board Nr 2 Area 25	
House at base of hill	3,610
Machine gun position	1,863
Tank	1,751
Anti-tank position	1,978
Machine gun position	811
White panel—ICS	1,691
Final Test Targets	
(Tank-mounted instruments used)	
Salt River Tank Range	
Machine gun bunker	770
Anti-tank position	974
House in flat	709
Moving jeep	1,107
Stationary tank	1,037
White panel—ICS	1,688
Machine gun (rock pile)	1,714
Anti-tank position (turret)	1,982
House on hill	2,082
Moving tank	1,753
Stationary truck	1,387

The panel targets were used for about one-fourth of the training, the targets in the village for another fourth, and the combat-type targets for the remaining half.

Training

The formal instruction on the ranging instruments was conducted by The Armor School. Classroom work included two hours on tank armaments, controls, and equipment, and two hours on the range finders to be tested. Groups C and S began the classroom work together, but were separated for the orientation lectures on the ranging devices which they were to use. (A schedule of the training and the Program of Instruction for the two range finders are given in Appendix B.)

Two hours of practical work in setting the ranging device into operation followed the classroom work. Then the students began ranging drill, conducted on the targets located in the training areas, as previously described. Each operator made a total of 2,165 practice rangings, distributed over these training areas. All range determinations, for both training and testing, were begun with the ranging system set for a battle range of 800 yards.

Proficiency Testing

The final proficiency test given at the end of the three-week training period made use of combat-type targets. Ten targets were set up in a range area which the men had not seen before; two of each of the following five types of targets were used:

(1) Building: Partial structure of a neutral beige color.

(2) Fortification: Emplacement where one might expect to find machine gun nests and a small group of personnel.

(3) Parked vehicles: One tank (3/4 front) in open area with trees in foreground and background, and one truck (side view) on forward slope of hill with wooded background.

(4) Anti-tank emplacement: Emplacement where one might expect to find anti-tank gun blended into terrain color and features.

(5) Moving vehicle: One 1/4-ton truck moving at right angles to the line of sight at 5 to 10 miles per hour, and a medium tank moving at right angles to the line of sight at 5 to 10 miles per hour.

Each of these target types was represented twice, once at a range of less than 1,400 yards, and once at a range of 1,400 to 2,200 yards. The 10 targets are listed in Table 1, and an outline of the training and testing schedules, showing the utilization of targets, is given in Appendix C.

Measures Used

Five measures of the effectiveness of the ranging devices were obtained, four of them during the final test.

(1) Identification Time. The time required by the gunner to identify the target which had been announced by the tank commander.

The time was measured in seconds from the instant at which the target came into the gunner's field of view[1] until the gunner announced "Identified." This time was recorded on the first trial for each of the 10 test targets. The time results reported here are based on this measurement and the procedure used did not make it possible to check accuracy of identifications. The tank commander in the test tank knew the target was in the gunner's field of view, but did not know just what object the gunner was ranging on. It is possible that the gunner made a valid target identification and then selected another object (usually judged as nearby) as a more desirable (i.e., more distinct) ranging object.

(2) Ranging Time: The time required by the gunner to determine the range to a target by adjusting the instrument. Time in seconds began when the gunner first touched the ranging knob and stopped when he released it.

(3) Ranging Bias: The difference between a single ranging (or average of a group of rangings) and the true target distance. On the final test, each of the 10 targets was ranged on five times. Thus individual target bias was the difference between the average of the five rangings for that target and the true target distance.

(4) Operator Spread: A measure of the consistency of an operator, independent of bias. Here the statistical range (difference between the highest and lowest rangings) of the five determinations on each target was taken as the index of variability or spread.

(5) Operator Variability (on a daily test target): Each operator was required to range 10 times on a panel target at approximately 1,500 yards at the conclusion of each training day. Statistical ranges were obtained and used as indices of training improvement.

Scoring Systems Used

The ranging performance of the operators was scored by three systems. First, to avoid the effect of bias,[2] the operators were scored as either qualifying or not qualifying on a target at 1,500 yards. This was done by referring to a graph (prepared at Frankford Arsenal for 90 mm ammunition, APT-T33E7)[3] which relates ranging performance to ballistic characteristics and ultimate hit probability. The curves on this graph (shown in Appendix D, Figure D-1) represent the maximum acceptable bias and spread at three different ranges which operators may

[1] The tank commander's periscope was bore sighted with the gunner's periscope. The field of view is identical for the two instruments when they are bore sighted on the same point. Therefore, any target which enters the TC's field of view is entering the gunner's field at the same time. In this experiment, one member of the testing team worked as tank commander and recognition timer. The time between the appearance of the announced target in the field of view and the gunner's announcement "Identified," was recorded by the TC with a stop watch.

[2] Theoretically, bias should not exist at 1,500 yards, for the Internal Correction System (ICS) adjustment to remove bias is made at this range. But in some ranging systems bias will exist at every range except the calibrating range.

[3] These curves were reported in *Tank Fire Control System Studies, Accuracy of Fire and First Round Hit Probability in [illegible] Fire* (Report [illegible]), Frankford Arsenal, Philadelphia, May 1955.

demonstrate and yet qualify as range finder operators (80% hit probability). The performances on the daily ranging tests were scored by this system.

Second, the operators were scored on two of the final test targets by using a composite of three graphs prepared by Frankford Arsenal (see Figure D-2). This composite graph makes it possible to score for three levels of hit probability at a range of 2,000 yards. These curves are based on the ballistic characteristics of the round, and therefore hit probabilities are determined by the relationship between spread and bias for any group of range determinations.

Third, to eliminate the effect of bias at ranges where it might exist,[1] another scoring system was used.[2] This system evaluates performance on operator consistency or spread. In this evaluation, bias is eliminated from consideration, and only the man-machine capability to reproduce a given set of conditions is tested.

FINDINGS

Percentage of Men Who Acquired Ranging Skill

In using the Frankford Arsenal scoring system on a 1,587-yard target, it was found that the ranging systems did not differ significantly in the number of men who qualified.[3] Out of 19 men in each group, nine stereoscopic operators and 13 coincidence operators qualified at this range. Since these frequencies do not differ significantly, 57 per cent of the operators might be expected, on the average, to qualify with either device when the target is near 1,500 yards.

When ranging skill is measured at 2,000 yards (using the composite Frankford Arsenal scoring system), there is a reliable difference between the two ranging devices in the number of men who qualified. The results, shown in Table 2, indicate that more operators qualified on the coincidence instrument.[4] On the clearly defined target, a house at 2,062 yards, 15 of 19 men in Group C qualified as marksman or better whereas only one of the men in Group S performed as well as this. On the indistinct target, an anti-tank position at 1,982 yards, nine men in Group C and two men in Group S qualified as marksman or better. It will be pointed out in the discussion that both target characteristics and bias inherent in the stereoscopic instrument may have influenced the result.

[1] See footnote 2, page 11.

[2] H.C. Olsen and N. Willard, Jr., *A Simplified Method for Rating the Performance of Stereoscopic Range Finder Operators*, HumRRO Technical Report 34 (Human Research Unit Nr 1, CONARC, Fort Knox, Ky.), December 1956.

[3] Dichotomizing each group of men into the number who *qualified* and the number who *failed* on a target at 1,587 yards, yields a Chi-square of 1.72, with one degree of freedom. This value falls between the .20 and the .10 level of probability.

[4] When each group is dichotomized into the number who were *qualified* and the number who were *unqualified*, the Chi-squares for frequency differences, corrected for continuity, are significant at the .05 level of probability for the target at 1,982 yards, and at the .001 level for the target at 2,062 yards.

Table 2

OPERATORS WHO QUALIFIED AT VARIOUS LEVELS ON TWO TARGETS AT ABOUT 2,000 YARDS

Qualification Level*	House at 2,062 Yards		Anti-Tank Position at 1,982 Yards	
	Group C (N = 19)	Group S (N = 19)	Group C	Group S
Expert	1	0	0	0
Sharpshooter	9	0	2	1
Marksman	5	1	7	1
Unqualified	4	18	10	17
Total	19	19	19	19

*The categories are based on Frankford Arsenal curves (see Figure D-2) for permissible bias and spread in range finder operation when the target is at 2,000 yards. Expert corresponds to a theoretical hit probability of 80%, Sharpshooter, 65%, and Marksman, 50%.

Another qualification picture is presented when proficiency on all the final test targets is measured by spread alone (operator consistency). For example, when the Human Research Unit system of scoring is used to determine how many men qualified as Class II operators or better (approximately equal to the expert category in the Frankford Arsenal method), on all targets an average of about four per cent of Group C qualified, whereas an average of 14 per cent of the Group S operators met the same standard. The number qualifying for this category on each target is given in Table 3. The HRU system, however, is a field expedient for operator classification; as such, it produces gross differentiations between operators and between groups through the use of exclusive categories.

Table 3

OPERATORS WHO QUALIFIED FOR CLASS II ON THE FINAL TEST TARGETS

Target Number	Range (yards)	Target Type	Number in Class II*	
			Group C (N = 19)	Group S (N = 19)
1	709	House	2	4
3	770	Bunker	0	2
4	974	A-T position	0	2
2	1,037	Tank	0	4
5	1,107	Moving jeep	1	4
10	1,587	Truck	0	3
6	1,714	MG position	0	2
7	1,753	Moving tank	0	2
8	1,[illegible]	A T position	1	1
9	2,062	House	4	3

*HRU System of scoring

Table 4

CONSISTENCY (SPREAD) MEASURES FOR EACH GROUP ON THE FINAL TEST TARGETS

Target Number	Range (yards)	Target Type	Median Spread (yards)		p[a]
			Group C (N = 19)	Group S (N = 19)	
1	709	House	40	30	NS[b]
3	770	Bunker	145	60	.01
4	974	A-T position	172	72	.01
2	1,037	Tank	112	70	NS
5	1,107	Moving jeep	110	85	NS
10	1,587	Truck	170	155	NS
6	1,714	MG position	445	280	NS
7	1,753	Moving tank	325	170	.01
8	1,982	A-T position	230	300	NS
9	2,062	House	150	290	.02

[a]Non-parametric test of unpaired replicates, in F. Wilcoxon, *Some Rapid Approximate Statistical Procedures*, American Cyanimid Company, New York, 1949, p. 4.

[b]Not significant.

The results of the statistical analysis of the ranging data (spread only) before they were categorized are shown in Table 4. Group S had significantly less spread (was more consistent) than Group C on Targets 3, 4, and 7, which may be classed as indistinct or ill-defined, because they tend to blend with their surroundings. Group C was significantly superior on Target 9, a clearly defined target at the maximum range used.

MEDIAN VARIABILITY FOR EACH GROUP ON FINAL TEST TARGETS

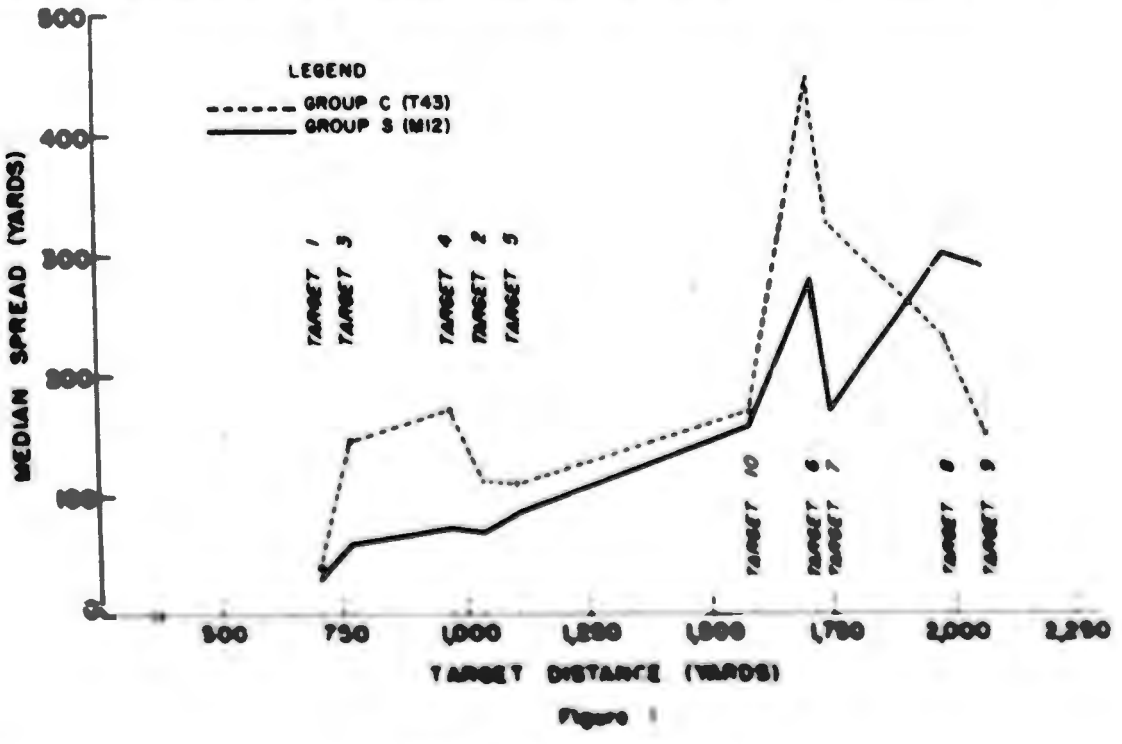

Figure 1

The relationship between variability (spread or consistency) in ranging and target distance is essentially the same for both ranging systems. Variability in yards increases as target distance increases. This relationship for both ranging systems is shown in Table 4 and Figure 1. On both instruments the increase appears to be nearly linear, but the coincidence instrument has greater deviation from linearity, independent of target distance, than the stereoscopic instrument. These deviations appear to be related to target characteristics. It is possible that, on indistinct targets, some of the men in Group C selected for ranging a distinct object which they judged to be in the vicinity of the indistinct target. As their selection of a distinct target varied and as their judgment of proximity failed, their apparent spread on the normally indistinct target may have increased.

Relationship Between Ranging Performance and Pre-Training Tests

Table 5 shows the correlations between ranging performance and the results of tests given before training began. Results indicate that aptitude test performance has very little relationship to ranging performance on either instrument. For vertical phoria is significantly related to ranging performance on both instruments; near vertical phoria is significantly

Table 5

CORRELATIONS BETWEEN APTITUDE AND VISION VARIABLES AND VARIABILITY IN RANGING PERFORMANCE FOR EACH GROUP

Variable	Group C (N = 19)	Group S (N = 19)
Aptitude		
CO-A	.16	-.20
CO-B	.05	-.02
GM	.01	-.06
MM	-.37	-.09
Far Vision		
Vertical Phoria	-.58 bis [a,b]	-.54 bis [b]
Lateral Phoria	.40 bis	.19
Right Eye Acuity	.15 bis	.04 bis
Left Eye Acuity	.00 bis	.22 bis
Stereopsis	.254 bis	.56 bis [b]
Near Vision		
Vertical Phoria	.03 bis	-.78 bis [c]
Lateral Phoria	.08	.26
Right Eye Acuity	.44 bis	.06 bis
Left Eye Acuity	.28 bis	.32 bis
Variability in IPD	-.44	-.01

[a] Two separate biserial correlation coefficients were computed because subjects received the same score. In all other cases, usual Pearson coefficients were computed.
[b] Significant at .05 level.
[c] Significant at .001 level.

related to stereoscopic ranging only; and stereopsis, as might be expected, is significantly related to stereoscopic ranging only.

Inspection of the training data shows that three men in Group S showed no learning. These three men were unable to discriminate between targets that were widely separated in range. Their performance is markedly atypical; hence, it might reasonably be expected that such men would be excluded from training on the instrument (and use of it) at a local unit level without special testing.

The optometric refractions[1] indicate that two of these men had severe (7 prism diopters) exophoria. The third had three prism diopters of exophoria, but more important, he had an interpupillary distance of 78.4 mm. On the M12 the upper limit for interpupillary adjustment is 72.0 mm. Therefore, independent of the exophoria, he could not be expected to use an instrument with such a limitation.

On the assumption that the poor performance of these men was not representative of the normal user, they were dropped from the analyses of ranging bias and ranging time. It must not be forgotten, however, that they represent about 15 per cent of a population randomly selected from the total test group, and that they could not operate the stereoscopic equipment. On the other hand, all the men in Group C were able to make gross range discriminations on the coincidence instrument.

ICS Applicability

The above discussion raises a question on the effectiveness of the Internal Correction System (ICS) for reducing bias. In this study, both instruments were ICSed at 1,500 yards. Previous investigation indicated that the coincidence instrument could be corrected by one operator, and that this correction would apply for every operator. Therefore, in this study the coincidence instruments used a fixed ICS throughout training. For the final test, two expert operators made the calibrating adjustment for the coincidence instruments, on which the settings were maintained throughout the test. On the stereoscopic instrument, on the other hand, the ICS setting is a personal correction, not transferable between individuals. Therefore, ICS determinations were made by each stereoscopic operator daily for each instrument he used, and each operator in Group S determined his ICS adjustment immediately before making his final test rangings.

The findings indicate that, when the ICS is established at 1,500 yards, the T43 appears to be adjusted correctly throughout the range of distances tested. Two specific deviations (see Figure 2) need further discussion. On Target 3 at 770 yards and Target 6 at 1,714 yards, the coincidence instrument yielded large deviations. Only a description of the targets offers a clue to these deviations, which conform to no system. Both targets had only normal terrain properties. Target 3 was a mound of earth and Target 6 was a pile of rocks. This type of target is not clearly defined and its color and that of its surroundings are homogeneous. This factor may directly increase the difficulty of superimposition as required

[1] Optometric refractions were performed by the optometrist assigned to the Psychology Section, Army Medical Research Laboratory, Fort Knox.

MEDIAN DEVIATIONS OF RANGE READINGS FROM TRUE RANGE FOR BOTH RANGE FINDERS ON THE FINAL TEST

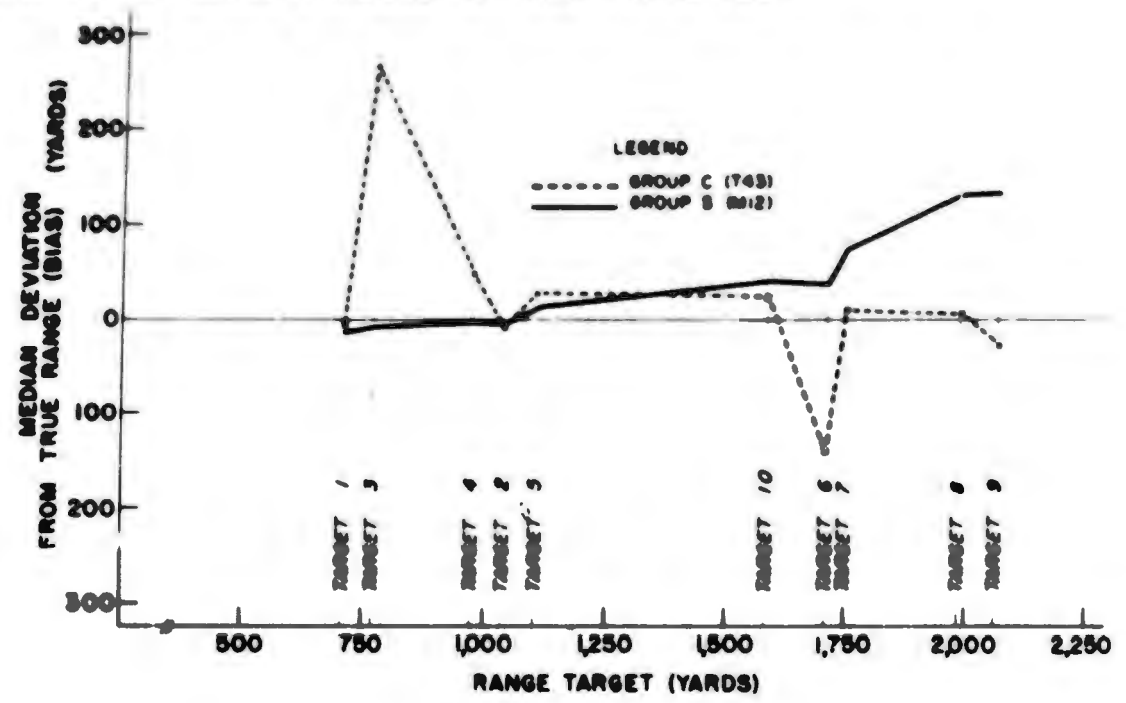

Figure 2

by the coincidence instrument; or, as explained previously, the choice of a distinct object near the indistinct target may have been influenced by an obvious choice to which several operators resorted. The data indicate that for Target 3, the obvious choice appears to lie between 950 and 1,050 yards distant; seven operators ranged in this area. For Target 6, eight operators selected a target between 1,450 and 1,550 yards away.

The stereoscopic instrument yielded different ICS data. The bias of Group S operators appears to increase as target range deviates more and more from ICS range. This deviation approaches its greatest size at ranges of 2,000 yards and beyond. It should be noted here that the comparison between Groups C and S on the basis of spread alone, in Table 4, for example, is appropriate only if the ICS error in the stereoscopic instrument were to be eliminated. The results shown in Figure 2 and Table 6 therefore indicate the presence of a bias error in the current model of the stereoscopic device.

Identification Time

Unlike the stereoscopic instrument, the coincidence instrument offers, before ranging, two images of every object in the field except those at the battle range of 800 yards which was indexed on the instrument. Measures were therefore taken of the time required, on each instrument, to identify a target after a fire command had been issued. The 10 targets of the final test were called one at a time, while the turret was being traversed, time was measured from the instant the target

Table 6

MEDIAN RANGE READINGS FOR EACH GROUP ON THE FINAL TEST TARGETS

Target Number	Target Range (yards)	Target Type	Median Range Reading (yards)		p[a]
			Group C (N = 19)	Group S (N = 16)	
1	709	House	704	695	.05
3	770	Bunker	1,037	763	.01
4	974	A-T position	1,021	970	.01
2	1,037	Tank	1,031	1,032	NS
5	1,107	Moving jeep	1,133	1,118	NS
10	1,587	Truck	1,610	1,625	NS
6	1,714	MG position	1,574	1,750	NS
7	1,753	Moving tank	1,762	1,825	NS
8	1,982	A-T position	1,987	2,112	.01
9	2,062	House	2,035	2,193	.01

[a]Non-parametric test of unpaired replicates, in Wilcoxon, *op. cit.*

came into the field of view until the gunner announced, "Identified." The stereoscopic and coincidence fields were compared on this time measure, with no significant difference being found between Groups C and S. Table 7 shows the results of an analysis of variance test between the identification times required for the two systems.

Table 7

ANALYSIS OF VARIANCE OF THE GROUPS ON TARGET IDENTIFICATION TIME

Source of Variance	Degrees of Freedom	Mean Square	*F*	*p*
Between groups	1	2.99	.38	NS
Between subjects	36	7.93		
Between targets	9	195.66	32.08	.001
Interaction: targets × groups	9	11.67	1.91	NS
Interaction: pooled subjects × targets	324	6.10		
Total	379			

Ranging Time

The systems under test were lso compared on operating time, that interval being defined as the time from the operator's contact with the ranging knob, when that knob was set at a battle range of 800 yards, to the instant he released the knob. The results indicate that Group C was reliably faster on nine of the 10 targets. (See Table 8.) The average over-all difference between systems in median ranging time was 4.1 seconds.

Table 8

MEDIAN RANGING TIME FOR EACH GROUP ON THE FINAL TEST TARGETS

Target Number	Range (yards)	Target Type	Ranging Time (seconds)		p*
			Group C (N = 19)	Group S (N = 16)	
1	709	House	3.8	7.0	.01
3	770	Bunker	7.3	7.3	NS
4	974	A-T position	5.3	7.9	.02
2	1,037	Tank	5.2	8.5	.02
5	1,107	Moving jeep	7.0	11.2	.01
10	1,587	Truck	5.7	9.8	.01
6	1,714	MG position	9.2	12.1	.05
7	1,753	Moving tank	7.7	15.8	.01
8	1,982	A-T position	7.4	13.0	.01
9	2,062	House	6.1	13.1	.01

*Non-parametric test of unpaired replicates, in Wilcoxon, *op. cit.*

Number of Range Readings Required in Acquiring Ranging Skill

The curve of acquisition of ranging skill as measured by median spread is plotted in Figure 3, based on the daily test performances of Groups C and S. The daily test required ranging on a panel target at about 1,500 yards. Tests of significance between groups were applied after 135, 245, and 505 practice rangings. After 135 rangings Group C was significantly superior[1] to Group S, but the groups are not significantly different at any later stage of training.

RELATIONSHIP BETWEEN OPERATOR VARIABILITY AND RANGING PRACTICE FOR BOTH RANGE FINDERS, AT 1,500 YARDS

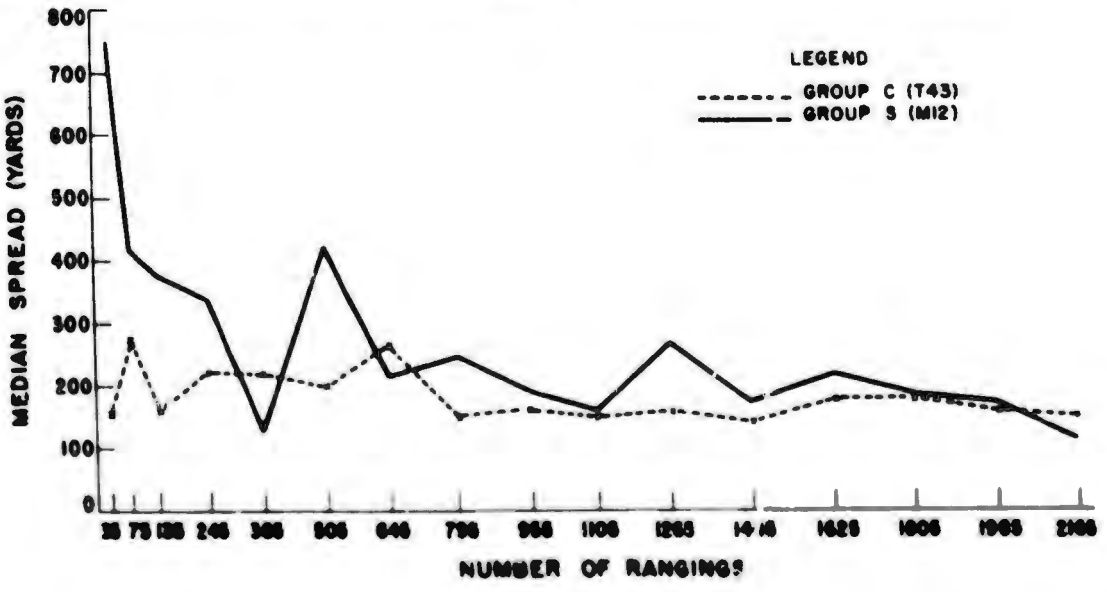

Figure 3

[1]Statistically significant at the .01 level on the basis of the non-parametric test of unpaired replicates in Wilcoxon, *op. cit.*

The learning curves in Figure 3 show that there is not a reliable difference between the two groups in median spread beyond 245 practice rangings. But the fluctuations in the curve for Group S, which represents only the consistency of the median operator, show that performance on the stereoscopic instrument is highly unstable for the first 1,500 practice rangings.

By selecting the first point in training at which an operator's daily test performance equaled or surpassed an average of his last three daily test performances, it was possible to demonstrate the amount of training required for each operator to achieve a level as good as his final level. By summing the cases within each group, it was possible to determine the percentage of operators who had reached their maximum performance at any stage of training. These results are given in Table 9. In this analysis the cutoff point selected for each man was based on his own performance at the end of training, not on an arbitrary qualification standard. Most of the operators in both groups failed to qualify.

Table 9

PERCENTAGE OF OPERATORS IN EACH GROUP
WHO REACHED MAXIMUM PROFICIENCY
AT EACH STAGE OF TRAINING

Cumulative Number of Practice Rangings	Cumulative Percentage of Operators Who Reached Maximum Proficiency	
	Group C	Group S
35	58	5
75	63	21
135	79	26
245	84	37
365	84	63
505	84	63
645	84	74
795	95	74
955	100	74
1,105		89
1,445		95
2,165		100

Table 9 shows that though more than half the operators in Group S reached their maximum proficiency after about 300 rangings, the leveling-off for the others in the group was distributed over the next 1,200 rangings. It might therefore be expected that in a training program for operators of the stereoscopic range finder (if the program did not provide for pre-training selection procedures), the average or modal trainee would reach peak performance after about 250 to 300 practice rangings. At least 1,000 ranging trials would be needed, however, before 89 per cent of the operators could be expected to reach peak performance.

In contrast, more than half the operators in Group C reached maximum proficiency by the end of the first testing period, that is, after 35 practice rangings. Table 9 and the learning curve in Figure 3 show that

operators of the coincidence range finder profit little from extended training. 84 per cent of them may be expected to reach peak performance after about 245 trials.

The performance curves for the two groups differed significantly during early stages of training, according to non-parametric comparison of the median variabilities for Groups C and S. Variability for Group S varied so extremely that it is not possible to develop tests of differences in trend between the two groups. However, to demonstrate differences between the groups in the variability of variability, variance ratio tests between the groups were computed for various points in training. Before these computations were made, it was necessary to apply a logarithmic transformation to all the variability scores.

The results of these computations show that Group C was significantly less variable on eight of the 16 tests given periodically during training. On no target was Group S significantly less variable than Group C. These results show that the performance of the two groups during training differed, but do not indicate a relationship between stage of training and evidence of a difference between groups. As Table 10 shows, initially there was no difference, during the middle stages of training the groups differed significantly, and in the later stages the difference was disappearing. A plot of the reduction in the variability of variability (Figure 4) indicates that the level of the groups was initially about the same, but that Group C improved more rapidly and reached maximum performance earlier. The curves for the two groups diverge during the middle stages of training, but the improvement made by Group S during the later stages closed the gap between the two curves.

Table 10

VARIANCE OF EACH GROUP AT EACH STAGE OF TRAINING

(Using Logarithmically Transformed Indices of Individual Variability)

Cumulative Number of Practice Rangings	Variance		*F*	*P*
	Group C	Group S		
35	2,264.38	2,070.59	.91	NS
75	1,113.45	2,184.06	1.96	NS
135	757.52	2,588.97	3.42	.01
245	1,325.15	2,071.02	1.56	NS
365	1,567.69	3,890.20	2.48	.05
505	640.50	1,648.54	2.58	.05
645	817.54	1,942.98	2.38	.05
795	573.10	1,537.43	2.68	.05
955	240.50	1,151.61	4.80	.01
1,105	573.10	1,255.26	2.19	NS
1,265	274.56	1,361.26	4.95	.01
1,445	781.58	942.54	1.21	NS
1,625	682.14	941.81	1.95	NS
1,805	691.81	1,347.37	2.74	.05
1,985	821.78	840.71	1.03	NS
2,165	[illegible]	[illegible]	[illegible]	[illegible]

RELATIONSHIP BETWEEN GROUP VARIANCES AND PRACTICE RANGINGS FOR BOTH RANGE FINDERS

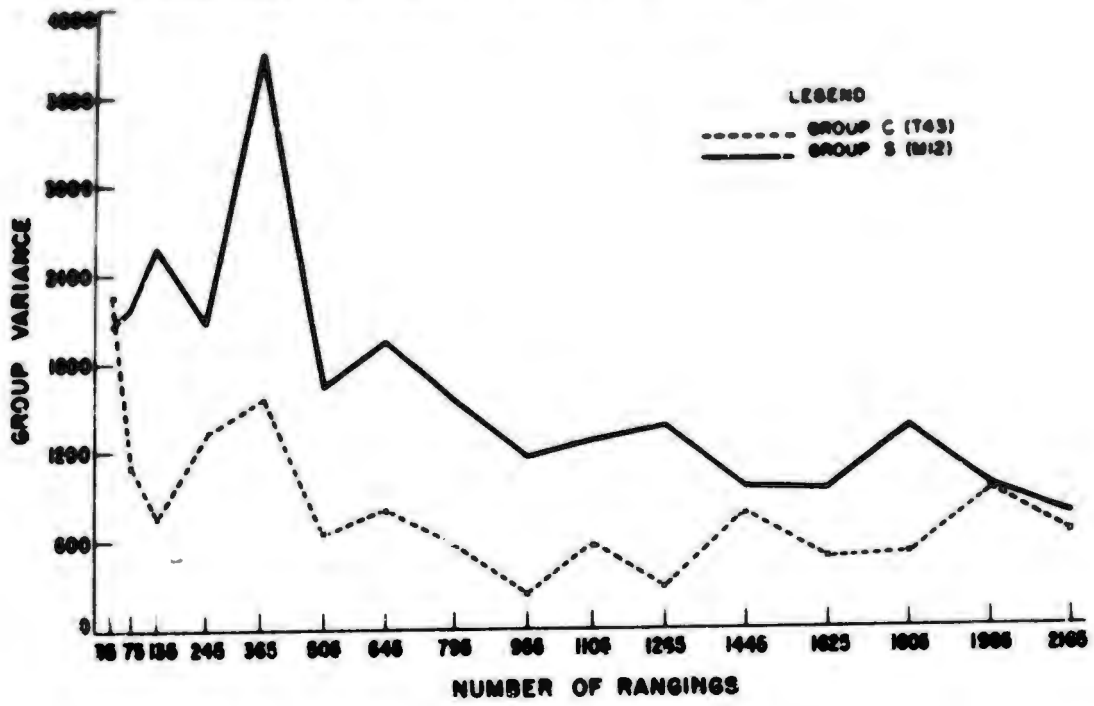

Figure 4

Variance ratio tests between the groups were also computed for the 10 targets used in the final ranging test (after a logarithmic transformation was applied to the variability scores). As Table 11 shows, on only two targets was there a significant difference between Group C and Group S in variability of the transformed variability scores. Both of these significant differences favored Group C, and the variability for Group S was somewhat larger than that for Group C on every target. This finding may be interpreted as an indication that there is a small but reliable difference between the groups, or that groups trained on the stereoscopic range finder require more training than those trained on the coincidence range finder.

Table 11

VARIANCE OF EACH GROUP ON THE FINAL TEST TARGETS

(Using Logarithmically Transformed Scores)

Target Number	Variance		F	P
	Group C	Group S		
1	1,721.06	2,188.89	1.27	NS
2	552.49	1,420.47	2.57	.05
3	1,798.54	2,910.82	1.62	NS
4	785.82	1,047.95	1.33	NS
5	883.04	1,553.80	1.76	NS
6	953.60	1,659.04	1.75	NS
7	652.09	981.87	1.50	NS
8	1,084.94	1,209.94	1.12	NS
9	516.67	1,018.67	1.98	NS
10	384.62	1,215.82	3.32	.01

DISCUSSION

This study was designed to evaluate two devices on criteria which are applicable only in the context in which the devices are to be used. It is not an attempt to establish theoretical or practical limits for either optical principle involved. Exhaustive comparisons of principles as they might theoretically be employed are necessary steps in developing an efficient piece of equipment. Nevertheless, it must be recognized that the consumer is not always aware of the conditions of such testing; and because conditions for the user may be specific, he should be able to temper his choice of principle by a full awareness of the risk of overgeneralizing to a nonlaboratory setting. When laboratory comparisons of stereoscopic and coincidence ranging devices are run, they make use of precision instruments and highly specialized, highly trained operators. The results are often interpreted as being applicable in the military setting. On the contrary, such results may be wholly inapplicable in everyday military practice, for only the run of manufactured instruments and military personnel are available when field comparisons are made.

For example, the method used to determine the percentage of men who can effectively operate the equipment can exert a strong influence upon the results. Whether to include instrument error which might be (but has not been) removed by engineering changes, or to score operators as if the error did not exist, is a decision that can alter the results of a test from a region of significant differences to one of statistical doubt. Instead of arbitrarily selecting one system, it seems wise to consider both, and the implications of both.

In the stereoscopic device, the ICS correction (theoretically) can be used to reduce the average bias to zero at the ICS range of 1,500 yards. But this correction reduces bias to zero at no range except 1,500 yards. At greater ranges, the bias increases gradually to about 100 yards at the 2,000-yard range. This instrument error in ranging accuracy is enough to preclude hitting a target at 2,000 yards; therefore, any scoring system which requires that ranging proficiency be related to hit probability will in certain range brackets disqualify every stereoscopic operator. On the other hand, the coincidence instrument may be corrected for bias at 1,500 yards, and the correction will hold in general for every range used in this study, including those up to and beyond 2,000 yards. (The exceptions, related to target clarity, have been discussed.) This difference between the instruments in the bias adjustment gives the T43 a distinct advantage when scoring systems which make reference to hit probability are used.

The time required for an operation which involves perceptual judgment may not appear significant to the laboratory investigator, but time is a very important factor in evaluations made by a military user. Past studies have dealt primarily with the precision with which judgments can be made. It is believed that more weight might justifiably be assigned to time differentials in the evaluation of fire control systems.

The results of this study, like those of past findings, suggest that the stereoscopic instrument is generally superior on indistinct or ill-defined targets. The probability of such targets appearing in combat must be

considered before any evaluation is complete. In this study, the five most probable combat target types were selected from the report[1] of a study on the occurrence of various target types (conducted by Board Nr 2, CONARC). As tactics and weapons change, the probabilities assigned to these target types should be reviewed and revised for use in systems evaluations.

CONCLUSIONS

The results of this study confirm those reported previously.[2] Five findings appear to have special significance for the military user.

(1) The stereoscopic range finder is an insurmountable problem for a small percentage of the American male population. In this study, 15 per cent failed completely.

(2) Though operators of the stereoscopic range finder improve rapidly during the first 250 to 300 trials, about 75 per cent of the men reach their peak performance after about 600 practice rangings; it appears therefore that lengthy ranging drill does not result in much operator improvement. Operators of the coincidence range finder improve even more rapidly; they master the coincidence principle quickly, and 75 per cent of them reach their peak performance on the instrument after about 100 rangings.

(3) Perhaps the most important difference between the instruments is in the functioning of the Internal Correction System. In the coincidence instrument, this system functions as a means of reducing bias throughout the usable range of the instrument. However, operator error of a bias nature may occur independent of range on indistinct or ill-defined targets. The ICS adjustment in the stereoscopic instrument fails to eliminate bias at any range except the range chosen for adjustment. As pointed out previously, a bias error of more than 100 yards may exist at a 2,000-yard target after the instrument has been perfectly adjusted at 1,500 yards. It has also been pointed out that mechanical adjustments or corrections might remove this instrument source of error.

(4) Since the military user evaluating equipment performance in the light of tactical requirements must be concerned with any device which adds to or reduces operating time in combat, two elements of range finder operation were timed during this test. Identification time was virtually the same for both instruments, but on ranging time operators were significantly faster with the T43 than with the M12. The average difference in median ranging time, about 4.1 seconds, is of practical significance in a total fire cycle which is not supposed to exceed eight seconds.

(5) Performance on the T43 was less consistent than that on the M12 on targets which were indistinct or ill-defined. Full appreciation of the importance of this difference will depend on detailed analysis of the probability that various target types will be encountered in combat.

[1] *Report of Test Project No. 1008, Army Ground Forces Board 2, Fort Knox, Ky., September 1943.*

[2] N. Willard, Jr., H.C. Olson, and R.D. Arnold, *A Study of Training of Stereoscopic Range Finder Operators for Armor (U)*, Human RR) Technical Report 38, (U.S. Army Armor Human Research Unit, Fort Knox), February 1957, (CONFIDENTIAL), see also, *First Partial Report on Coincidence Range Finder, T43* (Fourth Report on Project TT2-4009), Development and Proof Services, Aberdeen Proving Ground, Md., November 1954.

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AND
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19. *Tests of Raw and Sorted Range Finder No. 2*, Tank Armament Research Committee, April 1944, p. 11.

Appendix A

SCORES ON THE APTITUDE AND VISION TESTS GIVEN PRIOR TO TRAINING

Table A-1

COMPARISCN OF THE GROUPS ON APTITUDE AND VISION VARIABLES

Variable	Group C		Group S		t	p
	Mean	Standard Deviation	Mean	Standard Deviation		
Aptitude						
CO-A	91.26	17.59	93.21	14.08	.38	NS*
CO-B	92.84	13.06	96.68	10.76	.99	NS
GM	87.84	14.62	91.58	11.35	.88	NS
MM	86.10	11.34	91.53	11.34	1.47	NS
Far Vision						
Vertical Phoria	4.90	1.37	4.53	1.58	.77	NS
Lateral Phoria	7.63	2.17	7.84	2.69	.26	NS
Right Eye Acuity	9.90	1.05	9.05	.97	2.56	.02
Left Eye Acuity	9.47	1.78	9.16	1.26	.64	NS
Stereopsis	2.63	2.17	3.21	2.12	.83	NS
Near Vision						
Vertical Phoria	4.90	1.56	4.68	1.42	.43	NS
Lateral Phoria	14.74	4.23	15.32	5.84	.35	NS
Right Eye Acuity	9.32	1.11	9.37	.96	.15	NS
Left Eye Acuity	9.26	1.66	9.37	1.38	.22	NS
Interpupillary Distance						
Mean	65.67	3.61	67.70	3.53	1.75	.10
Variability (Range) in IPD	1.14	.98	.73	.36	1.70	NS

*Not significant.

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Appendix B

SCHEDULE OF TRAINING AND PROGRAM OF INSTRUCTION

Training Schedule on the T43 and M12 Range Finders

WEAPONS DEPARTMENT
THE ARMOR SCHOOL
FORT KNOX, KENTUCKY

T43 Range Finder Evaluation Schedule for Week 1

12 August 1955

Date and Time	Place	Unit Number	Subject	Study References	Student Equipment	Uniform	Instructor
Monday 0730-0815	Muirdment (T-2307)	N A	Orientation (C)	N/A	Pencil & Notebook	W-A	Capt. Hoke Capt. Rogers Dr. Willard
0825-1615	Muirdment (T-2307)	N A	Test group analysis, tests, and assignment (PE)	N/A	Pencil & Notebook	W-A	Dr. Willard
Tuesday 0730-0810	McPheeters (T-2307)	N A	Test group analysis, tests, and assignment (PE)	N/A	Pencil & Notebook	W-A	Dr. Willard
0815-1115	McPheeters	WX2.15002	Turret familiarization, M47 tank	None	Pencil & Notebook	W-A	9 A/Is Mr. Manning
1230-1410	Storch	WX2.11002	Group A Range finder M12 (C,D)	None	Pencil & Notebook	W-A	Mr. Manning
1417-1615	Storch & Muirdment (T-2307)	WX1.200502	Range finder M12 (C,PE)	None	Pencil & Notebook	W-A	M Sgt. Jackson

(Continued)

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Date and Time	Place	Unit Number	Subject	Study References	Stanflit Equipment	Uniform	Instructor
Tuesday (Continued)							
1230–1410	Vaidment (T–2307)	WX2.11002	Group B Range finder T43 (C,D)	None	Pencil & Notebook	W–A	Capt. Hoke
1435–1615	Vaidment (T–2307)	WX1.200502	Range finder T43 (C,PE)	None	Pencil & Notebook	W–A	M/Sgt. Crispy
Wednesday							
0730–1615	Vaidment (T–2307)	WX1.200812	Group A Range finder M12 practice (PE)	None	Pencil & Notebook	W–A	M/Sgt. Fleener
0730–1615	Vaidment (T–2307)	WX1.200812	Group B Range finder T43 practice (PE)	None	Pencil & Notebook	W–A	M/Sgt. Crispy
Thursday							
0730–1615	Vaidment (T–2307) & Area 25	N/A	Group A Test (PE)	N/A	Pencil & Notebook	W–A	Mr. Manning M/Sgt. Fleener
0730–1615	Vaidment (T–2307) & Area 25	N/A	Group B Test (PE)	N/A	Pencil & Notebook	W–A	M/Sgt. Crispy SFC Castle
Friday	(Same as schedule for Thursday)						
0730–1615							

(Continued)

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T43 Mango Finder Evaluation Schedule for Week 2 — 19 August 1955

Date and Time	Place	Unit Number	Subject	Study References	Student Equipment	Uniform	Instructor
Monday 0730–1615	Maidment (T–2307) & Area 25	N/A	Group A Test (PE)	N/A	Pencil & Notebook	W–A	Mr. Manning M/Sgt. Flooner
0730–1615	Maidment (T–2307) & Area 25	N/A	Group B Test (PE)	N/A	Pencil & Notebook	W–A	M/Sgt. Crispy SFC Castle
Tuesday 0730–1615	*(Same as schedule for Monday)*						
Wednesday 0730–1615	*(Same as schedule for Monday)*						
Thursday 0730–1615	*(Same as schedule for Monday)*						
Friday 0730–1615	*(Same as schedule for Monday)*						

(Continued)

T43 Range Finder Evaluation Schedule for Week 3

26 August 1955

Date and Time	Place	Unit Number	Subject	Study References	Student Equipment	Uniform	Instructor
Monday 0730–1615	Maidment (T–2307) & Area 25	N/A	Group A Test (PE)	N/A	Pencil & Notebook	W–A	Mr. Manning M/Sgt. Fleener
0730–1615	Maidment (T–2307) & Area 25	N/A	Group B Test (PE)	N/A	Pencil & Notebook	W–A	M/Sgt. Crispy SFC Castle
Tuesday 0730–1615	*(Same as schedule for Monday)*						
Wednesday 0730–1615	*(Same as schedule for Monday)*						
Thursday 0730–1615	Salt River Tank Range	N/A	Groups A and B Proficiency Test	N/A	Pencil & Notebook	W–A	All instructors Capt. Bohn Capt. Rogers Dr. Willard
Friday 0730–1615	Salt River Tank Range	N/A	Groups A and B Proficiency Test	N/A	Pencil & Notebook	W–A	All instructors Capt. Bohn Capt. Rogers Dr. Willard

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Program of Instruction on the T43 and M12 Range Finders
(120 hours)

Purpose: To give the student a working knowledge of the fighting compartment including the armament, controls, and range finder.

Subject, File Number, Classification	Hours and Type	Scope of Instruction	References
Orientation	1 D	Background of test, outline of test, introduction of test personnel, division of test group.	Plan of Test of Evaluation, T43 range finder, dated 28 April 1955
Eye Acuity Test and Record check	9 PE	Test group divided into two balanced groups, visually and mentally.	Plan of Test of Evaluation, T43 range finder, dated 28 April 1955
Tank Armament, Controls and Equipment, Tank, M47 (WV2.15002) (U)	2 D, PE	Tank armament, controls and equipment, M47. Nomenclature of tank guns. Familiarization with tank turrets, to include turret and gun controls, vision devices, fire control equipment, general principles of hydraulic systems, and common electrical circuits.	FM 17–12; TM 9–308A; TM 9–718B; Instructional Pamphlet W–2
Range Finders, M12 and T43 (WV2.1002) (U)	2 C, D	Characteristics, nomenclature, use, operation, inspection, maintenance, testing, and adjusting of M12 and T43 range finders.	Instructional Pamphlet W–2 (Revised), The Armor School DA, TC 36, 1952
Range Finder Practice, M12 and T43 (WV1.200502) (U)	2 PE	Practical work in placing range finders M12 and T43 in operation; familiarization with ranging procedure.	Instructional Pamphlet W–2, The Armor School
Range Finder Practice, M12 and T43 (WV1.200808) (U)	88 PE	Practical work in ranging with the M12 and T43 range finders; practice in determining individual ICS adjustment.	Instructional Pamphlet W–2, The Armor School
Range Finder Practice, M12 and T43, T43 Evaluation Test	16 PE	Test.	Plan of Test of Evaluation, T43 range finder, dated 28 April 1955.

Appendix C

SCHEDULE OF USE OF TARGETS AND RANGE FINDERS

Table C-1

USE OF TARGETS AND RANGE FINDERS IN DAILY TRAINING

Training Day[a]	Time	Type and Number of Range Finder Used on Targets at:		
		Civic Center	Cadman Army Air Field	Board Nr 2 Area 25
1	A.M.	M12(1) T43(1)	M12(2) T43(2)	M12(3,4) T43(3,4)
	P.M.	M12(2) T43(2)	M12(1) T43(1)	M12(3,4) T43(3,4)
2	A.M.	M12(3) T43(3)	M12(4) T43(4)	M12(1,2) T43(1,2)
	P.M.	M12(4) T43(4)	M12(3) T43(3)	M12(1,2) T43(1,2)

[a]Firing procedure on odd-numbered days was identical, and that on even-numbered days was identical.

Table C-2

USE OF TARGETS AND RANGE FINDERS IN THE FINAL TEST

(Salt River Tank Range)

Operators	Range Finder Used	Number of Targets	Rangings per Target
1–10	M12, Nr 1	10	5
11–19	M12, Nr 2	10	5
1–10	T43, Nr 1	10	5
11–19	T43, Nr 2	10	5

Appendix D

GRAPHS OF HIT PROBABILITY PREPARED AT FRANKFORD ARSENAL

MAXIMUM SPREAD AND BIAS IN RANGE READINGS ACCEPTABLE IN QUALIFYING AS RANGE FINDER OPERATOR AT THE 80% HIT PROBABILITY LEVEL

(Used in Scoring Daily Tests)

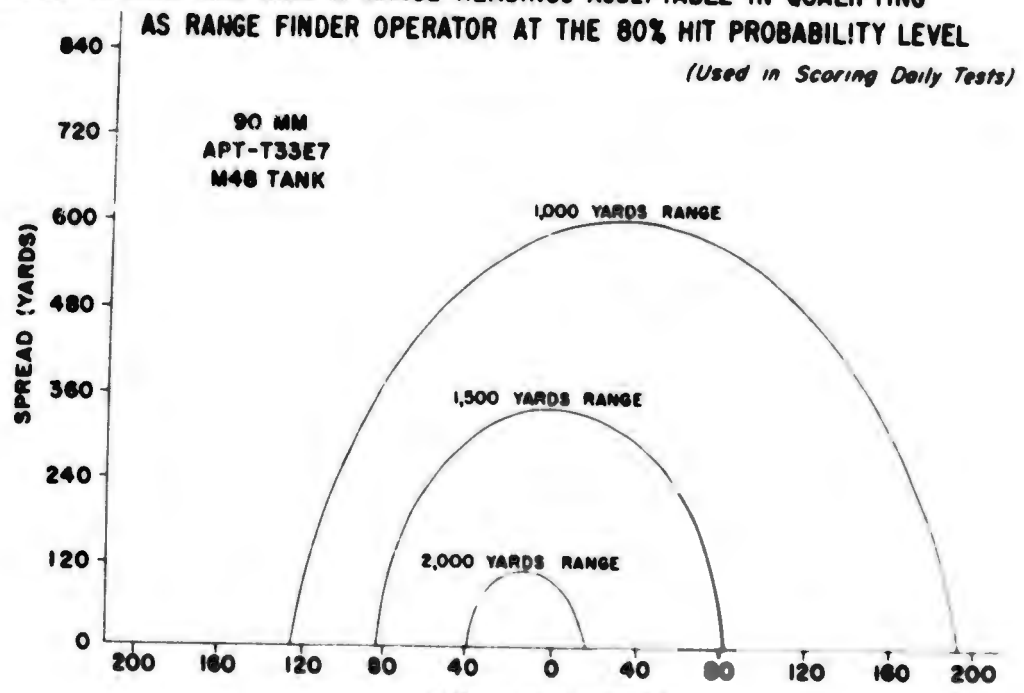
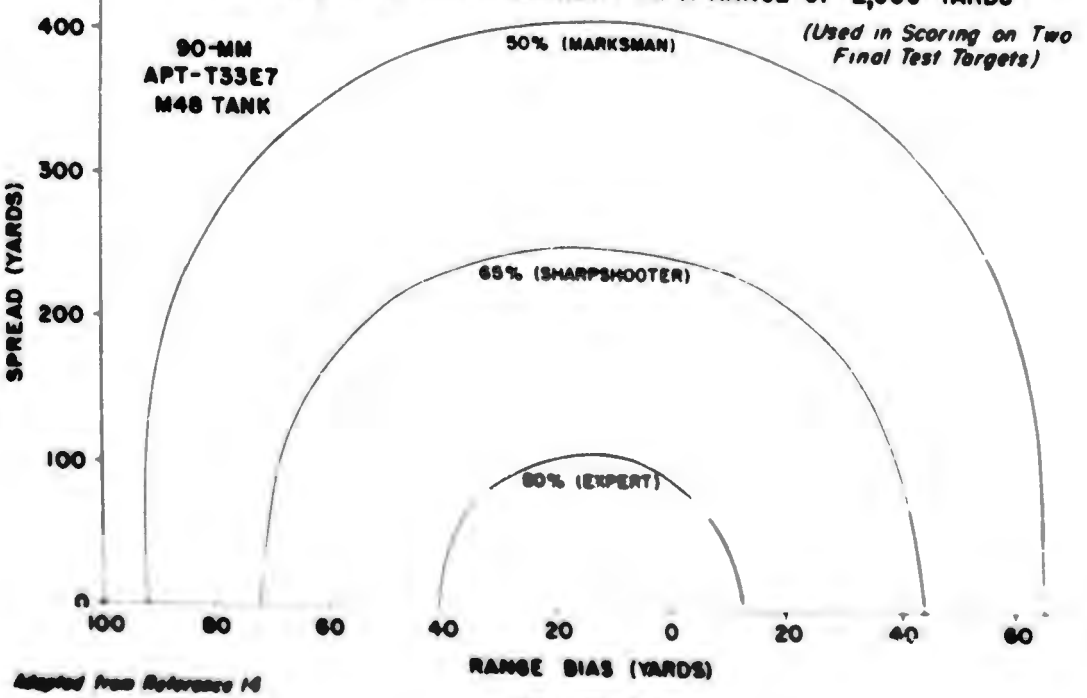


FIGURE D-1

MAXIMUM SPREAD AND BIAS IN RANGE READINGS ACCEPTABLE IN QUALIFYING AT THREE LEVELS OF HIT PROBABILITY AT A RANGE OF 2,000 YARDS



Adapted from Reference 14

FIGURE D-2

ACKNOWLEDGMENTS

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