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The methods employed and the results obtained in a large-scale field test of optical instruments are described. The tests were instituted to check the correctness of theoretical considerations and of laboratory tests which have been used in the selection and design of such instruments. Field conditions approximated as far as possible those in actual service. The test procedure was to approach a group of distant targets in a destroyer escort and, using the instruments to be tested, to record the ranges at which each target could be first glimpsed, then seen continuously, and finally identified. Observations were made by teams of six men on the signal bridge and other three-men teams on the number two gun deck and on the lower deck. Tests were runin blocks of six muns, during which six instruments were rotated among six men so that each man used a different instrument on each urn. Of a total of 190 successful runs, 177 were made at night and 13 in the daytime. Tests were made on the 18 different instruments and some were made with an unaided naked eye. The .50 Relative Range performance of the instruments based on the 7x50x7° as 100 is given

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RESTRICTED **NAVORD REPORT 77-46**

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FIELD TESTS
OF OPTICAL INSTRUMENTS

A BUREAU OF ORDNANCE PUBLICATION 15 MARCH 1947

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FIELD TESTS
OF OPTICAL INSTRUMENTS

DEPARTMENT OF THE NAVY
BUREAU OF ORDNANCE

15 MARCH 1947

Approved:
C. W. Shilling, Capt. (MC), U. S. N.
Medical Officer-in-Charge
U. S. Naval Medical Research Laboratory
U. S. Naval Submarine Base
New London, Conn.

This publication is RESTRICTED and shall be safeguarded in accordance with the security provisions of U. S. Navy Regulations, 1920, Article 76.

NAVY DEPARTMENT

BUREAU OF ORDNANCE

WASHINGTON 25, D. C.

RESTRICTED 15 March 1947

NAVORD REPORT 77-46

FIELD TESTS OF OPTICAL INSTRUMENTS

1. NAVORD REPORT 77-46 describes the procedure and discusses the results of a series of field tests on various binoculars, monoculars, and gun sights, and states the relative merits of each.

2. The report should be useful to those engaged in the design and procurement of such instruments, and will serve as a guide to further testing of optical instruments in the field. Comments and suggestions are invited.

3. This report does not supersede any existing publication.

4. NAVORD REPORT 77-46 is RESTRICTED and shall be safeguarded in accordance with the security provisions of U. S. Navy Regulations, 1920, Article 76.

C W Shilling

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Medical Officer-in-Charge
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New London, Connecticut

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FOREWORD

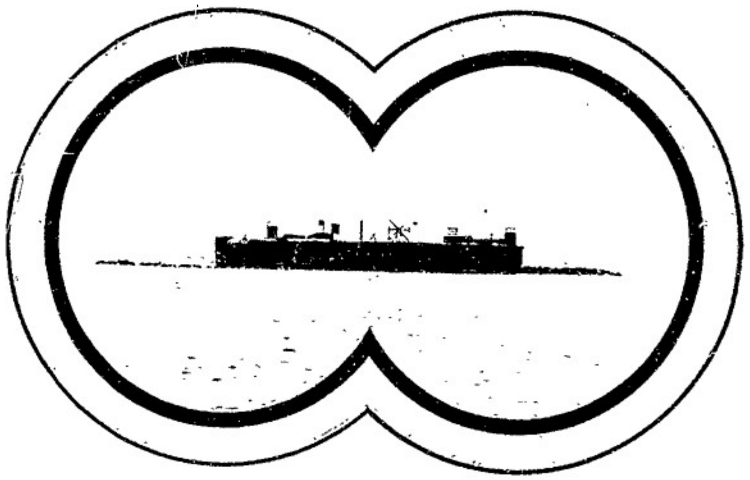
This report describes the methods employed and the results obtained in a large-scale field test of optical instruments. The purpose of these tests was not to supersede laboratory tests, but, rather, to supplement and verify their results in order to assist in the design and selection of such instruments. The findings of this report show that the laboratory testing of optical instruments must be supplemented by a large-scale field test before valid conclusions may be drawn. It has been found, as a result of these field tests, that some of the conclusions reached solely as the result of laboratory tests have been misleading. Laboratory findings, although precise and essential, can not cover all of the variable factors which affect the performance of optical instruments when used by naval personnel under operating conditions.

The results of these tests show the need for additional field work of this type, and also show that future design and selection of optical instruments should be based on field as well as laboratory results.

Because of rapid demobilization during the course of the test, much valuable data was accumulated which has not yet been analyzed to yield the information which may be derived from it. To obtain full value from the experiment it is essential that the statistical analysis of the data be completed.

This experiment, which is the first of its kind to be attempted, was performed as a Bureau of Ordnance project. All work was performed by the Medical Research Department, C. W. Shilling, Capt., MC, U. S. N., Medical Officer-in-Charge, U. S. Naval Submarine Base under the immediate direction of Lieut. W. S. Verplanck, H(S), U.S.N.R. Lt. Comdr. Nathan Pulling, U.S.N.R. acted for BuOrd throughout the experiment.

The present report was prepared by Lt. Verplanck, Dr. Charles E. Osgood and the remainder of the staff of the experiment, with the collaboration of the Stanley F. Chamberlain organization, and of the Optical Inspection Laboratory, Pennsylvania State College. The basic reports presents,briefly, the methods used and the results obtained Appendix A presents detailed findings on each instrument tested; Appendix B, the full technical detail and discussion of all procedures and conclusions; Appendix C summarizes the basic data, and personnel is listed in Appendix D.



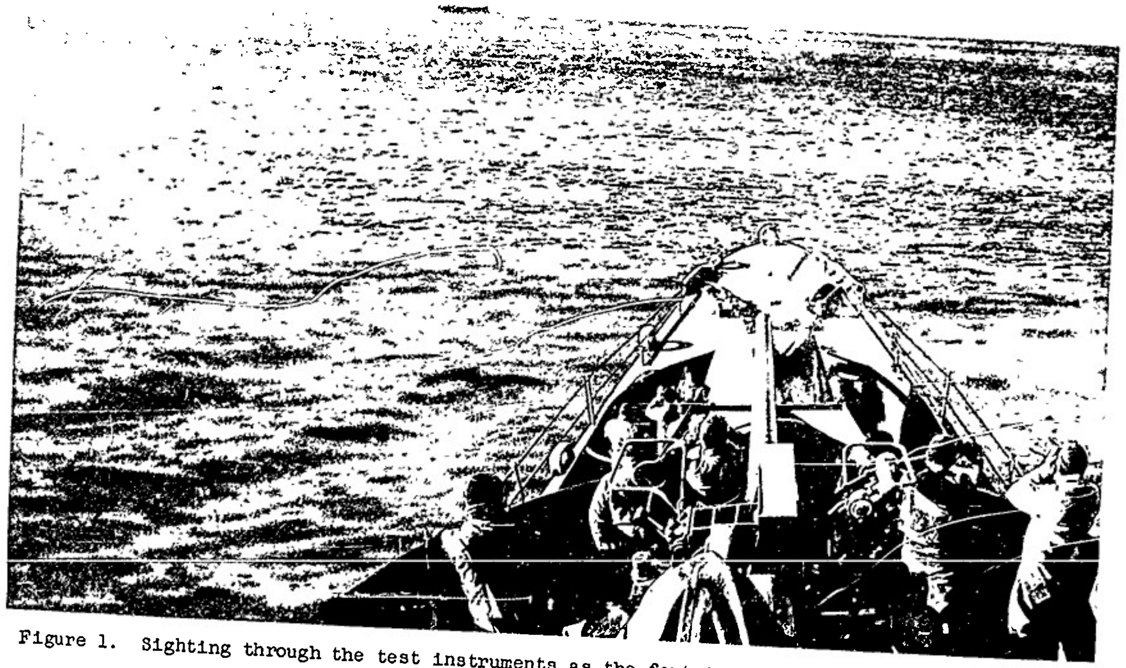
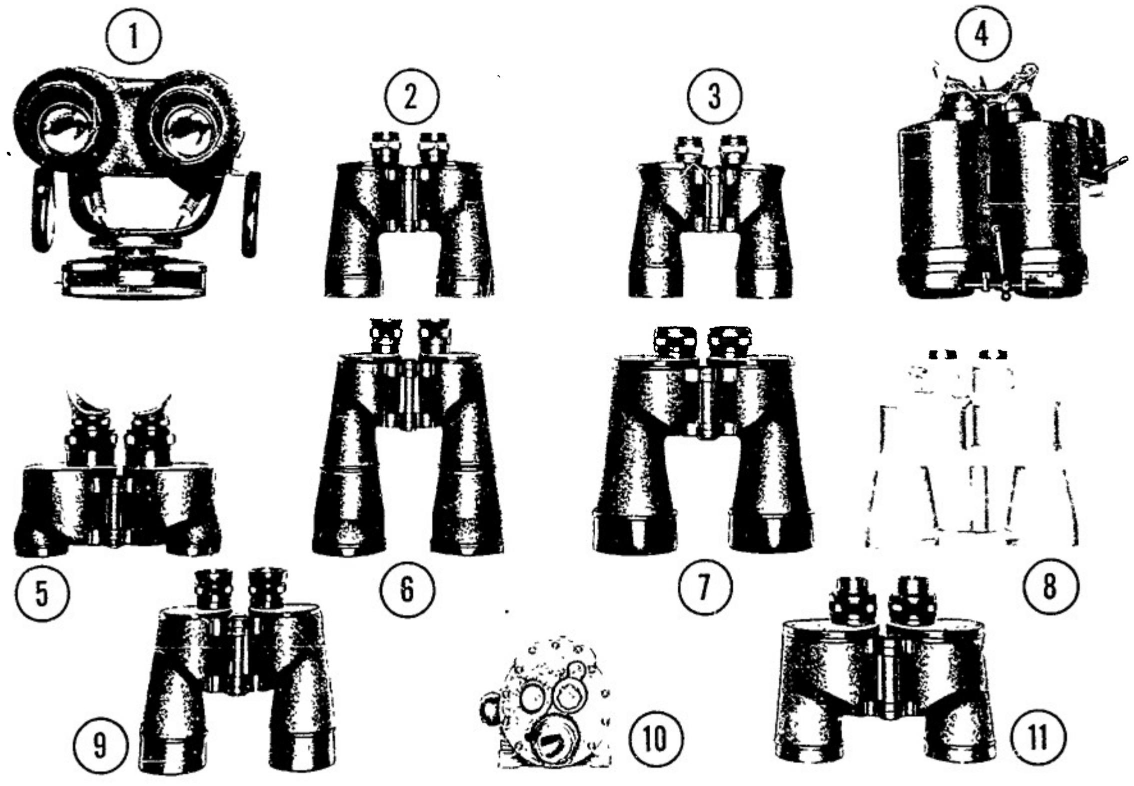


Figure 1. Sighting through the test instruments as the fort is approached, the observers pick up and identify first the fort and then one target after another, while a careful record of radar ranges is kept to measure the instrument's performance

SUMMARY

The tests were conducted in Gardiner's Bay, Long Island Sound, during September, October, November and the first half of December 1945. These tests, the first of their kind, were instituted to check the correctness of theoretical considerations and of laboratory tests which have been used in the selection and design of such instruments. It was thought that the laboratory data, while precise, could not cover all the factors which affect actual performance of the instruments as used by typical naval personnel at sea, and might mislead designers. These field experiments were therefore made under conditions approximating, in so far as possible, those of actual service.

Briefly described, the test procedure was to approach a group of distant targets in a



LEGEND

(1) 7x50x7° Anti-Vibration Mount
(2) 10x50x7°
(3) 7x50x7°
(4) 6x50x7°
(5) 6x42x12°
(6) 9x63x5.7°
(7) 10x70x7° NDRC
(8) 8x60x9°
(9) 7x50x7°
(10) 4x28x10°
(11) 7x50x10°

Figure 2. Some of the instruments tested

destroyer escort and, using the instruments to be tested, as shown in Figure 1, to record the ranges at which each target could be first glimpsed, then seen continuously, and finally identified. Observations were made by teams of six men on the signal bridge and other three-men teams on the number two gun deck and on the lower deck*. Tests were run in blocks of six runs, during which six instruments were rotated among six men so that each man used a different instrument on each run. This rotation was designed to control variations resulting from differences in the abilities of the observers and in the particular

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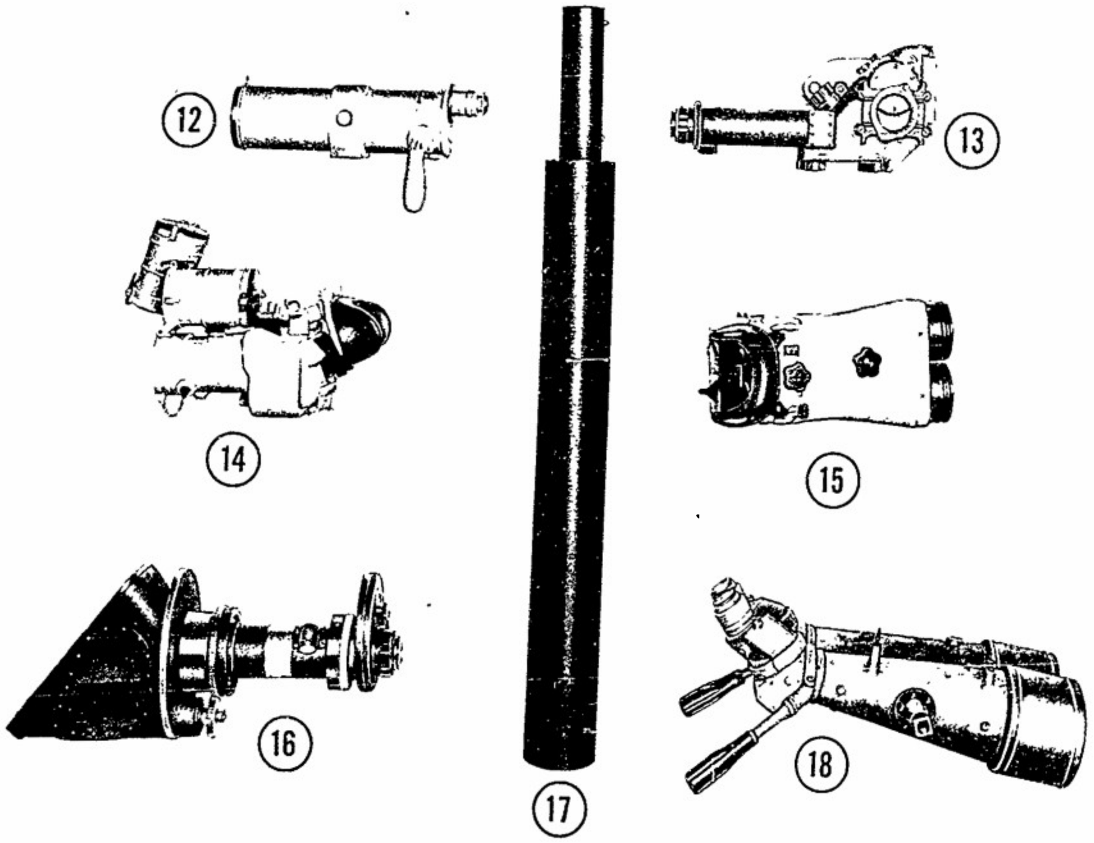
* These three observation positions might more properly be termed respectively, "navigator's bridge","boat deck", and "main deck." Usage differs on this nomenclature.



LEGEND

(12) 21x76x2.8°
(13) 6x30x8.5°
(14) 10x80x7°
(15) 25x100x3.6°
(17) 16 (or 24) x 96x3.2° (or 2.2°)
(16) 6x33x8°
(18) 20x120x3°

Figure 3. More of the test instruments.

conditions of each run. For all tests, at least one of the instruments was a 7x50x7° binocular, held by hand, which was adopted as the standard with which all others were compared. Ranges obtained with this instrument were taken as 100%, and ranges for other instruments are expressed in terms of this 7x50x7° range.

A total of 190 successful runs was made during the three-and-one-half-month period of the experiment. Of these, 177 were at night, and 13 in the daytime. Tests were made on the 18 different instruments shown in Figs. 2 and 3, and some were run on the unaided naked eye. The .50 Relative Range performance (.50RRP) of the instruments, based on the 7x50x7° as 100, is given in Fig.4.

Besides rating the instruments, a number of conclusions of obvious practical value or implication have been drawn from the data and are included in this report. These include quantitative results on the effects of magnification and exit pupil diameter, of the use of mounts, of vibration, and on other special problems.

A secondary objective of the tests--to devise a successful method of field testing--was accomplished, and new statistical methods of handling data obtained in such tests were developed. Proposed tests on aircraft and on sky-scanning procedure were not made because of difficulties in securing the aircraft. Tests of the effectiveness of various color filters for haze penetration were carried out and will be described in a separate report.

STATEMENT OF FINDINGS

The principal conclusions derived from these tests are summarized as follows:

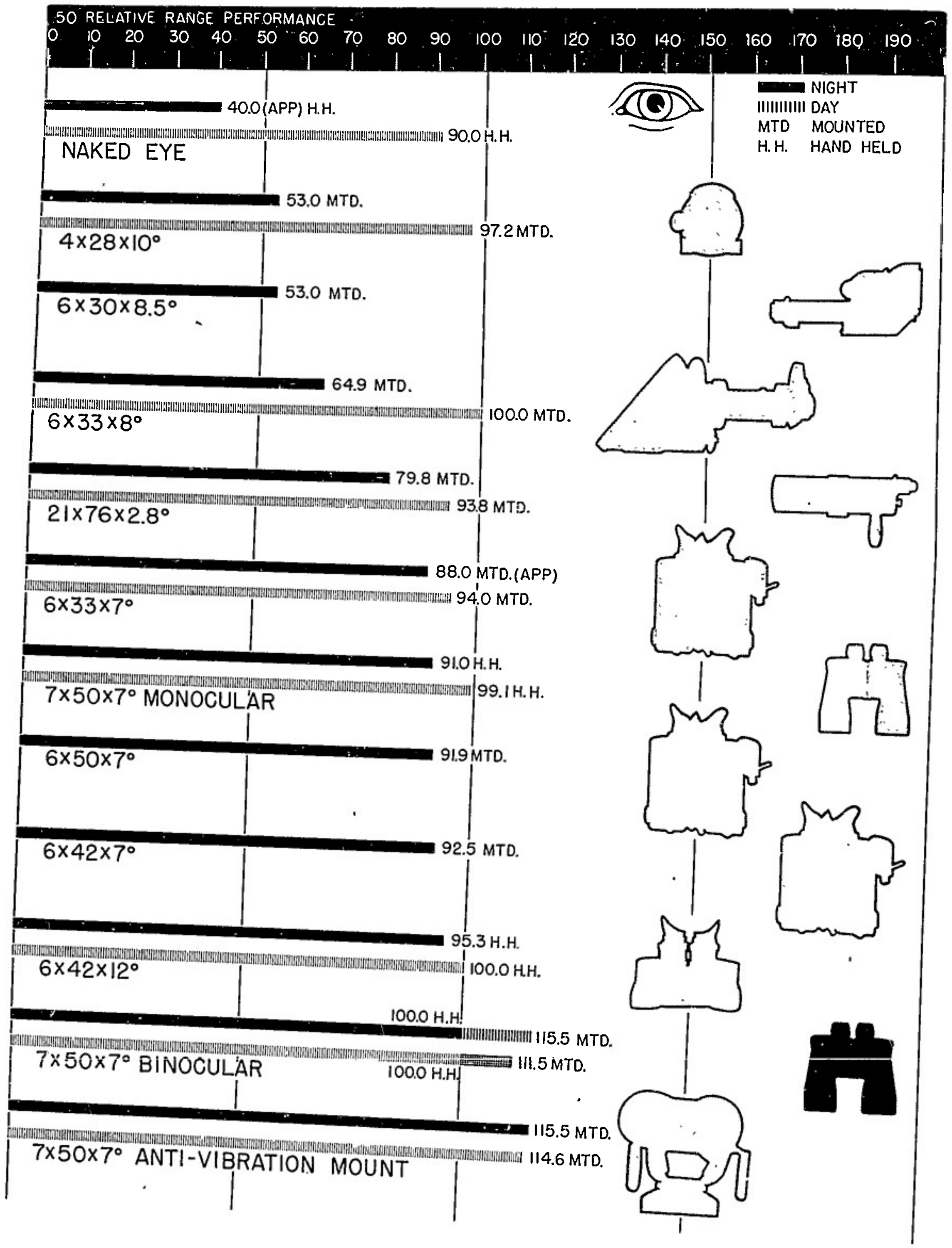
(1) For night use a binocular is to be preferred to a monocular instrument since a binocular increases the visual range by at least 10%. This clear-cut advantage does not obtain by day, when the monocular shows but slightly inferior performance.

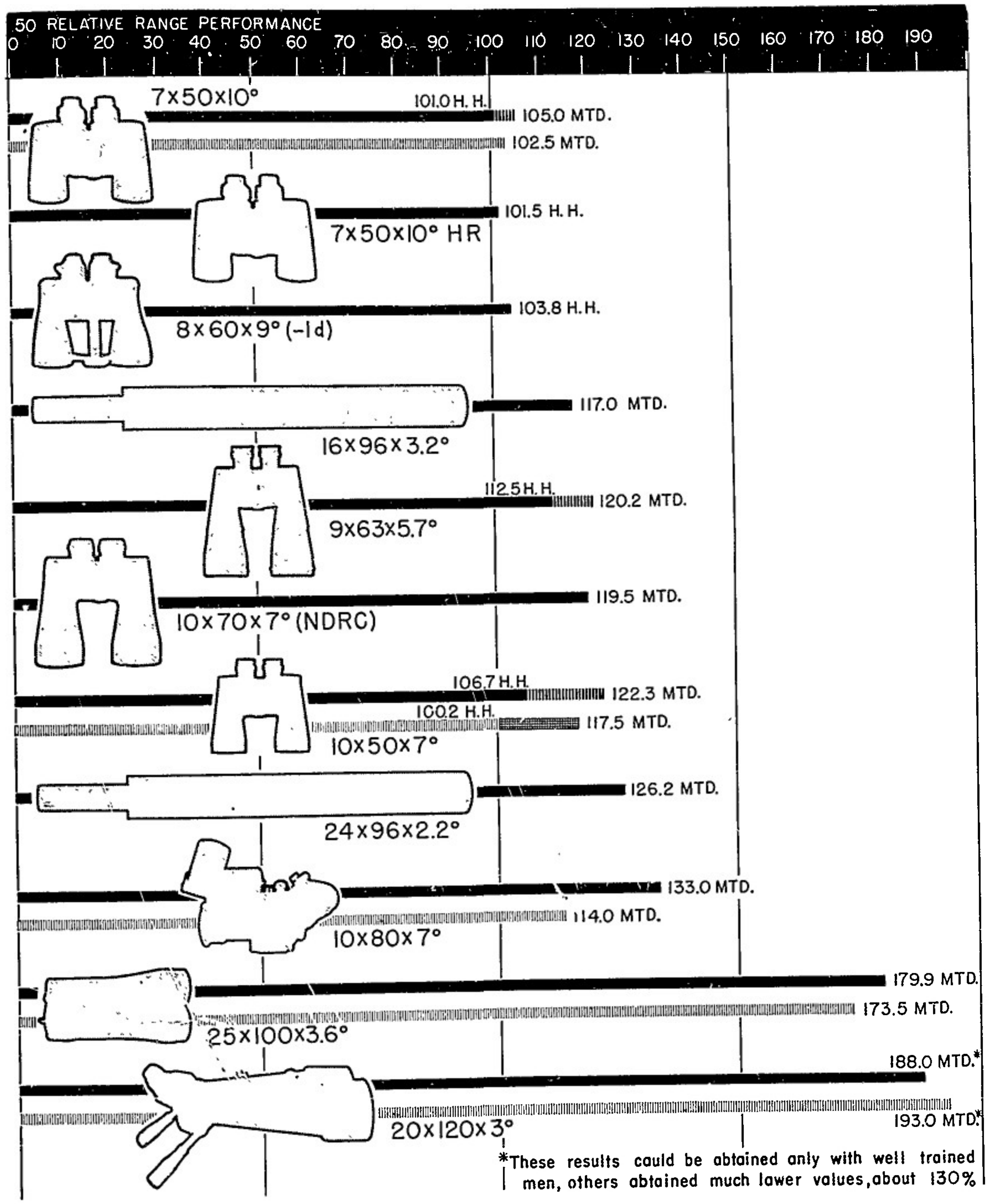
(2) If exit pupil is held constant, increase in range at night occurs, with increase in magnification, up to at least 10-power for a hand-held instrument, and up to at least 20-power for a mounted instrument. By day, 6, 7, and 10-power hand-held binoculars are equally effective, but ranges of mounted instruments increase with magnification up to at least 20 power, as they do by night. Higher power might have shown further increases but suitable instruments were not available for test, e.g., the Japanese 30x180x2.5°.

(3) The best all-around hand-held binocular was the 10x50x7°, which possesses substantial advantages over the 7x50x7°.

The best all-around mounted binocular was the 20x120x3°, which was the most powerful binocular tested, having an ample exit pupil.

(4) The provision of suitable mounts, or of rests for hand-held instruments, will extend the range of any instrument by approximately 10%. Anti-vibration mounts, if they





*These results could be obtained only with well trained men, others obtained much lower values, about 130%

Figure 4. Results of the tests. Relative day and night ranges attained with each instrument. Performance of the standard 7x50x7° binocular, hand-held, is taken as 100

are fully developed, should lead to even more substantial gains, especially by day. It is strongly urged that suitable mounts, or elbow rests, be provided wherever binoculars are employed.

(5) Differences among instruments are most striking in the sighting and identification of targets in known positions at night; in search problems such differences are less marked.

(6) Several phenomena, some unexpected, relative to the use of optical instruments by different observers, and under different conditions of visibility were discovered, and require further research if the most efficient use of optics is to be obtained.

The rating of the instruments tested is summarized in Fig. 4. Supplementary findings are reported and discussed in the text and in Part II of Appendix B.

BASIC INFORMATION

The human eye, with the instruments which modern optical design and engineering provide for it, remains the only detection device which does not betray its presence. For this reason, the development of improved radar equipment has not made optical devices obsolete, but, on the contrary, has created a fresh demand for their improvement, so that they can efficiently supplement the information obtained by electronic means.

This section describes briefly some of the problems of optical design, and discusses the considerations entering into the design of the experimental tests. The section should serve both to clarify the terminology used and to indicate why the experiment took the form it did.

Critical Problems of Optical Design

Optical instruments are designated by three figures: one, the magnification of the instrument; two, the diameter of the objective lens in millimeters; and three, the diameter of the visual field in degrees. Thus, the 6x42x12° binocular magnifies 6 times, has an objective lens 42 millimeters in diameter, and covers a visual field 12° in diameter. The exit pupil diameter may be obtained by dividing the objective-lens diameter by the magnification. Thus, for the 6x42x12°, the exit pupil is $\frac{42}{6}$, or 7 mm. in diameter. The 24x96x2.2 monocular telescope magnifies 24 times, has an exit pupil of $\frac{96}{24}$ or 4 millimeters, and covers only a 2.2° field. Three variables--magnification, exit pupil, and field size--are of great importance in the design of instruments from the point of view of vision and compromises must be made among them.

Magnification is the ratio of the linear dimensions of the image, as seen through the instrument, to the linear dimensions of the object as seen by the naked eye. In general, high power requires a longer instrument or a longer optical path from objective to eyepiece.

Exit pupil is the diameter, in millimeters, of the beam of light leaving the optical instrument, which may enter the pupil of the eye when the instrument is held the proper distance from the eye.* The larger the exit pupil, the wider is this beam of light and the brighter is the image which can fall on the light-sensitive membrane of the eye. By the laws of optics, increase in exit pupil diameter can be obtained only at the expense of decreasing magnification or by increasing the diameter of the objective lens and thus the size of the instrument.

Field size is the diameter, in degrees, of the circular area visible through a given optical instrument. Increase in field size requires larger prisms, thus increasing the size and weight of the instrument, and creates other technical difficulties in the manufacture of the optical system.

Each of these factors plays a large role in determining the effectiveness of an optical instrument in increasing the range at which targets may be seen. Magnification is important for both night and day use. At all times it increases the size of the image on the light-sensitive membranes of the eye, making details visible which would otherwise be too small to be distinguished because of the limiting grain of the eye. Furthermore, the eye is actually more sensitive to large objects than to small, especially at night. Under a given level of night brightness, the eye is better able to detect a large, dim target than a brighter but smaller one. No definitive data have yet appeared from the laboratory on the useful top limit of magnification for either hand-held or mounted instruments. It has been considered that vibration of a vessel and tremor of the observers head and eye would set a sharp limit beyond which further increase in magnification would have no effect.

Exit pupil diameter is a factor which is significant only at night. Since the pupil of the eye itself finally limits the size of the beam which can enter it, a large exit pupil achieves nothing when the eye pupil is contracted, as it is by day. But exit pupil is highly important at night. First, the eye needs the maximum amount of light possible to function most efficiently, and, second, the pupil of the dark-adapted eye is fully expanded, so that a maximum amount of light can enter. Since the average individual's dark-adapted pupil diameter is in the neighborhood of 7 mm., it has been considered that little could be gained by manufacturing optical instruments with exit pupils larger than this figure. However, since many people have larger pupil diameters, and since a large exit pupil prevents losses of light by "clipping," (when it is impossible to keep exit pupil and eye pupil exactly lined up), some have considered that a definite gain might be obtained by further increase in exit pupil diameter beyond 7 mm.

In order to see best at night, a certain minimum area of the eye must be stimulated uniformly. This area is smaller than the magnified field size of all optical instruments used in the service, and from the physiological point of view, all glasses have large enough fields. A larger field does, however, permit more rapid and efficient scanning, and is thus important for search, and for location of targets of known position.

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*This distance is termed "eye relief" or "eye distance."

Each of these three variables--magnification, exit pupil, and field size--should be as large as possible, but an increase in any one of them involves either a sacrifice of one or both of the others, or else an overall increase in size, weight, cost, and difficulty of production. Where the size or weight of an instrument is limited it is necessary to compromise among the three requirements, and to choose the values of each which will meet the weight and size limitations and still yield the greatest visual efficiency.

Other optical properties which enter into design of a lens system are resolving power, light transmission and contrast rendition. Resolving power is the ability of the optical system to measure very small angles. Light transmission is the percentage of incident light which emerges after losses within the optical parts by absorption, and by reflection. Contrast rendition measures the ability of an optical instrument to produce good image contrast at the eye by reduction of those factors which scatter stray light over the image and consequently reduce its visibility. These factors constitute an engineering problem in improved techniques of design and manufacture. Since such improvements do not require increase in size and weight, they do not tend to be mutually exclusive as do increases in magnification, exit pupil and field size.

WHY FIELD TESTS ARE NEEDED

Since the design of binoculars and other optical instruments requires a series of compromises between mutually exclusive qualities, only experiment can prove which compromises give best results. Laboratory tests serve to evaluate these properties separately and have the advantage of being performed under controlled conditions, so that the effect of other factors can be excluded. They do not, however, give much indication of the weight to be given each quality in the ultimate design of equipment for general service. There is no assurance that the controlled laboratory conditions sufficiently reflect the action of all factors encountered in actual use. Field tests, on the other hand, if properly devised, give an overall picture of the performance of optical instruments under the conditions in which they will be employed. If sufficient tests are performed, under a wide range of conditions, the most representative performance of an instrument may be determined and the effect of the various conditions may be derived from the data by statistical methods. When the results of such field tests agree with laboratory results, a check on the soundness of both is provided, and when failure to agree is apparent, new factors which must be further analyzed and studied are revealed.

DESIGN OF THE EXPERIMENT

In the design of the experiment, it was necessary to provide means for measuring and controlling the effect of variable conditions which might otherwise confuse and obscure the results obtained.

There are three main groups of causes which affect the range at which a given target may be seen with an optical instrument. These are:

(a) The quality and design of the instrument used. It is the object of the experiment to measure the effect of these factors.

(b) What is being looked at and under what conditions--that is, the size and brightness of the target, and the effect of varying weather, visibility and brightness of background, and sea and ship conditions.

(c) The ability of the observer, including his eyesight, his skill, and his attention to duty.

Variations in target and conditions were eliminated by testing six instruments on the same target at the same time, and therefore under the same conditions of visibility.

Differences between observers were minimized by using experienced observers and giving them special training in their work before the test started. But the main control in this respect was to rotate the six instruments being tested among the six observers of a team over the six runs. Thus each instrument was used on one run by each member of the team. The schedule of rotating the instruments among the observers over the six runs was based on the six by six Latin square, as explained in Appendix B, and was set up using random numbers, to avoid any systematic effects. Comparable three by three schedules permitted comparison of three instruments in three runs by three men.

In so far as conditions for the tests permitted, a standardized procedure was set up and followed. Thus, the runs were made on set courses, and at constant speed (except where tests for the effect of vibration were made), and the night runs were confined to moonless nights, when sky brightness is remarkably constant. As far as was possible, uniform targets were used throughout the tests.

By expressing results in terms of the standard 7x50x7° instrument, a common baseline is established so that comparisons can be made between instruments tested on different sets of runs.

CRITERIA OF SEEING

In order to establish when each observer sighted the targets so that consistent results could be obtained, observers were trained to report sighting each target to each of three "criteria of seeing." These are as follows:

(a) First glimpse (G)-- when he could just see the target for an instant, only to have it fade out of sight.

(b) 100% frequency (100)-- when he could see the target continuously in its correct position, but only as a blur or blob.

(c) Positive identification (PI)-- when he could positively recognize the particular target by its peculiarities of size, shape, or position.

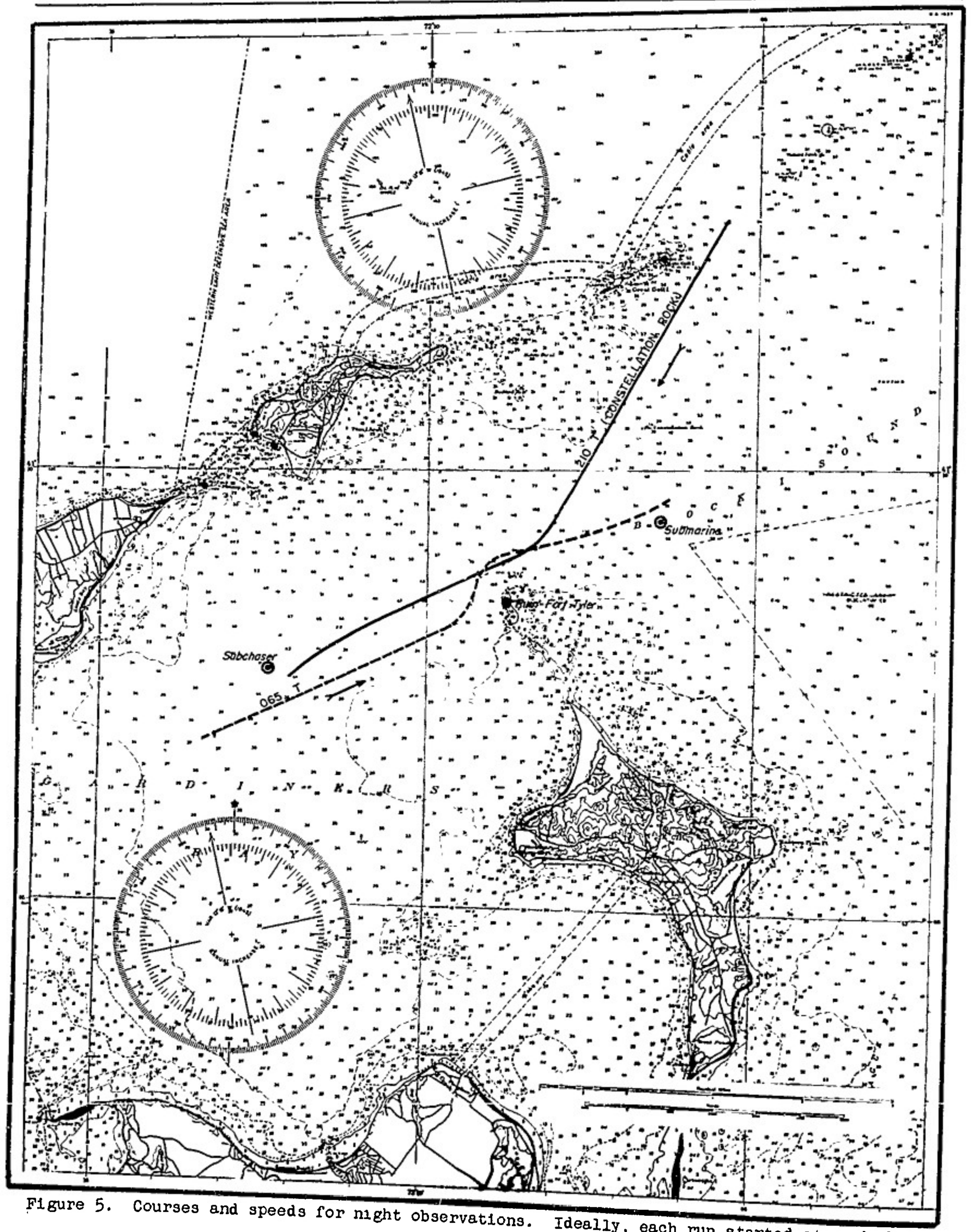


Figure 5. Courses and speeds for night observations. Ideally, each run started at such distance that the target was out of sight

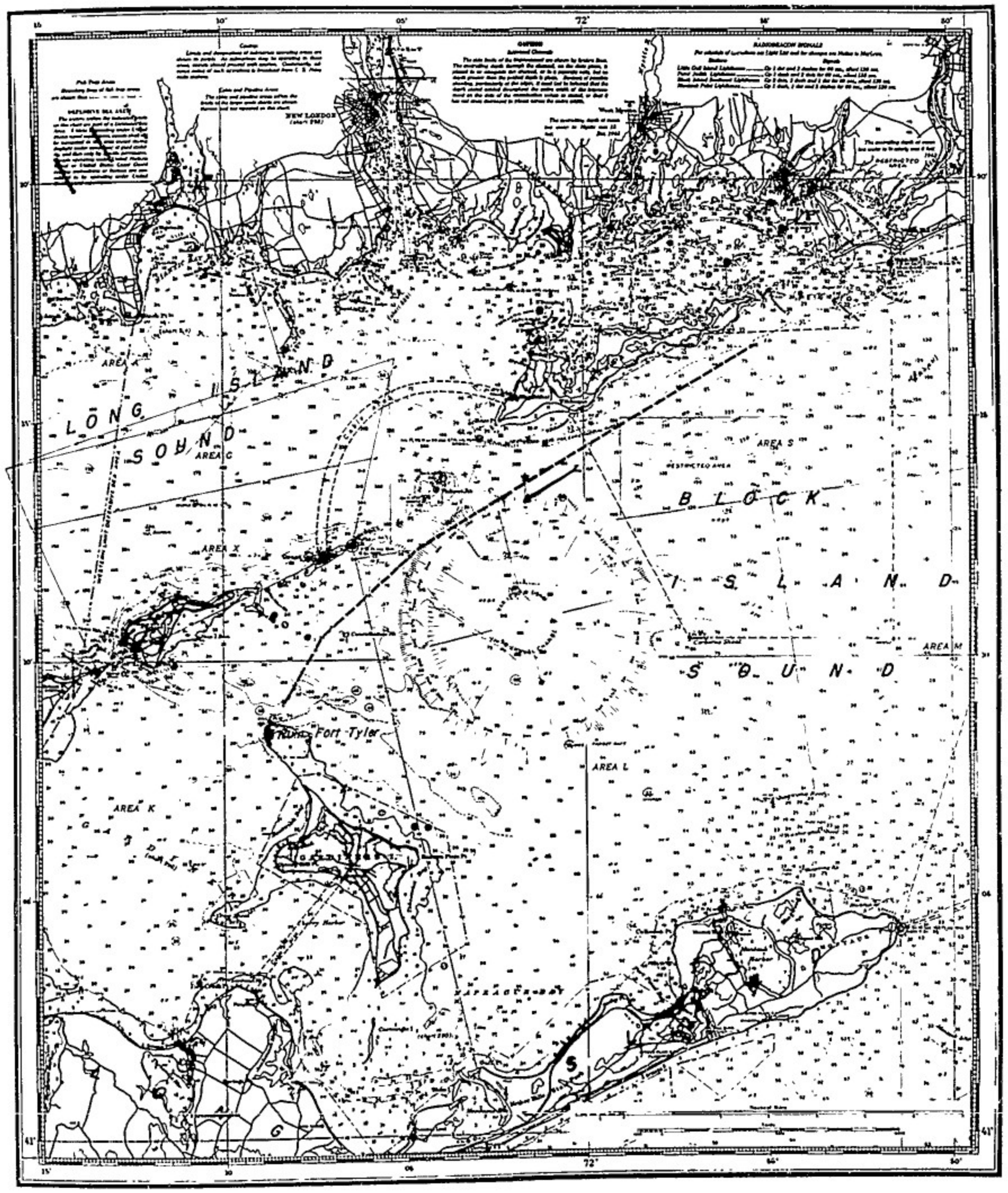


Figure 6. Courses and speeds for day observations. Fort Tyler is in Gardiners Bay, at the eastern end of Long Island

FACILITIES AND PERSONNEL

Area of Test

All runs were made in Gardiner's Bay, in the waters at the eastern end of Long Island. This area provided about 90° of land-sea horizon and an equal amount of sky-sea horizon reasonably free from lights. The lights of the other 180° were neither numerous nor bright enough to interfere. After V-J Day, more lights appeared, but not in sufficient strength to cause serious interference. The general area is shown on the chart, Fig. 6, which also shows the location of Fort Tyler, a ruined structure that served as a target itself, and as the site for other stationary targets. Visibility in this area during the night experiments covered a wide range, from 3,000 yards to "unlimited visibility" on certain very clear nights. The day observations were made under less variable conditions of visibility, the visual range being in the neighborhood of 8 - 9 miles, due to haze and atmospheric refraction. Sea conditions were disappointing, as there were only two days when there was any appreciable roll or pitch of the observing vessel.

Courses

The night courses are shown on Fig. 5. One course approaches the fort from the southwest (065 T); the other from the northeast (210 T). The first course was later changed from 055 T, which was first used, to 065 T because of the appearance of a distant light in line with the 055 course. A complete circuit of the courses included two approaches to the fort, one with a land and one with a sea background, and of one approach to each of two search targets: a surfaced fleet-type submarine and a subchaser. These craft were not always available throughout the test period. Fig. 6 shows the day course, which is essentially an extension of course 210 T.

Runs were planned to start at such a distance from the fort that it could not be seen by the most powerful glass, and to continue to a point as close as considerations of ship-handling permitted. On some clear nights, the ship was turned toward the fort at too short a range, and, rather than lose the time required to turn back, the run was continued. In thick weather, it was not considered safe to approach the fort as close as on clear nights, and all targets were not seen. Such runs, however, gave data on intermediate targets and also estimates of the maximum and minimum ranges of the targets affected.

Night approaches to the fort were made uniformly at a speed of 9 knots, except for vibration tests at 17 knots. The rest of the course was run at 12 knots to save time, since the vibration at this speed was not appreciably greater than at 9 knots. Day runs were made uniformly at 12 knots.

Targets

The ruins of Fort Tyler itself served as one of the targets, and other, artificial targets were mounted on its walls, as shown in Fig. 7. The largest was a radar screen erected by the army for range calibration, which consisted of wire fencing supported by a wooden frame, and painted orange. Viewed from course 210 T, it was 16 feet square; from course 65 T, its apparent width shrank to 13 feet. Other targets consisted of cylindrical frames covered with canvas, which presented the same appearance from any aspect. These various cylinders were 8 feet, 6 feet, and 4 feet in diameter, with height equal to diameter, and with the tops about 12 feet above the top of the fort. The "flagpole" target was two feet in diameter by 15 feet high, with a six-inch-by-eight-foot extension on the top. Besides the cylinders, two white eight-foot canvas-covered squares were used; one of these faced the approaching vessel on each course.

The targets were selected on the basis of trial runs, and the sizes adopted were found to become visible at night successively from a range of 6,000 yards down to 1,500 yards. Some of the targets were of high contrast, others of low, so that the effect of contrast on range could be studied.

For the day runs, additional targets containing stripes, either vertical or horizontal, were added. Complete details of all the targets will be found in Appendix B.

It proved unexpectedly difficult to keep the targets in operating condition. Nearly all the targets were damaged by wind and had to be rebuilt at one time or another, so that all targets were not available for all the runs.

Besides Fort Tyler and the targets on it, two vessels were used at night for

Figure 7. Unretouched photo of fort and targets, using a telescopic lens at a range of 1,150 yards. This is how it appeared through the instruments at the end of the run. Figures of men on the fort indicate the scale

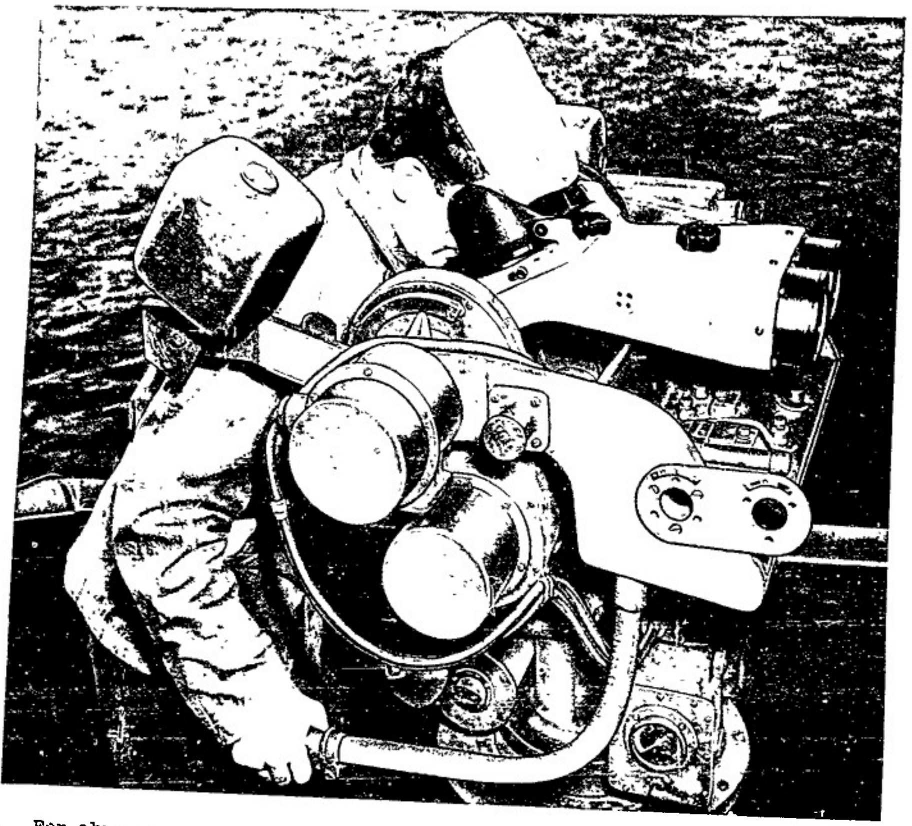


Figure 8. For observers with mounted binoculars, a Director Mount Mk 51 with a special adaptor to hold the binoculars was used. This is the 25x100x3.6° binocular

search. One of these was a fleet-type camouflaged submarine, which was stationed at the position shown on Fig. 5, heading north and south. The other search target was a submarine chaser (SC) which lay hove to at the position shown on the same chart.

Observation Vessel

The observation vessel was the U.S.S. ROBERT E. PEARY, DE 132. A DE was chosen because it was representative of combatant naval vessels, large enough to accommodate the observers, small enough for the maneuvers required and because it carried the radar and other equipment necessary for accurate range determination.

Night observations were made from the signal bridge and the number two gun deck, and by day the number one gun deck, or lower deck, was also used. In order to accommodate the six observers on the signal bridge, the port and starboard 24-inch searchlights and two 20-mm. mounts were removed. Six Mark 51 director mounts were installed, four, spaced evenly across the bridge and one on each searchlight platform. Adaptors were constructed so that the various instruments could be held properly in the director mounts. Fig. 8 shows the 25x100x3.6° binocular mounted in such an adaptor. Provision was made on all three levels for mounting a BuShips Mark 5 Alidade and an anti-vibration alidade mount developed under NDRC contract. The ship, with the mounts in place, and posts manned, is shown in Fig. 9. For observation with hand-held instruments, the men were lined up at the forward rail of the signal bridge at about five-foot intervals. Positions were numbered 1 to 6, from port to starboard. The three positions on the gun deck were numbered 7, 8 and 9, and the three on the lower deck (used only in the day runs) were numbered 10, 11 and 12. Height of eye for the signal bridge was about 32 feet, putting the observer on a level with

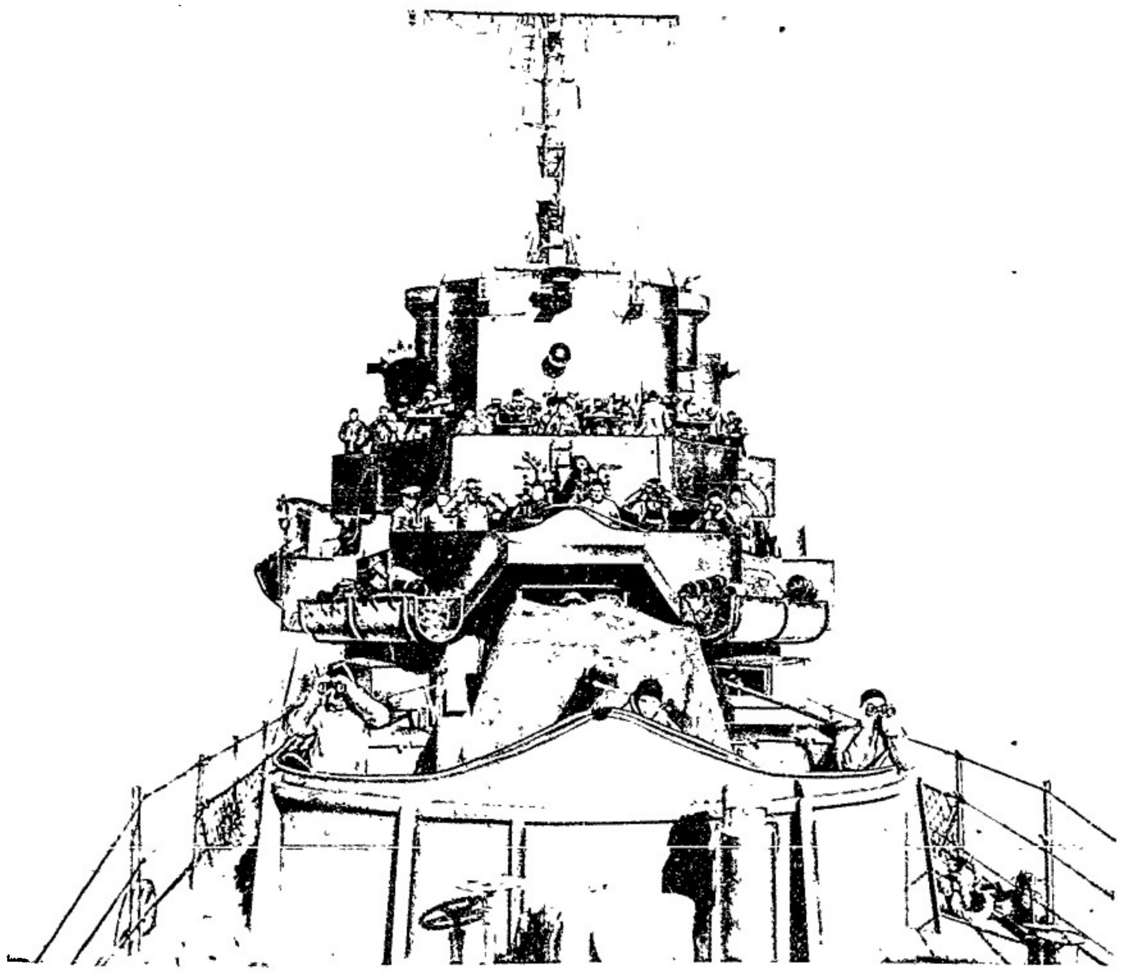


Figure 9. All eyes ahead. Six men on the signal bridge and three on each gun deck making simultaneous observations

the top of the fort.

Personnel

The personnel required for the experiment was considerable. Because of the preponderance of night observations and the desirability of using every night suitable for observation, it was found advantageous to have duplicate crews of observers and other operating personnel to work alternately. Personnel consisted of the shore staff which had general supervision and direction of the experiment, and the operational staff, on board the DE. The duties of the shore staff included the scheduling of the various runs, planning the tests to be made and analyzing the results obtained as a guide to further testing. Separate crews of men were employed for handling and maintenance of the targets. An operational crew consisted of an officer responsible for the operation, an officer supervisor, a CPO supervisor, a quartermaster to keep necessary records and to check data, a talker, to call out time intervals; and the observers and recorders at the instruments.

A total of 64 enlisted men served as observers during the experiment. Of these, 15, all experienced quartermasters, signalmen or men of other deck ratings from the surface fleet, received extensive training before the start of the observations. This included lookout training, special training on the use of binoculars at night, and observations on a scale model of the fort and targets in dim light. They were fully instructed on the three criteria of seeing used in the experiment and in the general purpose of the experiment. They knew that it was the binoculars, and not themselves, that were being tested. With the termination of the war, many of the original group were demobilized, and it was possible to keep only one such trained six-man team throughout the entire experiment. The others were replaced with submarine men awaiting discharge, almost all of whom had had lookout training, or had served as lookout, but it was not possible to give them as thorough training on the experiment as the original group. After V-J Day, many of the short-time men had little interest in the work, and had to be handled carefully to ensure that results would not be spoiled by inattention or carelessness. A group of officer-observers were tried, but were unable to adapt themselves to the rigid routine required, and were not utilized after four runs. A number of scientists and other technical personnel from laboratories working on night vision or binoculars were also used as observers. They received an intermediate amount of training and their results show some evidence of the lack of practical experience in handling binoculars at night.

Almost without exception, the subjects received a visual examination.

TEST PROCEDURE

Scheduling of Tests

Because of the requirements of the tests for moonless nights, the necessity of training runs, and the occurrence of unforeseen difficulties, night operations were limited to six nights in September, seven in October, eight in November and two in December. Consequently, careful scheduling to make the best use of the available nights was required. Day runs were more easily scheduled. Full details of scheduling problems and operational dates are given in Appendix B.

Since the plan of the experiment required a set of six runs by six observers or three runs by three observers, the observers were divided into six-man and three-man teams. Continuous observation by the same team proved too fatiguing, so that two six-man and two three-man teams were taken out each night, and made their observations alternately. The men of the idle team served as recorders and the same recorder was always paired with the same observer. This alternation had the advantage of tending to put all the runs of one set on the same course, either 65 T or 210 T. However, because of it, it was not possible to run the complete test of a set of six instruments on any one night, and the set had to be completed on the next operating night.

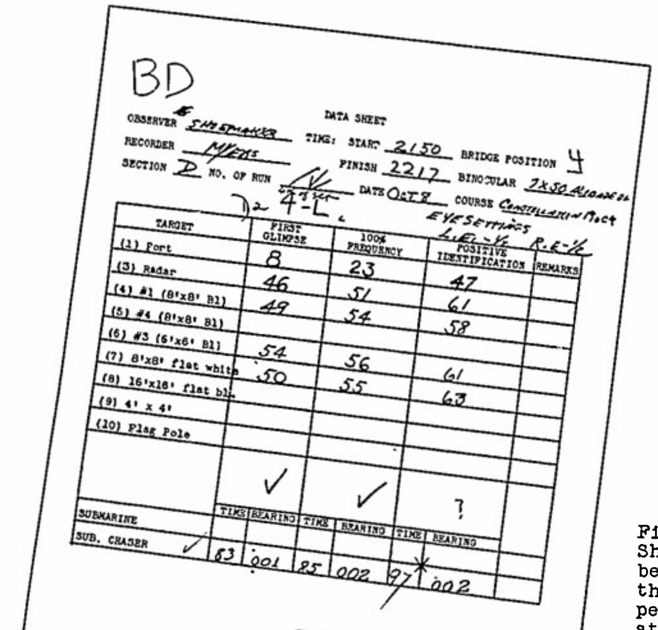
After the schedule for a night's runs was drawn up, cards were prepared for each observer, listing the runs he would make, the stations and instruments he would use and other pertinent data. A master schedule was also made up for the use of the supervisors.

Running the Test

At ten minutes and again at five minutes before the beginning of a run, warnings were delivered over the loudspeaker system, which enabled the observers to check their cards, take their stations, and clean and focus the instruments. During this preliminary interval, the recorders filled out the headings on the data sheet and the supervisor checked to see that all observers were at their proper stations.

The beginning of the run was announced over the loudspeaker, together with the time, date, course and number of the run. At fifteen-second intervals thereafter, the mark number was announced, this being the number of fifteen-second intervals since the beginning of the run. On alternate mark numbers the range to the targets was measured by radar and recorded on a range sheet. Radar ranges were checked against a plot of the course made by the Dead-Reckoning Tracer, on which the mark numbers were also recorded. As each target came into view, the observer reported it to his recorder, who entered the last mark number announced in the appropriate space of the data sheet, Fig. 10.

After completion of the run, the ob-



BD

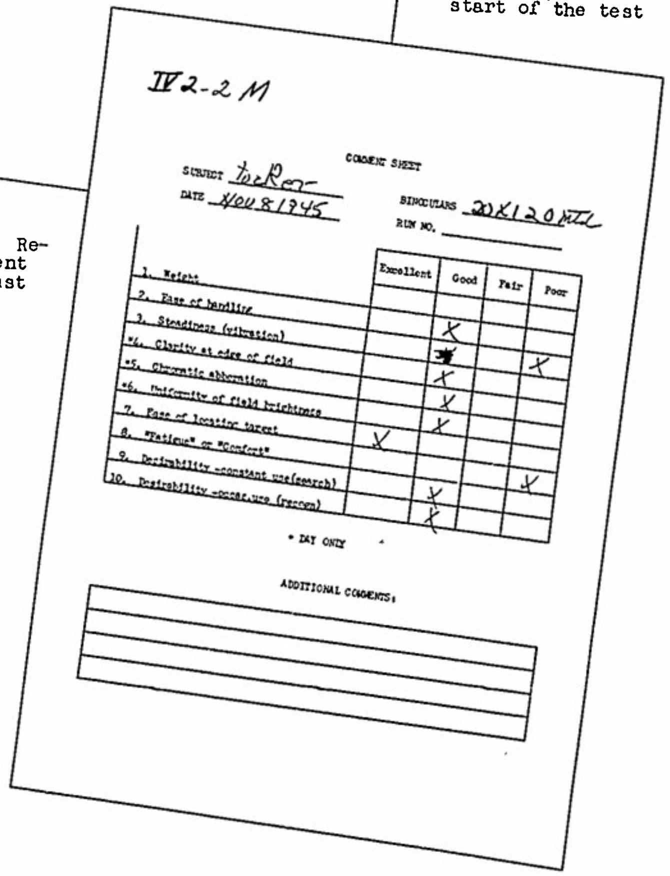
DATA SHEET

OBSERVER Shoemaker TIME: START 2150 BRIDGE POSITION 4
RECORDER Myers FINISH 2217 BINOCULAR 7x50 Aldoro?
SECTION D NO. OF RUN IV 2-4-L DATE Oct 8 COURSE Constellation Rock
EYE SETTINGS L.E. -½ R.E. -½

TARGET	FIRST GLIMPSE	100% FREQUENCY	POSITIVE IDENTIFICATION	REMARKS
(1) Fort	8	23	47	
(3) Radar	46	51	61	
(4) #1 (8'x8' Bl)	49	54	58	
(5) #4 (8'x8' Bl)				
(6) #3 (6'x6' Bl)	54	56		
(7) 8'x8' flat white	50	55	61	
(8) 16'x16' flat bl.			63	
(9) 4' x 4'				
(10) Flag Pole				
	✓	✓	?	

	TIME	BEARING	TIME	BEARING	TIME	BEARING
SUBMARINE						
SUB. CHASER ✓	83	001	85	002	97	002

Figure 10. Observer's Data Sheet. Figures show mark numbers. Shoemaker first glimpsed the Fort eight fifteen-second periods (two minutes) after the start of the test



IV 2-2 M

COMMENT SHEET

SUBJECT Tucker
DATE Nov 8 1945
BINOCULARS 20X120 MTL
RUN NO.

	Excellent	Good	Fair	Poor
1. Weight				
2. Ease of handling				
3. Steadiness (vibration)		X		
*4. Clarity at edge of field		X		X
*5. Chromatic abberation		X		
*6. Uniformity of field brightness		X		
7. Ease of locating target		X		
8. "Fatigue" or "Comfort"	X			
9. Desirability -constant use(search)		X		X
10. Desirability -occas.use (recon)		X		

* DAY ONLY

ADDITIONAL COMMENTS:

Figure 11. Comment Sheet. Records the observer's judgment of the instrument he has just been using

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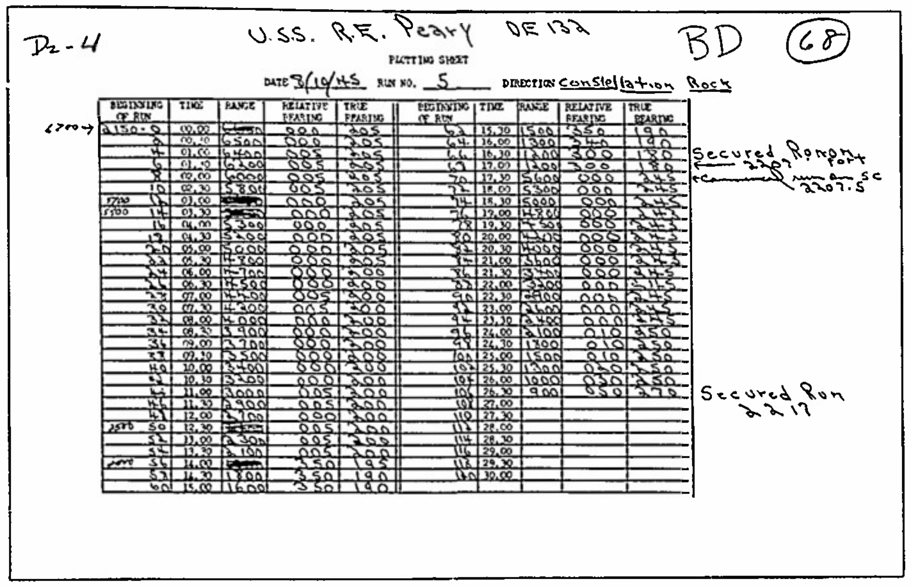


D2-4 U.S.S. R.E. Peary DE 132 BD (68)

PLOTTING SHEET

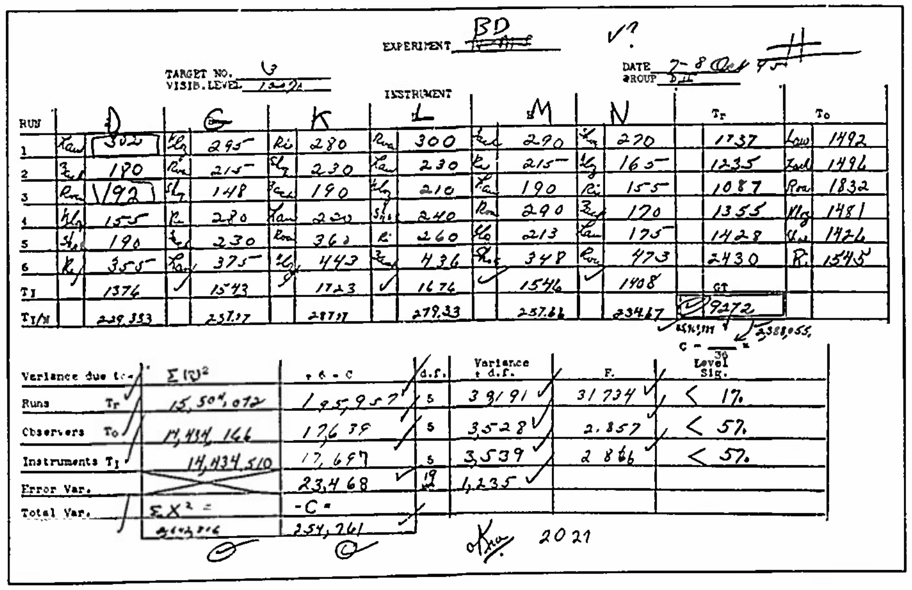
DATE 3/10/45 RUN NO. 5 DIRECTION Constellation Rock

BEGINNING OF RUN	TIME	RANGE	RELATIVE BEARING	TRUE BEARING	BEGINNING OF RUN	TIME	RANGE	RELATIVE BEARING	TRUE BEARING
2700→ 2150-0	00.00	[illegible]	000	205	62	15.30	1500	350	190
2	00.30	6500	000	205	64	16.00	1300	340	190
4	01.00	6400	005	205	66	16.30	1200	300	180
6	01.30	6200	005	205	68	17.00	1200	300	180
8	02.00	6000	005	205	70	17.30	5600	000	245
10	02.30	5800	005	205	72	18.00	5300	000	245
5700 12	03.00	[illegible]	000	205	74	18.30	5000	000	245
5500 14	03.30	[illegible]	000	205	76	19.00	4800	000	245
16	04.00	5300	000	205	78	19.30	4500	000	245
18	04.30	5400	000	205	80	20.00	4200	000	245
20	05.00	5000	000	205	82	20.30	4000	000	245
22	05.30	4800	000	205	84	21.00	3600	000	245
24	06.00	4700	000	200	86	21.30	3400	000	245
26	06.30	4500	000	200	88	22.00	3200	000	245
28	07.00	4400	005	200	90	22.30	2900	000	245
30	07.30	4200	005	200	92	23.00	2600	000	245
32	08.00	4000	000	200	94	23.30	2400	000	245
34	08.30	3900	000	200	96	24.00	2100	010	250
36	09.00	3700	000	200	98	24.30	1800	010	250
38	09.30	3500	000	200	100	25.00	1500	010	250
40	10.00	3400	000	200	102	25.30	1300	020	250
42	10.30	3200	000	200	104	26.00	1000	030	250
44	11.00	3000	005	200	106	26.30	900	050	270
46	11.30	2900	005	200	108	27.00			
48	12.00	2700	000	200	110	27.30			
2500 50	12.30	[illegible]	005	200	112	28.00			
52	13.00	2300	005	200	114	28.30			
54	13.30	2100	005	200	116	29.00			
2000 56	14.00	[illegible]	350	195	118	29.30			
58	14.30	1800	350	190	120	30.00			
60	15.00	1600	350	190					

Secured Ron on port 2207
commenced run on SC 2207.5

Secured Ron 2217

Figure 12. Plotting Sheet, or Range Sheet, is a record of the bearings and ranges to the targets. Mark number 8, in this case, corresponds to 6,000 yards from the fort.



EXPERIMENT BD ✓?

TARGET NO. 3
VISIB. LEVEL 100%

DATE 7-8 Oct 45
GROUP D II

INSTRUMENT

RUN		D		G		K		L		M		N	Tr		To
1	Kau	302	Klg	295	Ri	280	Rou	300	Zel	290	Sh	270	1737	Low	1492
2	Zel	190	Rou	215	Klg	230	Kau	230	Ri	215	Klg	165	1235	Zel	1496
3	Rou	192	Klg	148	Kau	190	Klg	210	Kau	190	Ri	155	1087	Rou	1832
4	Klg	155	R	280	Kau	200	Sh	240	Rou	290	Zel	170	1355	Klg	1481
5	Sh	190	Zel	230	Rou	360	Ri	260	Klg	213	Kau	175	1428	Sh	1426
6	Ri	355	Kau	375	Klg	443	Zel	436	Sh	348	Rou	473	2430	R	1545
TI	✓	1374	✓	1543	✓	1723	✓	1674	✓	1546	✓	1408	GT		
TI/N		229.333		257.17		287.17		279.33		257.66		234.67	9272		

1545,111 2388,055

C = ——— /36 =

Variance due to	Σ(T)²	÷ 6 - C	d.f.	Variance ÷ d.f.	F.	Level Sig.
Runs Tr	15,504,072	195,957	5	39191	31734	< 1%
Observers To	14,434,166	17,639	5	3528	2.857	< 5%
Instruments TI	14,434,510	17,697	5	3539	2 866	< 5%
Error Var.		23,468	19	1,235		
Total Var.	ΣX² = [illegible]	-C = 254,761				

2021

Figure 13. This Summary Data Sheet shows, for all observers and instruments in a set of six runs, the ranges at which Target 3 (radar screen) wwas continuously seen (100% seeing). Computations for this set are performed on the bottom of the sheet.

server filled in the comment sheet, Fig. 11, giving his ratings of the instrument he had just used. Data sheets for the run were then collected and checked to see that none were missing and that the headings were complete and legible. A run-by-run log was kept by the quartermaster of all pertinent data and a weather sheet was filled out for every three runs, or whenever the weather changed.

The actual runs averaged from 35 to 50 minutes in length with a 15-minute interval during which the DE maneuvered into position for the next run.

Observers were cautioned to make their reports in a low tone of voice, so that they would not influence the reports of the observers on either side. This rule was enforced by the supervisors and evidence indicates that such influence as may have occurred was insufficient to affect the results.

The recorder paired with each observer also served as prompter, reminding the observer which criterion he had reported, and on which targets, and what targets he might be expected to report soon. It was found that without this prompting, some observers would forget to report things they obviously had seen--i.e., they might omit positive identification of an easy target even after a smaller target had been identified.

Data Sheets

The data sheet filled out by the recorder is shown in Fig. 10, and the comment sheet in Fig.11. Figure 12 shows the range sheet filled in by the radar operator, giving the ranges for every other mark number and showing corrections made by the DRT. One such sheet was filled out for each run. These data were then summarized on the data sheet shown in Fig. 13, which covers the sighting of one target to one criterion on a set of six runs. The instruments are identified by the capital letters at the head of each column. In the column is the name of the observer and the range in yards at which he reported on each run. On the last line is the average range of all six observers. This data sheet is made out for target No. 3, the radar screen, for a criterion of seeing of 100%. Similar sheets were made out for the other two criteria and for each of the other targets. It is thus evident that a single block of six runs yielded a considerable amount of data on the instruments tested.

TREATMENT OF DATA AND RELIABILITY OF RESULTS

Procedures

The first step in the treatment of the data was performed on the data sheet, Fig. 13. The ranges were averaged by instruments, (line marked $\frac{T_I}{N}$); by runs (next to last column); and by observers (last column). On the lower half of the sheet, certain operations, described in the appendix, were performed which measure the probability that the differences among runs, instruments, and observers, are not the result of chance.

The next step was to express the mean range for each instrument as a percentage of the mean range of the 7x50x7° hand-held binocular, yielding the Relative Range Performance of the instrument for one set of runs. The results for all targets and all sets in which the instrument was used were then summated. The statistical procedure followed is treated in full in Appendix B.

In the combined results, the mean 7x50x7° range is taken as the base. The most representative measure of the performance of any other instrument is the .50 RRP, which is the percentage of the mean 7x50x7° range which will be equalled or exceeded by that instrument 50% of the time*. The .50RRP of the 7x50x7° binocular is, of course, 100.0. The full relative range performance curves for each instrument give more information on the instrument's performance: they give the probability that the instrument will give performances equalling or exceeding <u>any</u> percentage of the mean 7x50x7°range. Such curves may show, for example, that there is one chance in ten that the instrument X will give ranges thirty percent greater than the standard, as compared with one chance in ten that the instrument Z will give ranges only ten percent greater, even when their .50 RRP's are identical in value. The Relative Range Performance Curves obtained on each instrument on each set are given in Appendix A.

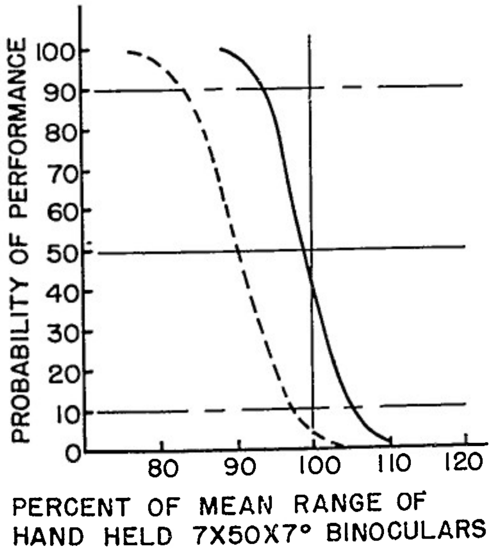


Figure 14. Probability graph, showing the Relative Range Performance of a hand-held 7x50x7° monocular. Solid line indicates day, and dotted line night tests.

Figure 14 is a typical graph. It shows that, in a series of day observations with the 7x50x7° monocular, 50% of the ranges will be 98% or more of the mean ranges obtained with the standard 7x50x7° hand-held binocular, that 10% of the ranges will be 105% or more of the standard, and 90% will be at least 95%. Similarly, the dotted line for night observations shows the 50% value to be 90% of the standard, the 10% value about 97% of the standard, and that 9 out of 10 observations will yield ranges at least 85% of those from the standard instrument. Thus the curves express the performance in terms of the frequency with which such performance will be exceeded.

Tests for Reliability of Results:

A number of tests were made of the data obtained, designed to check its general reliability. They are fully described in the appendix, and will only be briefly mentioned here.

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* Literally the percentage of the mean 7x50x7° range which has five chances in ten of being equalled or exceeded by the mean performance of the instrument compared. Practically this means the same thing.

Analysis of Criteria of Seeing: The ratio between the ranges at which first glimpse, 100%, and positive identification occurred were computed for all the tests, to check how definite these concepts were, and how consistent the men were in applying them. Between "First Glimpse" and "100%" the ratio was quite uniform for all the men, and for the same man from time to time. The ratio between "First Glimpse" and "Positive Identification" was more variable between men, although it was very consistent for any one man. These results indicate that the criteria of seeing provided a definite and reliable basis for reporting and that they were well-adapted to the purpose of the test.

Effect of Variability of Standard Binoculars: Since so much of the data depended on the 7x50x7° binocular, tests were run on several samples of this instrument, which optical tests showed to be nearly identical, to see how uniform the results obtained would be. The results showed that the worst single performance fell about 8½% below the average of the group, the best about 15% above it. This variability in performance (which will appear in the performance of both the standard and the instrument being tested) indicates the error which may appear in the results of a single test of an instrument. For this reason, it is necessary to combine as many tests as possible to obtain a reliable Relative Range Performance.

Interaction Between Binocular and Observer: The hypothesis that certain observers might perform better with one instrument while others might do better with different instruments was tested and verified. It was found that no one type of instrument was best for all observers; some men perform better on one instrument; others on a different one. For some individuals, this effect was large, and for this reason, it is necessary, in making tests of optical instruments, to employ a large number of observers so that the average performance of the instruments will not be thrown off by such interaction. Since this interaction occurs, it is highly important to determine its causes, and to develop means of selecting the right equipment for each man, or of selecting men who are adapted to most efficient use of the equipment available.

Effect of Position on Ship

For night observations, the ranges obtained by observers on the gun deck averaged approximately 18% less than those taken on the signal bridge. By day, there was no appreciable difference. Observation from the lower deck was poor on some days due to wind and spray. A comparison of the results from the six stations on the bridge showed little difference except for station 6, which seems to yield poorer results. A full discussion of this problem is found in Appendix B.

The general result of these investigations of the reliability of the data was to underline the need for using large numbers of observers, instruments and sets of runs, as was originally planned. Results from a few runs on a few instruments might be considerably in error because of sampling errors and interaction of instrument and observer.

TEST RESULTS

The results summarized here are explained in full detail in the appendices, together with tabular and graphical presentation of the data. One conclusion stands out -- namely, that the field tests performed have proven themselves a valuable tool to supplement, to confirm, and, in some cases, to disprove, laboratory findings. Such practical evaluation of the performance of the instruments may serve to place the whole procedure of optical design on a sounder and more practical basis.

Comparison of Instruments:

Utility of Optical Equipment: A number of tests using the unaided("naked") eye as one of the "instruments" showed that at night the ranges obtained with the standard 7x50x7° binocular were about 250% those for the naked eye. In day observations, the binocular advantage was 122%. The night value checks very closely with those of other field tests on sighting naval vessels, but are lower than might be expected from laboratory tests, some of which report a 7x50x7° binocular advantage as high as 6. The most reliable comparable laboratory data yield an advantage of 4.1 compared with the 2.5 obtained in the field.

The Advantage of a Binocular over a Monocular: By night the ranges obtained with a monocular averaged 91% of the range of a binocular of the same optical properties; by day, about 99%. The less the illumination, the greater is the advantage gained from the use of binocular vision. Thus, binoculars are decidedly preferable to monoculars by night, not only for their increased range, but because of their greater comfort, acceptability and ease of use. The quantitative findings of this field experiment are in close accord with both theoretical predictions and with laboratory findings.

Hand-Held Binoculars: Tests were run on a series of binoculars held in the hands without support for body or elbows, ranging from the 6x42x12° to the 10x50x7° in power and to the 9x63x5.7° in size. The 10x50x7° was the best of this group for night use, yielding .50 RRP's of 106.7 on the signal bridge and 117 on the gun deck* as compared with the RRP of 94 of the 6x42x12°. Considerations of size and weight sharply limit the exit pupil and magnification which can be combined in one instrument designed for hand-held use. No substantial difference appeared among any of these instruments in the daylight series of tests; all were equivalent.

Mounted Binoculars: A series of tests was run on mounted binoculars ranging from the 6x42x12° up to the 25x100x3.6°. These instruments were rigidly mounted in the director mounts or Mk. 5 alidades. The Relative Range Performance values ranged from 91.9 for the 6x50x7° up to 188 for the

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* No reason has yet been adduced for this discrepancy in findings. Stack gases have been suggested as a possible reason, but these were never noticeable.

20x120x3°, which excelled the 25x100x3.6°, with its smaller exit pupil and larger field. The mounted 7x50x7° instrument had a .50 RRP of 115.5, which indicates the advantage secured by mounting an instrument. The 50 RRP results obtained on these same instruments by day corresponded closely with those obtained at night.

Mounted Monoculars: A similar series of tests was performed on monoculars ranging from a 4x28x10° gunsight up to a 24x96x2.2° telescope. The gunsight performance was 53, a little better than the naked eye at 40. Up to six-power, the mounted monocular performance was less than 100. The 24x96x2.2° telescope gave a .50 RRP of 126.2, the best performance in this group. The day tests were less extensive and showed the low-power instruments performing relatively better and closer to the standard 7x50x7°.

Search Results:

Successful runs on the search targets at night were much less numerous than on the fort, due to the occasional absence of these vessels from their station, so the data are less extensive, and could not be treated as fully. Results are sufficiently complete to show that ranking of the instruments is the same for search as for the detection and identification of targets in known locations, but that the differences between instruments are much reduced; all tend to have about the same performance. Data were not sufficiently complete to permit, as yet, evaluation of the role of field size in these results. It is anticipated that further statistical analysis of the data may throw some light on this problem.

Summary of Effects of Design Factors: By analysis of the results presented, it becomes possible to evaluate the effect of such factors as magnification, exit pupil, and mounts on the performance of the instruments.

Magnification: By selecting a series of instruments of increasing magnification, but having nearly the same exit pupil it was possible to develop curves for night and day showing the relation of magnification to the Relative Range Performance of an instrument. These show that .50 RRP, in general, increases directly with magnification up to the upper limit of the instruments in the test -- 25-power. This result is not in accordance with laboratory findings, which indicate a much lower power as the upper limit of useful magnification.

Exit Pupil: A similar curve could not be developed to show the relation of the diameter of the exit pupil to RRP for night use. There is evidence, however, of an improvement in performance as the exit pupil is increased from 5 through 8 millimeters. Since this latter size is somewhat greater than the average diameter of the pupil of the dark adapted eye, it is doubtful if greater exit pupils would continue to bring better performance.

In the appendix an analysis of the results on three pairs of instruments gives a rule of thumb method of estimating the relative performance of instruments of different magnifications and exit pupils. It may be stated that if magnification is increased by 33% or more with a loss in exit pupil diameter not exceeding 33%, a

net gain in performance may be expected.

Instrument Mounts: Tests were run on the standard 7x50x7° supported in various ways: hand-held, without support; hand-held, with elbows on rail or chest, or in any other position selected by the observer; mounted rigidly on the vessel in one of the director mounts (Fig. 8); and mounted in a special anti-vibration alidade mount (VFA) (Fig 15). These tests indicated an advantage of 115.5 for hand-held rested, 115.5 for rigid mountings, and 114.8 for mounting in the vibration-free alidade.

It may be concluded that providing any kind of mounting for an optical instrument yields improved performance. Tests of this same factor in other instruments verify these results; 10% to 15% gain is made. In the daytime this is especially important. It is probably of great assistance to relieve the observer of the weight of the instrument.

The effect of mounting the instruments was also tested in runs where the speed was increased from 9 to 17 knots, at which point the vibration of the ship appeared most noticeable. The tests were run on

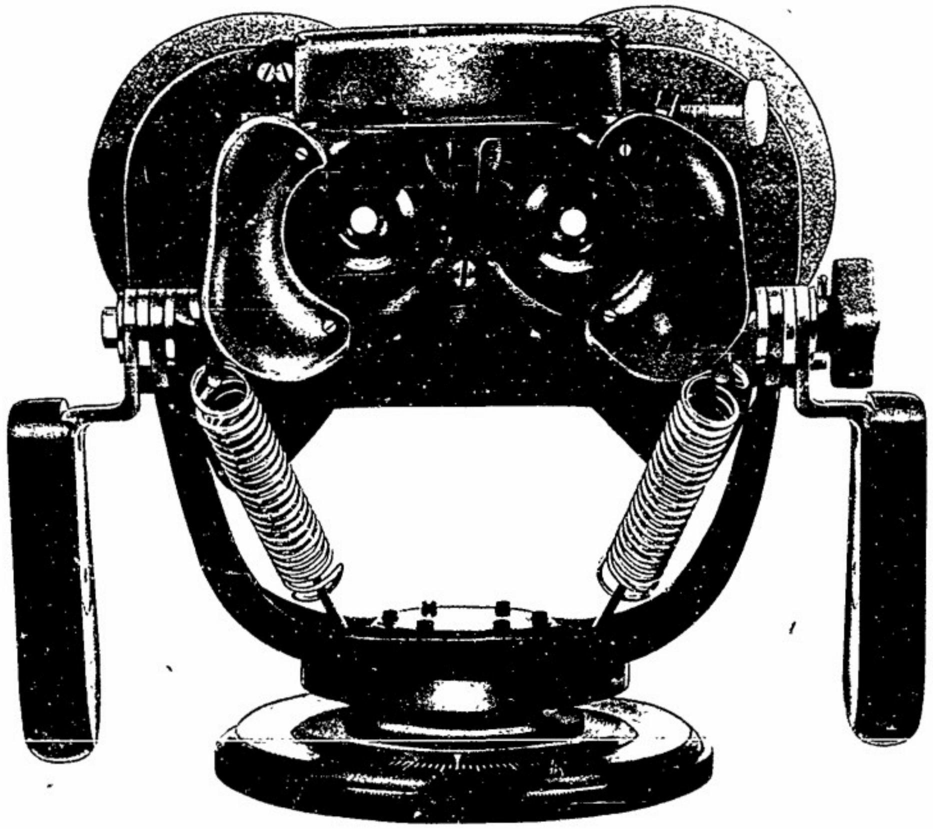

Figure 15. An experimental anti-vibration mount designed to reduce vibration transmitted from the ship

the 7x50x7° and the 10x50x7° instruments. The performance of low-power (7 and less) hand-held instruments dropped off in the presence of vibration. The mounted 7x50x7° and the 10x50x7° hand-held binoculars were substantially unaffected by vibration. The mounted 10x50x7° and the anti-vibration mounted 7x50x7° showed a possible improvement. These results are directly contrary both to theoretical expectations, and to such laboratory data as are available, which indicate that vibration should interfere more seriously with the performance of high-power than of low-power glasses. It is suggested that, because the vibration is more noticeable in the higher-power glasses, and at the higher speeds, the observer makes more, and more successful, efforts to compensate for it. More research is greatly needed in these problems.

This test also emphasizes the gain in performance of the standard hand-held binocular when the observer rests his elbows on the rail or otherwise braces himself against the ship to steady the instrument. This gain makes it practically the equal of the mounted binoculars.

Fixed Focus: Two of the 8x60x9° binoculars were set at fixed focuses of -1 and -2 diopters in the Submarine Base Optical Shop and were tested against each other and the standard binocular. The average results with these fixed focus instruments showed a slightly better average .50 RRP with the setting fixed at -2 diopters. Thus, the use of this fixed-focus would be advantageous on the average. However, analysis of individual performance showed wide variations, some observers gaining as much as 33% with -2 d as compared with -1 d, others losing 12½% of the range. It would probably be desirable to use more than one focus on fixed-focus instruments and fit them to the observers. It is important to note that the observer's own focus setting offered no clue to the fixed focus with which he might achieve longer ranges.

Head Rests: A study of the usefulness of head rests was made. They had almost no effect on performance. Consequently no substantial error is introduced by comparing the larger instruments equipped with headrests directly with other instruments not so equipped. Many of the men preferred the headrests and they are acceptable if properly designed, since they will neither help nor hinder the visual task. By adding to the comfort of observers they may make them more efficient in the standing of long watches.

Subjective Evaluation of Instruments:

Correlation studies between the ratings of the instruments made by the observers on the comment sheets (see Fig. 11), and the actual performance as measured by the test were made. These studies showed that the experienced observers, who were familiar through long use with the various instruments, could evaluate them remarkably well in terms of their actual performance. Upon analysis, it proved that the evaluation of an instrument is based not only on its visual efficiency, but also on a "comfort" or "ease of handling" factor, which contaminates the judgment. It is therefore urged that a skeptical eye be kept on such evaluations, especially by those who have not familiarized themselves with a series of instruments.

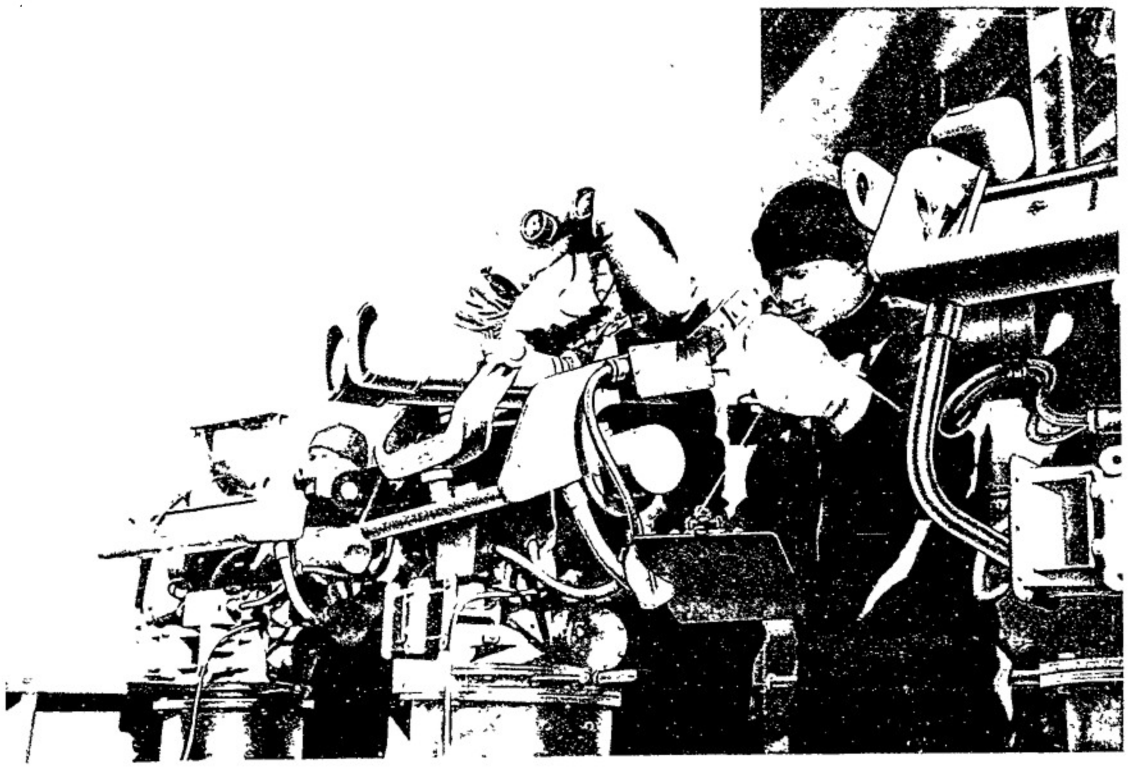

Figure 16. Observers and recorders worked together and reversed their jobs on alternate runs

Interaction:

Attention is again drawn to the previously cited findings that all men do not perform best with the same binocular; some do better with one, some with another. The implications of this finding are many, and it is clear that further research is needed on the problem, since design and procurement of binoculars, or selection of personnel for use of equipment must be adapted to it if best performance is to be obtained from both men and instruments.

Weather and Visibility:

Weather may affect range performance in several ways - through changes in cloud coverage and sky brightness, through roughness of sea, wind and visibility. Our results have not permitted analysis upon the basis of the first two of these. High wind appears to increase the variability of performance, but not at the cost of reducing mean ranges. Visibility analysis of the results is not yet complete. Our night data were obtained under a wide variety of conditions, ranging from haze (2-3 miles visibility), such that operations necessarily were suspended, to unlimited visibility, and so are representative of all conditions. Day observations were made under average to poor conditions (8-9 miles visibility). Visibility analysis must be pushed further, to determine whether certain binoculars perform better in poor visibility, to permit evaluation of the ranges by comparison with laboratory data and to evaluate the various visibility nomographs which have been presented for use by the Navy.

Differences Between Observers:

The 76 men who were used as observers at one time or another in the experiment were classified into three groups: good, fair, and poor, on the basis of their performance. This classification was not entirely satisfactory, because some men were more experienced and made more observations than others, and some only observed under poor visibility conditions. Attempts were made to relate the classification of each man to the results of a series of visual and other tests which he had been given. The only suggestions derived from this analysis were that the "poor" group had a slightly higher incidence of phoria (tendency to be cross-eyed or wall-eyed) than did the "good" group, and a higher proportion of Radium Plaque Adaptometer scores below 10/10. Because of the variations in visibility and experience, which obscure the differences between observers, a further analysis is required before any definite conclusions or recommendations can be made.

CONCLUSIONS AND RECOMMENDATIONS

(1) For night use, a binocular is to be preferred, since it will give visual ranges at least 10% greater than a monocular of the same power, exit pupil and field size. For day use, this is a matter of indifference.

(2) If exit pupil is held approximately constant, range increases linearly with power up to the highest powers which were tested, for both monoculars and binoculars, hand-held and mounted, night or day. Only day hand-held binoculars stand out as the exception to this finding. It was not feasible to determine the upper limit beyond which further magnification contributes nothing.

(3) For a given magnification, an exit pupil increase from 7 to 8 millimeters yields definitive gains.

(4) In balancing exit pupil and magnification, it appears that if 33% or greater increase in magnification can be traded for a drop not greater than 33% in exit pupil diameter, a small net gain in range can be obtained.

(5) The provision of suitable mounts or rests may be expected to extend the range of any instrument by at least 10%.

(6) Head rests are of little, if any, value.

(7) Fixed-focus instruments may be of substantial benefit to some individuals. However, selection of the proper fixed setting is critical, and perhaps two fixed focuses should be used and fitted to personnel.

(8) Optical instruments differ less among themselves with respect to search problems than with respect to the location and identification of targets in known positions.

(9) It has not been possible to evaluate the role of field size; with this procedure, field size appears to contribute little, but certainly this result is not a final one.

SPECIFIC CONCLUSIONS

1. That the 10x50x7° is a better all-around hand-held binocular than the 7x50x7° binocular.
2. That the 20x120x3° binocular is the best all-around optical instrument tested. But it was not possible to test a higher power instrument with satisfactory exit pupil, namely, the Japanese 30x180x2.5°.
3. That suitable mounts, or at least elbow rests be provided at all locations where personnel employ binoculars, even if only occasionally.
4. That investigations of fixed-focus instruments be conducted on large numbers of observers.
5. That further field experimentation be performed on the finding that all individuals do not find the same instrument best, but may differ considerably in performance. This has implications for optical design and personnel selection as well.
6. That further analysis of the data be undertaken, to determine the effect of field size, visibility, and individual differences.
7. That further research be performed to develop a simple, rugged anti-vibration mount.

ACKNOWLEDGMENTS

The writer wishes to take the present opportunity to express acknowledgement to the many individuals who have contributed to the success of the experiment herein reported.

(1) To Captain C. W. Shilling, (MC) USN, Commanding Officer, Medical Research Laboratory, U. S. Naval Submarine Base, New London, Conn., whose backing and assistance in many and important matters rendered the experiment possible.

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(3) To Dr. Howard S. Coleman whose Optical Inspection Laboratory, Pennsylvania State College, gave very substantial assistance in the preparation of much of the graphical and similar material herein presented.

(4) To the Commander, Submarine Force, U.S. Atlantic Fleet, the Commanding Officer, U.S. Naval Submarine Base, New London, Conn., and to the Commanding Officer, Squadron Two, for facilitating the necessary operations, and for the provision of personnel.

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McKinley, Jr., the ship met all operational requirements with ease, and an interest and willingness which exceeded expectations. Throughout the experiment, the most cordial and helpful cooperation in all relationships was maintained between the ship and the experimental crew, even though the operations required many consecutive nights of operation which were not required of the experimental crew.

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(7) To members of the Binocular Subcommittee of the ANOSRD Vision Committee, and especially to Dr. Selig Hecht, for their great assistance in the conception and design of the experiment.

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APPENDIX A

APPENDIX A

Detailed results of the tests are shown in this appendix.

Table A-1 lists the instruments and the runs in which each was tested. The instruments are grouped into hand-held binoculars, mounted binoculars and mounted monoculars. Tests whose results were excluded from final calculation of the summary curves are indicated by foot-notes. Within each group the instruments are arranged, first, in order of magnification and secondarily, according to size of exit pupil.

The balance of the appendix gives data on each instrument as follows:

(a) Three views of the instrument.

(b) Table of optical properties. The measurements given were obtained from an examination of the instruments at the Optical Inspection Laboratory, the Pennsylvania State College. Where more than one instrument of the same kind was used, average values are presented. The individual instruments, even of different manufacturers, do not differ greatly from these averages.

(c) A series of Relative Range Performance curves, as obtained from each set of runs in which the instrument was tested, and the numerical value of the .90, .50, and .10 RRP's from each curve.

Table A-2 lists a number of corrections which should be made to the graphs as presented.

TABLE A-1

SUMMARY OF TESTS MADE OF EACH INSTRUMENT

SB - Signal Bridge
LD - Lower Deck
GD - Gun Deck
HR - Head Rest

HH - Hand-held
HHR - Hand-held rested
MTD - Mounted
VFA - Vibration-free alidade

Instrument	Location	Time	Sets
NAKED EYE	SB	Night	HA-1, HC-1, HY, HZ-1*, HZ-2
	LD	Day	cG, cQ
MONOCULAR 7x50x7° HH	SB	Night	HA-1, H_1A-2, HC-1 H_1C-2, HY, HZ-1*, HZ-2
	LD	Day	cG, cQ, c_1A,
	GD	Day	kD
HAND-HELD BINOCULARS 6x42x12°	GD	Night	$D_{12}o$*, $D_{12}p$*, $D_{12}q$*, $D_{12}r$*, Wg-1, Wg-2 Wh-1, Wh-2, Wi-1, Wj-1, Wz-1, Wz-2, W_si-2**, W_si-3, W_sj-2**, W_sj-3**
	GD	Day	wC, wB
7x50x7°	SB	Night	BA, BB**, BD, BE, B_1X, B_sA, B_sF, EH, EJ, HAI, H_1A-2, HC-1 H_1C-2, HY, HZ-1*, HZ-2, MA, MB, M_1D** M_1E, P_1A, PD, P_1F, PG, VD, VE, IAF
	GD	Night	Aa-1, Aa-e, Ab-1, Ab-2, Ac-1, Ac-2, Ad-1, Ad-2, Fa-1, Fa-2, Fb-1, Fb-2, Fe-1, Fe-2, Ff-1, Ff-2, Wg-1, Wg-2, Wh-1, Wh-2, D_5i D_5j, D_5k, D_5m, $D_{10}n$, $D_{10}j$, $D_{10}o$, $D_{10}p$, $D_{12}o$*, $D_{12}p$*, $D_{12}q$*, $D_{12}r$*, Hi, Hj, Hk, Hl, Wz-1, Wz-2, Wi-1, Wj-1, W_si-2** W_sj-2**, W_si-3, W_sj-3
	SBa	Day	k_1Q, oL, oH, o_1L
	SBb	Day	pE, pF, mE, mJ
	GD	Day	wC, wB, kD, bR
	LD	Day	c_1A, cQ, cG, bS
7x50x10° HH	GD	Night	Aa-1, Aa-2, Ab-1, Ab-2, Ac-1, Ac-2, Ad-1, Ad-2, D(10)j D(10)n, D(10)o, D(10)p, Hi, Hj, Hk, Hl, Wz-1, Wz-2, Wh-1, Wh-2, Wi-1, Wj-1, Wz-1, Wz-2, W_si-2**, W_sj-2** W_si-3, W_sj-3, IAF
	GD	Day	wC, wB
7x50x10° HH Headrest	SB	Night	HA-1, H_1A-2, HC-1, H_1C-2, HY, HZ-1,* HZ-2
	GD	Night	Aa-1, Aa-2, Ab-1, Ab-2, Ac-1, Ac-2, Ad-1, Ad-2,
8x60x9° (-1d Fixed Focus)	SB	Night	HA-1, H_1A-2, HC-1, H_1C-2, Hy, HZ-1* HZ-2
	GD	Night	Fa-1, Fa-2, Fb-1, Fb-2, Fe-1, Fe-2, Ff-1, Ff-2
8x60x9° (-2d Fixed Focus)	GD	Night	Fa-1, Fa-2, Fb-1, Fb-2, Fe-1, Fe-2, Ff-1, Ff-2
9x63x5.7°	GD	Night	D_5i, D_5j, D_5k, D_5M
10x50x7°	SB	Night	BA, BB**, BD, BE, B_sA, B_sF, HA-1, H_1A-2, HC-1, H_1C-2, HY, HZ-1* HZ-2, IAF
	GD	Night	Hi, Hj, Hk, Hl,
	GD	Day	kD
	LD	Day	c_1A
10x70x7° (Johnson Foundation Experimental Design)	SB	Night	H_1A-2, H_1C-2
MOUNTED BINOCULARS 6x33x7°	SB	Night	EH, EJ,
	GD	Night	Ep*, Et*
	SBa	Day	oL, oH, O_1L
6x42x7°	SB	Night	EH, EJ
	GD	Night	Ep*, Et*
6x42x12°	GD	Night	$D_{12}o$*, $D_{12}p$*, $D_{12}q$*, $D_{12}r$*
6x50x7°	SB	Night	EH, EJ
	GD	Night	Ep* Et*
7x50x7°	SB	Night	BA, B_sA, BB** BD, BE, B_sF, B_1X
	SBa	Day	K_1q
	GD	Day	bR
	LD	Day	bS
7x50x7°VFA	SB	Night	BA, B_sA, BB**, BD, BE, B_sF, B_1X
	GD	Day	bR
	LD	Day	bS
7x50x7°HHR	SB	Night	BA, B_sA, BB**, BD, BE, B_sF
7x50x10°	GD	Night	$D_{10}j$, $D_{10}n$, $D_{10}o$, $D_{10}p$
9x63x5.7°	GD	Night	D_5i, D_5j, D_5k, D_5m
10x50x7°	SB	Night	BA, B_sA, BB**, BD, BE, B_sF, B_1X, MA, MB
	SBa	Day	K_1q
10x70x7° (NDRC)	SB	Night	B_1X, MA, MB, M_1D** M_1E
10x80x7°	SB	Night	P_1A, PD, P_1F, PG
	SBa	Day	oL, Oh
20x120x3°	SB	Night	M_1D**, M_1E, P_1A, PD, P_1F, PG
	SBb	Day	pE, pF
25x100x3.6°	SB	Night	P_1A, PD, P_1F, FG
	SBb	Day	pE, pF
MOUNTED MONOCULARS			
4x28x10°	SB	Night	MA, MB, M_1D** M_1E
	SBb	Day	mE, mJ
6x30x8.5°	SB	Night	MA, MB, M_1D**, M_1E
6x33x7°	SB	Night	EH, EJ
	GD	Night	No*, Ns*
6x33x8°	SB	Night	B_1X, EH, EJ, MA, MB M_1D**, M_1E
	GD	Night	No*, Ns*
	SBb	Day	mE, mJ
16x96x3.2°	SB	Night	PD, PG
21x76x2.8°	SB	Night	P_1A,PD, P_1F, PG
	SBa	Day	o_1L
24x96x2.2°	SB	Night	P_1A, P_1F

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* Set was discarded because of insufficient data due to poor visibility.

** Set was discarded because of incorrect scheduling or other reasons.

TABLE A-2

ERRORS ON GRAPHS

Instrument	Set		Probability	As Shown	Correct Value
6x42x12	HH	Wz-2	90	73	80.2
7x50x10	HH	Aa-1	50	100	96.5
7x50x10	HH	Hk	50	77	83.1
7x50x10	HH	$D_{10}o$	10	106	116
7x50x10	HH	$D_{10}n$	10	108	118
7x50x10	HH	Wz-1	90	85.0	80.1
7x50x10 Head Rest	HH	H_1C-2	90	78.0	82.5
7x50x10 Head Rest	HH	H_1C-2	50	88	92
7x50x10 Head Rest	HH	H_1C-2	10	99	101.8
7x50x10 Head Rest	HH	HY	90	98	91
7x50x10 Head Rest	HH	HY	50	114	106.7
7x50x10 Head Rest	HH	HY	10	132	125.5
9x63x5.7	HH	D_5j	10	121	117
10x50x7	HH	HY	90	90	97.5
10x50x7	HH	HY	50	108	113
10x50x7	HH	HY	10	127	132
7x50x10	MTD	$D_{10}P$	90	98	102.6
7x50x10	MTD	$D_{10}P$	50	112	116
7x50x10	MTD	$D_{10}P$	10	126	130.7
25x100x3.6	MTD	PD	10	204	208
6x30x8.5	MTD	MB	90	22	18
6x30x8.5	MTD	MB	50	44	47
6x30x8.5	MTD	MB	10	68	74.5

RRP VALUES

NAKED EYE	DAY		
SETS	PROBABILITY		
	90	50	10
cQ (Lower Deck)	61.8	83.5	97.5
cG (Lower Deck)	72.0	84.0	96.0
Combined values for all sets	80.6	90.0	99.4

RRP VALUES

NAKED EYE	NIGHT SIGNAL BRIDGE		
SETS	PROBABILITY		
	90	50	10
HA-1	Insufficient	Data:	Visibility
HC-1	Insufficient	Data:	Visibility
HY	Insufficient	Data:	Visibility
HZ-1	Insufficient	Data:	Visibility
HZ-2	Insufficient	Data:	Visibility

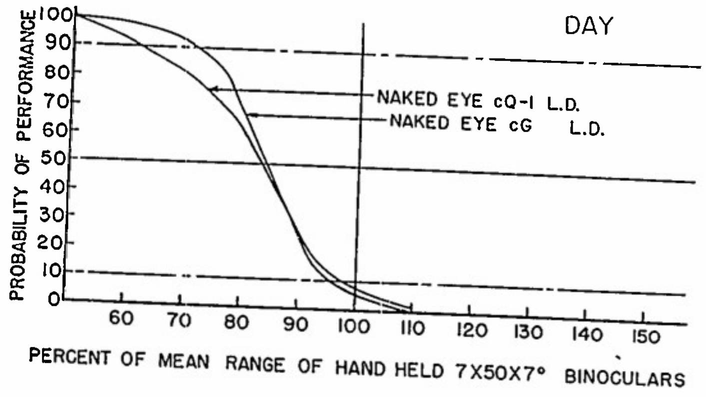
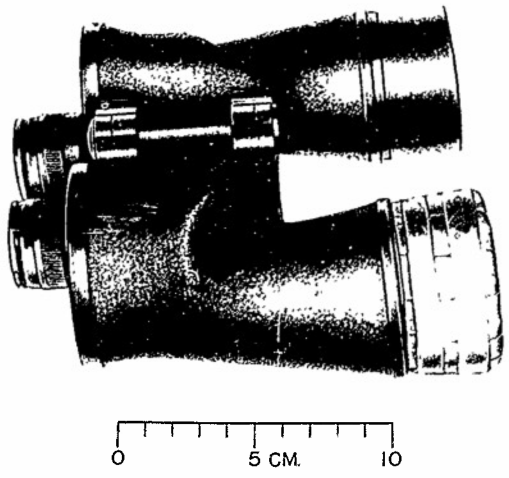
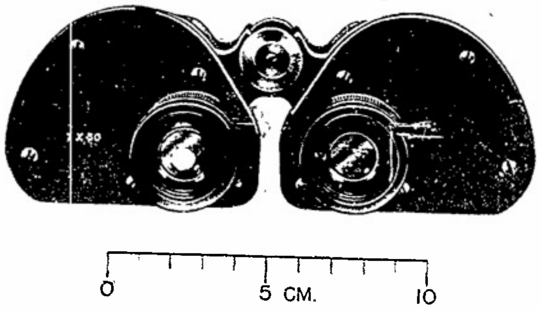
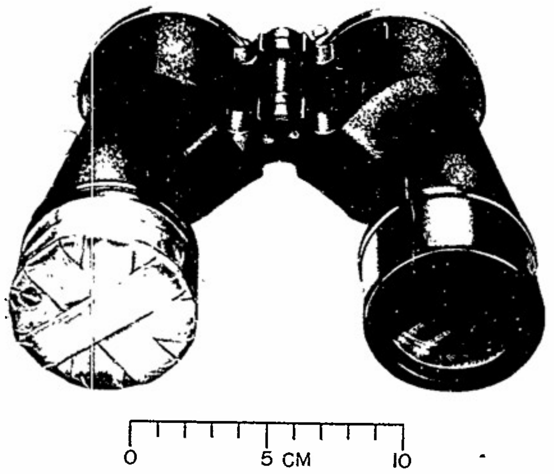


Figure A-1. Graph of RRP values for tne naked eye.

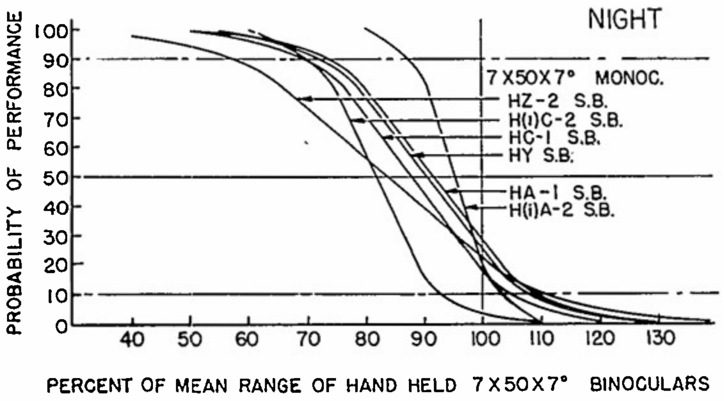






THE 7x50x7° MONOCULAR

OPTICAL SPECIFICATION	
Magnification	7
Diameter of Objective in MM	50
True Field Angle	7.25°
Apparent Field Angle	50.8°
Exit Pupil diameter in MM	7.1
Eye Relief in MM	14.5
Light Transmission--Specified	.77
--By test (at Penn State Optical Inspection Laboratory)	.70
Contrast Rendition--Day	97
--Night	92
Kinetic Definition Chart, Efficiency in %	73
Weight in Grams	1,420
Length of Instrument, CM	18.5



RRP VALUES

7 x 50 x 7°	HH MONOCULAR	NIGHT SIGNAL BRIDGE	
SETS		PROBABILITY	
	90	50	10
HA-1	74.5	91.2	108.0
H(1)A-2	87.5	95.0	103.0
HC-1	70.0	87.5	104.5
H(1)C-2	72.0	82.0	92.5
HY	72.3	90.0	107.5
(HZ-1)	Insufficient Data		
HZ-2	57.5	83.5	109.5
Combined values for all sets	84.5	91.0	97.0

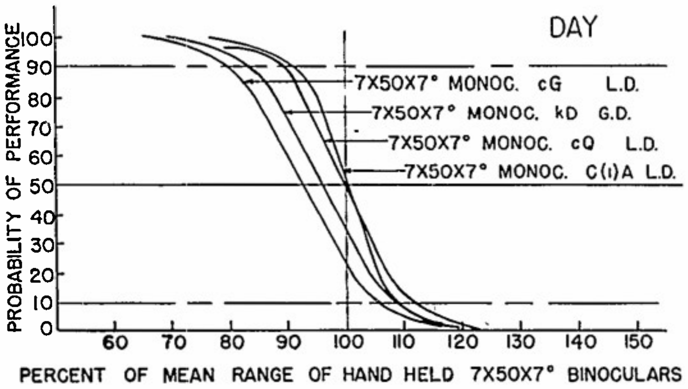
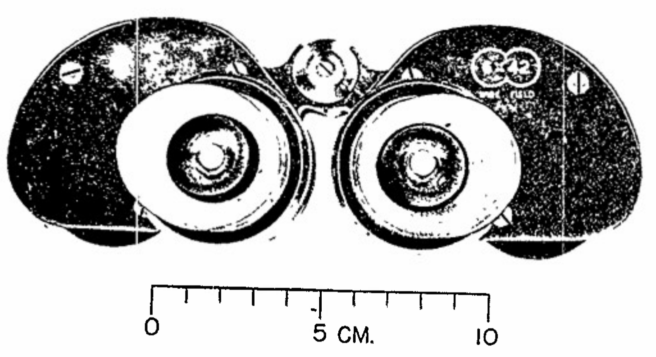
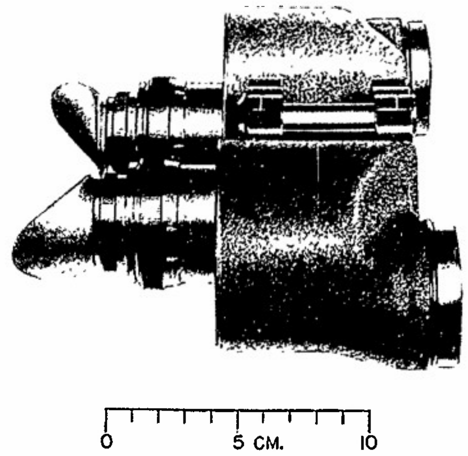


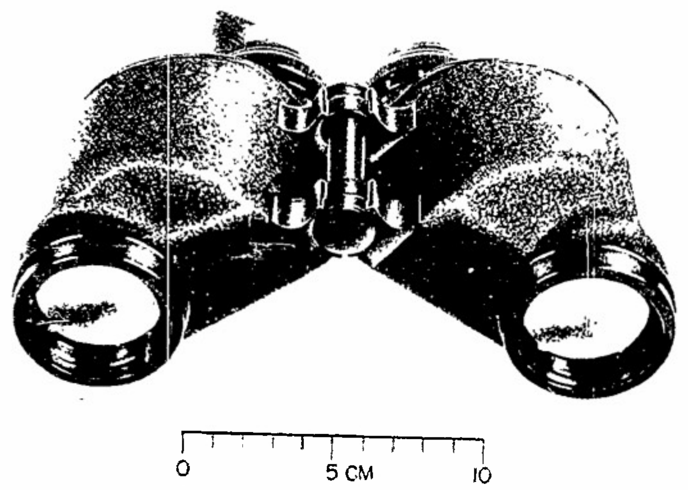
Figure A-2. The standard 7x50x7° with one lens covered to test it as a monocular.

RRP VALUES

7 x 50 x 7°	HH MONOCULAR	DAY	
SETS		PROBABILITY	
	90	50	10
cQ (Lower Deck)	89.9	99.5	111.0
cG (Lower Deck)	80.5	92.0	106.0
c(1)A (Lower Deck)	92.0	100.0	109.0
kD (Gun.Deck)	83.5	96.0	108.0
Combined values for all sets	93.1	99.1	105.0



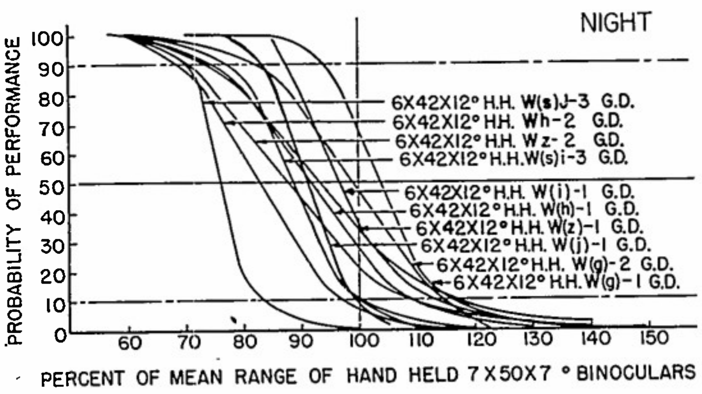




THE 6x42x12° BINOCULAR

OPTICAL SPECIFICATION

Magnification	6
Diameter of Objective in MM	42
True Field Angle	12°
Apparent Field Angle	72°
Exit Pupil diameter in MM	7.0
Eye Relief in MM	19.5
Light Transmission--Specified	.68
--By test (at Penn State Optical Inspection Laboratory)	.66
Contrast Rendition--Day	96
--Night	82
Kinetic Definition Chart, Efficiency in %	77
Weight in Grams	1,730
Length of Instrument, CM	14.5



RRP VALUES

6 x 42 x 12° — HAND-HELD — NIGHT GUN DECK

SETS	PROBABILITY 90	50	10
D(12)(o)*	Insufficient	Data:	Visibility
D(12)(p)*	Insufficient	Data:	Visibility
D(12)(q)*	Insufficient	Data:	Visibility
D(12)(r)*	Insufficient	Data:	Visibility
Wg-1	94.5	104.0	116.0
Wg-2	82.8	99.0	114.8
Wh-1	74.5	91.8	109.5
Wh-2	69.0	83.0	96.7
Wi-1	87.5	96.2	116.0
Wj-1	83.5	91.0	99.0
Wz-1	74.0	93.5	112.6
Wz-2	80.2	87.6	110.0
(W(s)i-2)	Excluded.	Randomizing	off.
W(s)i-3	77.5	89.0	100.1
(W(s)j-2)	Excluded.	Randomizing	off.
W(s)j-3*	70.5	76.1	83.5
Combined values for all sets	90.3	95.3	100.5

*Not included in combined values.

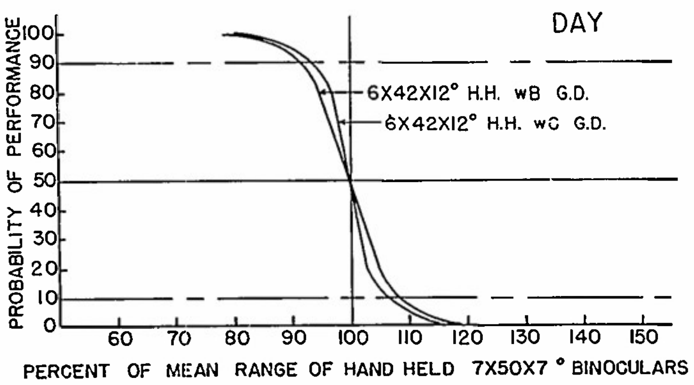


Figure A-3. The 6x42x12° binocular, which was tested both hand-held and mounted.

RRP VALUES

6 x 42 x 12° — HAND-HELD — DAY GUN DECK

SETS	PROBABILITY 90	50	10
wC	93.5	99.9	106.0
wB	92.0	99.8	108.0
Combined values for all sets	93.8	100.0	106.5

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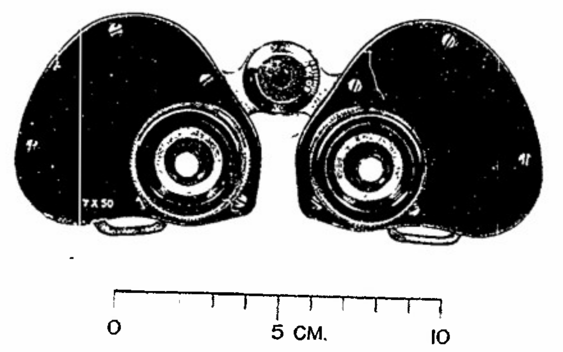
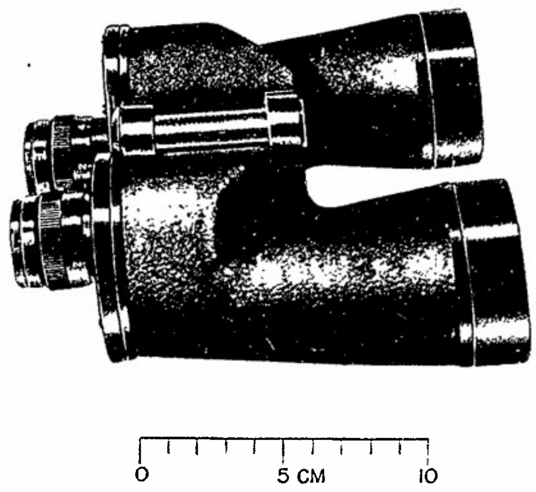
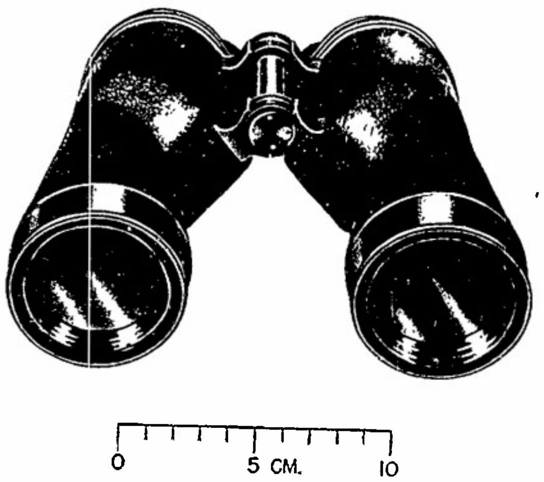
6 x 42 x 12°	RRP VALUES MOUNTED NIGHT GUN DECK		
SETS	PROBABILITY 90	50	10
D(12)(o)	Insufficient Data: Visibility		
D(12)(p)	Insufficient Data: Visibility		
D(12)(q)	Insufficient Data: Visibility		
D(12)(r)	Insufficient Data: Visibility		

Figure A-3. (Continued) The 6x42x12° binocular, which was tested both hand-held and mounted.







THE 7x50x7° BINOCULAR

OPTICAL SPECIFICATION

Magnification	7
Diameter of Objective in MM	50
True Field Angle	7.25°
Apparent Field Angle	50.8°
Exit Pupil diameter in MM	7.1
Eye Relief in MM	14.5
Light Transmission--Specified	.77
--By test (at Penn State Optical Inspection Laboratory)	.70
Contrast Rendition--Day	.96
--Night	.94
Kinetic Definition Chart, Efficiency in %	82
Weight in Grams	1,360
Length of Instrument, CM	18.4

SUMMARY OF TESTS OF STANDARD INSTRUMENT

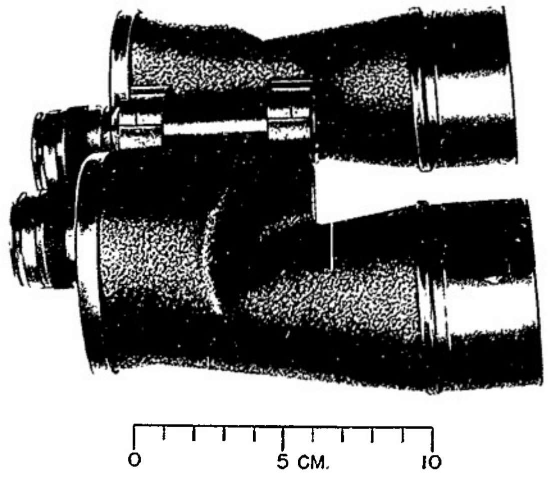
7x50x7° HAND-HELD (MEAN)

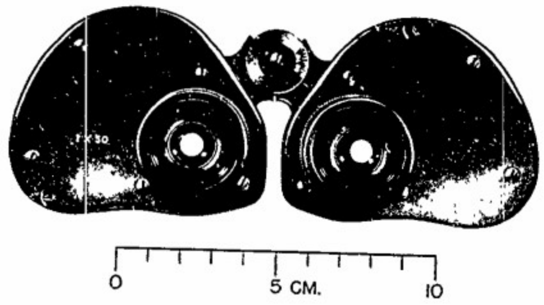
NIGHT		SIGNAL BRIDGE	
Sets	90	50	10
BA	83.2	100.0	116.8
BB	Excluded. Randomizing off.		
BD	86.0	100.0	114.0
BE	86.0	100.0	114.0
B_sA	84.0	100.0	116.0
B_sF	80.5	100.0	119.5
B_1X	81.5	100.0	118.5
EH	85.0	100.0	115.0
EJ	82.5	100.0	117.5
HA-1	82.5	100.0	117.5
H_1A-2	90.2	100.0	109.8
HC-1	82.5	100.0	117.5
H_1C-2	88.5	100.0	111.5
HY	83.0	100.0	117.0
HZ-1	Insufficient data. Visibility.		
HZ-2	76.5	100.0	123.5
MA	83.5	100.0	116.5
MB	76.0	100.0	124.0
M_1D	Excluded. High wind.		
M_1E	76.0	100.0	124.0
P_1A	77.8	100.0	122.2
PD	76.8	100.0	123.2
P_1F	72.5	100.0	127.5
PG	72.8	100.0	127.2
VD	83.0	100.0	117.0
VE	86.5	100.0	113.5
VD-I	96.0	115.0	130.0
II	60.0	91.5	
III	69.8	101.0	
IV	75.0	107.0	
V	53.2	85.5	
VI	66.0	97.5	
VE-I	88.0	101.8	116.2
II	86.0	97.0	105.0
III	92.5	103.3	110.2
IV	86.8	99.0	107.0
V	93.5	104.0	111.3
VI	83.0	94.0	101.3

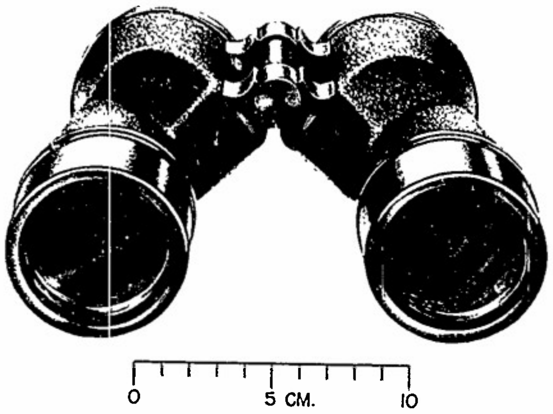
NIGHT			GUN DECK
Sets	90	50	10
Aa-1	75.0	100.0	125.0
Aa-2	82.3	100.0	117.7
Ab-1	81.2	100.0	118.8
Ab-2	75.2	100.0	124.8
Ac-1	83.0	100.0	117.0
Ac-2	71.5	100.0	128.5
Ad-1	70.6	100.0	129.4
Ad-2	82.8	100.0	117.2
D_5i	76.1	100.0	123.9
D_5j	82.7	100.0	117.3
D_5k	75.9	100.0	124.1
D_5m	80.3	100.0	119.7
$D_{10}n$	75.5	100.0	124.5
$D_{10}j$	70.7	100.0	129.3
$D_{10}o$	83.5	100.0	116.5
$D_{10}p$	79.4	100.0	120.6
$D_{12}o$	Insufficient data. Visibility.		
$D_{12}p$	Insufficient data. Visibility.		
$D_{12}q$	Insufficient data. Visibility.		
$D_{12}r$	Insufficient data. Visibility.		
Ep	Insufficient data. Visibility.		
Fa-1	84.2	100.0	115.8
Fa-2	82.5	100.0	117.5
Fb-1	77.8	100.0	122.2
Fb-2	77.3	100.0	122.7
Fe-1	75.6	100.0	124.4
Fe-2	82.4	100.0	117.6
Ff-1	72.7	100.0	127.3
Ff-2	83.1	100.0	116.9
Hi	83.2	100.0	116.8
Hj	60.0	100.0	140.0
Hk	77.0	100.0	123.0
Hl	79.0	100.0	121.0
Ns	Insufficient data. Visibility.		
Wg-1	83.9	100.0	116.1
Wg-2	83.0	100.0	117.0
Wh-1	80.0	100.0	120.0
Wh-2	84.5	100.0	115.5
Wi-1	83.8	100.0	116.2
Wj-1	86.2	100.0	113.8
W_si-2	Excluded. Randomizing off.		
W_sj-2	Excluded. Randomizing off.		
W_si-3	79.9	100.0	120.1
W_sj-3	83.5	100.0	116.5
Wz-1	72.8	100.0	127.2
Wz-2	75.7	100.0	124.3

DAY			
Sets	90	50	10
wC	83.0	100.0	117.0
wB	81.2	100.0	118.8
c_1A	86.3	100.0	113.7
kD	85.0	100.0	115.0
k_1q	77.9	100.0	122.1
pE	78.0	100.0	122.0
pF	74.0	100.0	116.0
cQ	77.6	100.0	122.4
cG	77.0	100.0	123.0
bR	76.0	100.0	124.0
bS	77.8	100.0	122.2
oL	81.5	100.0	118.5
oH	75.0	100.0	125.0
mE	79.0	100.0	121.0
mJ	81.9	100.0	118.1
o_1L	78.2	100.0	121.8

Figure A-4a. Appearance and optical specifications of the 7x50x7° binocular. This instrument, hand-held, was used as the standard for comparison.



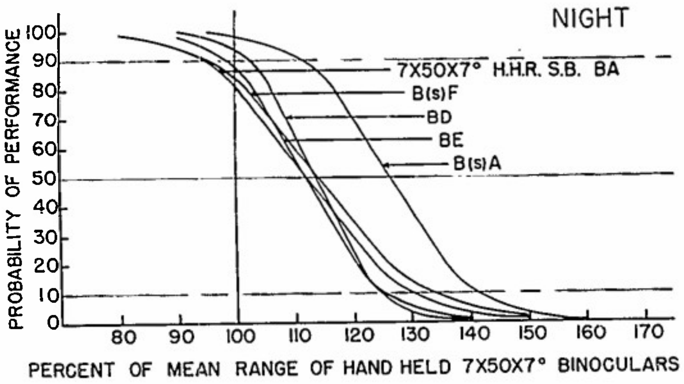




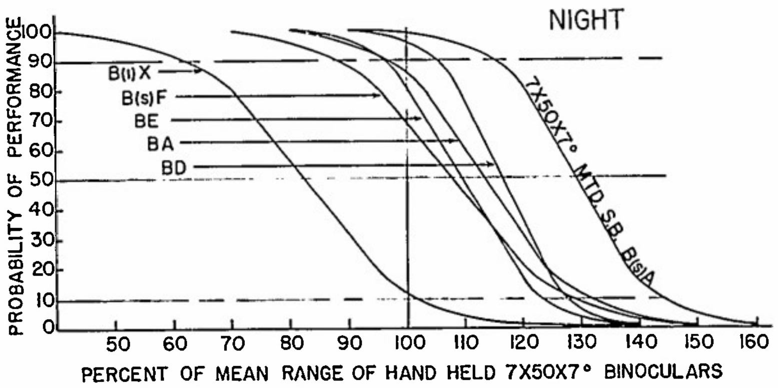
THE 7x50x7° BINOCULAR

OPTICAL SPECIFICATION

Magnification	7
Diameter of Objective in MM	50
True Field Angle	7.25°
Apparent Field Angle	50.8°
Exit Pupil diameter in MM	7.1
Eye Relief in MM	14.5
Light Transmission--Specified	.77
--By test (at Penn State Optical Inspection Laboratory)	.70
Contrast Rendition--Day	97
--Night	92
Kinetic Definition Chart, Efficiency in %	73
Weight in Grams	1,420
Length of Instrument, CM	18.5



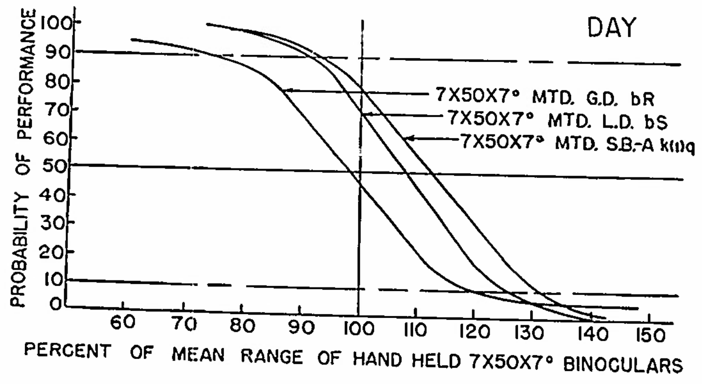
7 x 50 x 7°	RRP VALUES HH RESTED		NIGHT SIGNAL BRIDGE
SETS		PROBABILITY	
	90	50	10
BA	95.0	112.0	130.0
B(s)A	111.5	126.0	141.0
(BB)	Excluded.	Randomizing	off.
BD	103.0	113.5	125.0
BE	98.5	112.0	125.5
B(s)F	95.5	114.0	132.5
Combined values for all sets	107.3	115.5	124.0



7 x 50 x 7°	RRP VALUES MOUNTED		NIGHT SIGNAL BRIDGE
SETS		PROBABILITY	
	90	50	10
BA	97.5	115.0	132.0
B(s)A	115.5	129.5	143.8
(BB)	Excluded.	Randomizing	off.
BD	105.5	117.0	128.5
BE	96.0	109.0	123.8
B(S)F	87.5	108.0	129.2
B(1)X*	63.0	82.5	101.5
Combined values for all sets	106.8	115.5	124.0

* Not included in combined values.

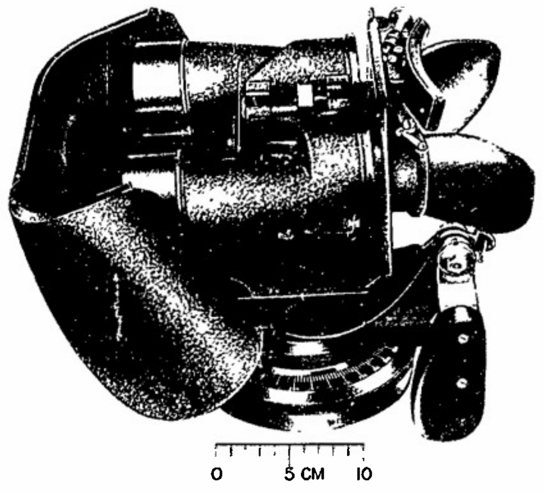
Figure A-4b. The 7x50x7° binocular was also tested in a mount, and hand-held rested.



RRP VALUES

7 x 50 x 7°		MOUNTED	DAY	
SETS		PROBABILITY		
		90	50	10
K(1)Q	(Signal Bridge A)	93.5	112.5	131.5
bR	(Gun Deck)	75.0	98.5	119.5
bS	(Lower Deck)	91.0	108.0	126.0
Combined values for all sets		99.9	111.5	124.3

Figure A-4b. (Continued) The 7x50x7° binocular was also tested in a mount, and hand-held rested.



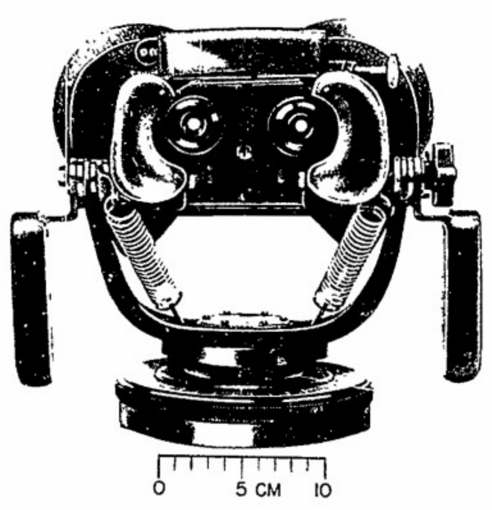
THE 7x50x7° BINOCULAR

OPTICAL SPECIFICATION

Magnification	7
Diameter of Objective in MM	50
True Field Angle	7.25°
Apparent Field Angle	50.8°
Exit Pupil diameter in MM	7.1
Eye Relief in MM	14.5
Light Transmission--Specified	.71*
--By test (at Penn State Optical Inspection Laboratory)	.64*
Contrast Rendition--Day	
--Night	
Kinetic Definition Chart, Efficiency in %	
Weight in Grams	11,250
Length of Instrument, CM	25.0

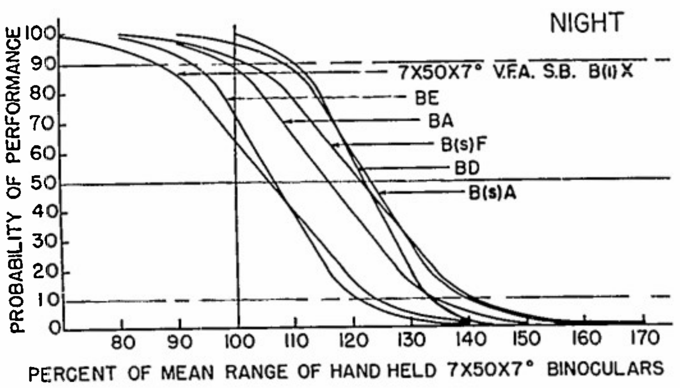
*Computed from transmission of night-treated glass

Vibration-Free Alidade



7 x 50 x 7°	RRP VALUES VIBRATION-FREE ALIDADE		NIGHT SIGNAL BRIDGE
SETS	PROBABILITY		
	90	50	10
BA	98.5	116.8	133.5
B(s)A	109.5	123.5	137.2
(BB)	Excluded.	Randomizing	off.
BD	110.5	122.8	134.8
BE	93.5	107.0	120.5
B(s)F	102.0	121.0	141.0
B(1)X	87.0	107.0	124.0
Combined values for all sets	107.5	114.8	123.0

7 x 50 x 7°	RRP VALUES VIBRATION-FREE ALIDADE		DAY
SETS	PROBABILITY		
	90	50	10
bR (Gun Deck)	95.5	119.0	138.5
bS (Lower Deck)	98.5	116.5	133.0
Combined values for all sets	100.8	114.6	127.5



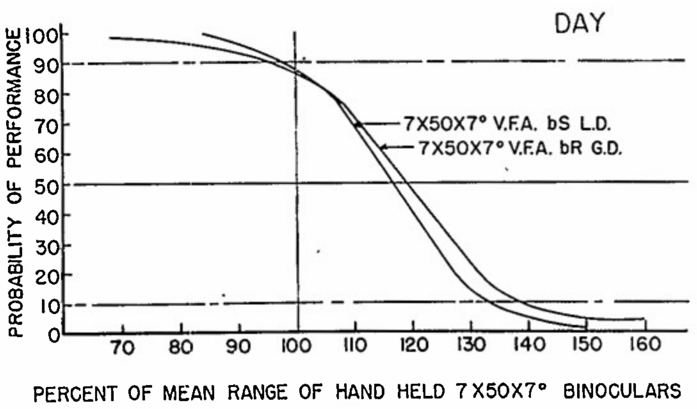
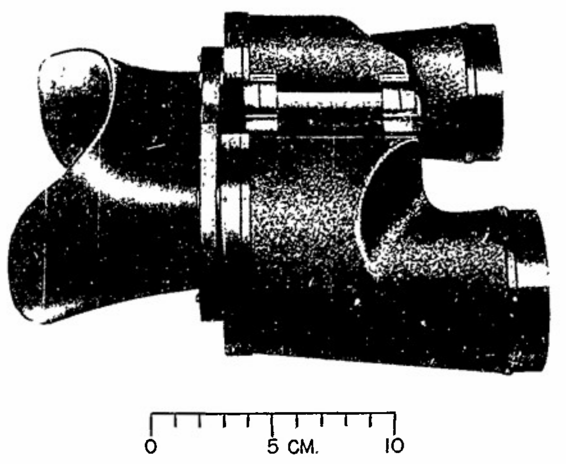
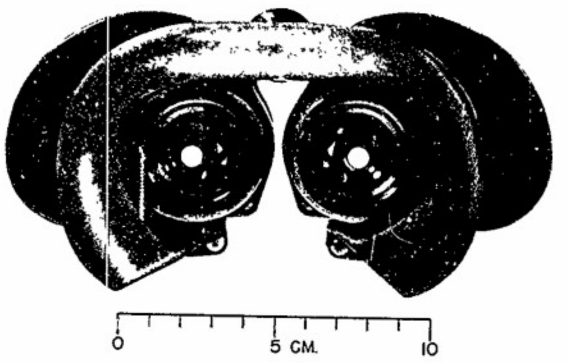


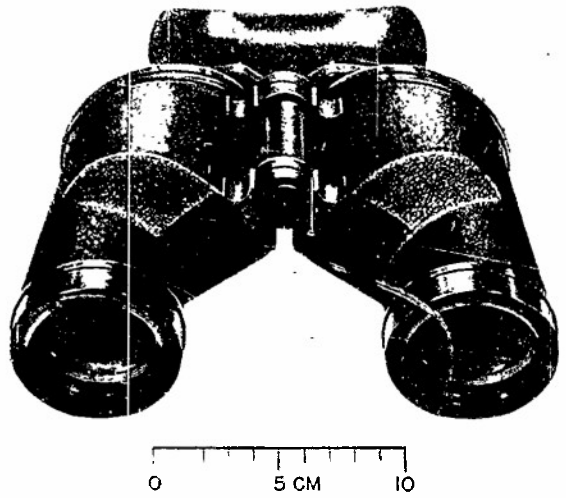
Figure A-4c. The 7x50x7° binocular mounted in the anti-vibration mount (VFA).



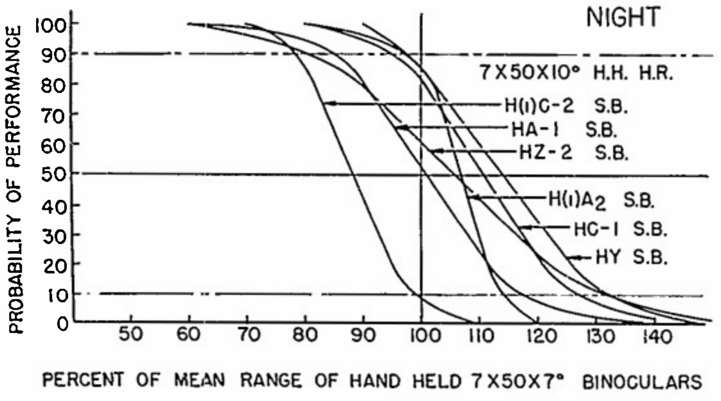


THE 7x50x10° BINOCULAR

OPTICAL SPECIFICATION	
Magnification	7
Diameter of Objective in MM	50
True Field Angle	10°
Apparent Field Angle	70°
Exit Pupil diameter in MM	7.1
Eye Relief in MM	21.5
Light Transmission--Specified	.75
--By test (at Penn State Optical Inspection Laboratory)	.70
Contrast Rendition--Day	97
--Night	87
Kinetic Definition Chart, Efficiency in %	83
Weight in Grams	1,700
Length of Instrument, CM	17.5



7 x 50 x 10°	RRP VALUES HH (Headrest)		NIGHT SIGNAL BRIDGE
SETS	PROBABILITY 90	50	10
HA-1	85.0	101.0	117.0
H(1)A-2	98.8	96.2	113.8
HC-1	95.0	110.0	127.0
H(1)C2	82.5+	92.0+	101.8+
HY	91.1+	106.7+	125.5+
(HZ-1)	Insufficient Data.		
Hz-2	81.2	106.0	132.4
Combined values for all sets	97.5	101.5	105.0



7 x 50 x 10°	RRP VALUES HH (Headrest)		NIGHT GUN DECK
SETS	PROBABILITY 90	50	10
Aa-1	79.0	103.0	133.5
Aa-2	80.5	96.8	115.2
Ab-1	81.5	95.0	107.0
Ab-2	90.0	110.0	129.5
Ac-1*	112.0	143.0	169.0
Ac-2*	52.0	84.0	112.0
Ad-1	85.0	113.5	140.0
Ad-2	81.5	95.5	116.8
Combined values for all sets	96.4	103.9	111.8

*Not included in combined values.

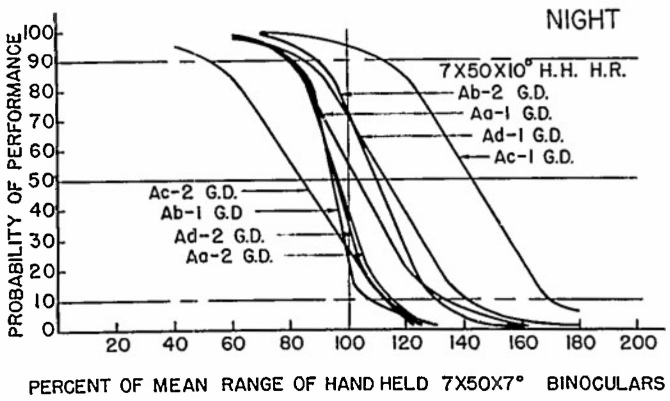
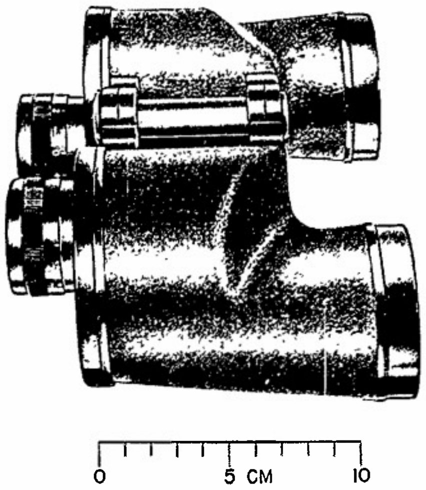
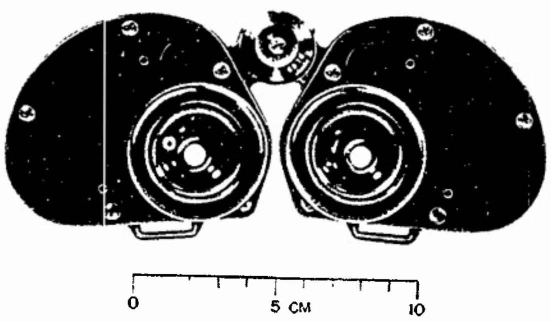
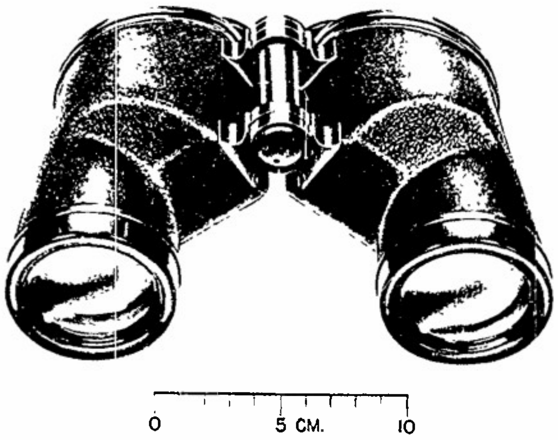


Figure A-5. The 7x50x10° binocular, with head-rest. The same instrument without the head-rest is shown in Fig. A-6.



THE 7x50x10° BINOCULAR



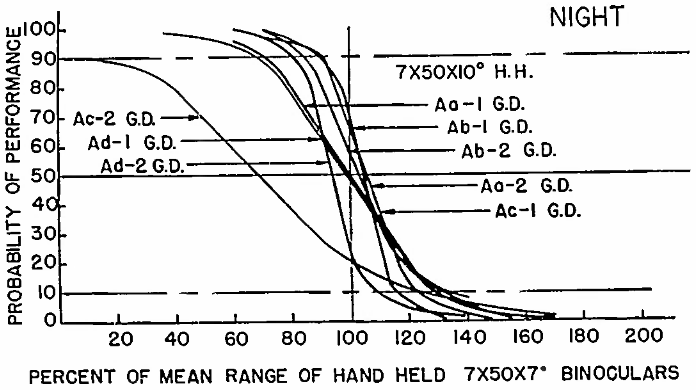


OPTICAL SPECIFICATION

Magnification	7
Diameter of Objective in MM	50
True Field Angle	10°
Apparent Field Angle	70°
Exit Pupil diameter in MM	7.1
Eye Relief in MM	21.5
Light Transmission--Specified	.75
--By test (at Penn State Optical Inspection Laboratory)	.70
Contrast Rendition--Day	97
--Night	87
Kinetic Definition Chart, Efficiency in %	83
Weight in Grams	1,700
Length of Instrument, CM	17.5

7 x 50 x 10°	RRP VALUES HAND-HELD	NIGHT GUN DECK	
	PROBABILITY		
SETS	90	50	10
Aa-1	70.5	96.5	129.0
Aa-2	91.5	106.0	122.8
Ab-1	89.2	105.0	116.0
Ab-2	84.6	103.8	122.0
Ac-1 *	90.C	106.1	123.0
Ac-2 *	-	69.0	126.0
Ad-1	68.5	98.6	134.2
Ad-2	82.0	94.0	109.2

*Not included in combined values.



7 x 50 x 10°	RRP VALUES HAND-HELD	NIGHT GUN DECK	
	PROBABILITY		
SETS	90	50	10
D(10)j	81.0	101.4	119.8
D(10)n	84.0	96.3	118.0
D(10)o	85.2	96.0	116.0
D(10)p	102.6	116.5	130.8
Hi	100.7	107.5	115.0
Hj	78.9	104.0	131.9
Hk	51.0	83.1	101.1
Hl	90.9	108.0	123.6

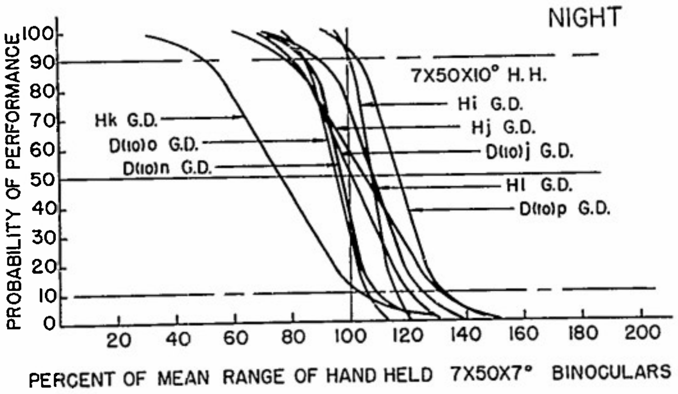
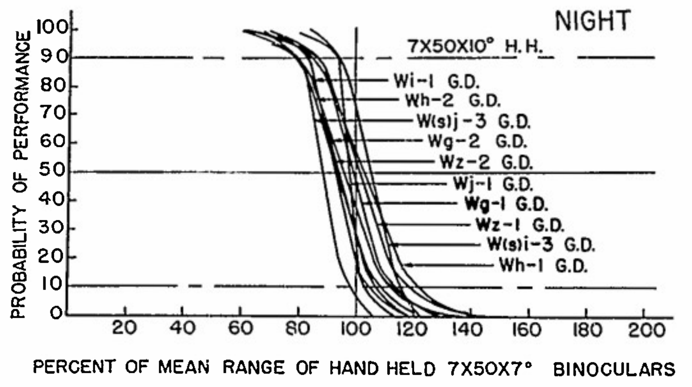
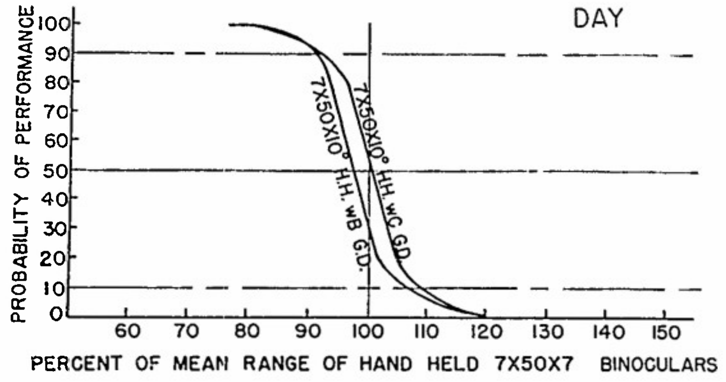


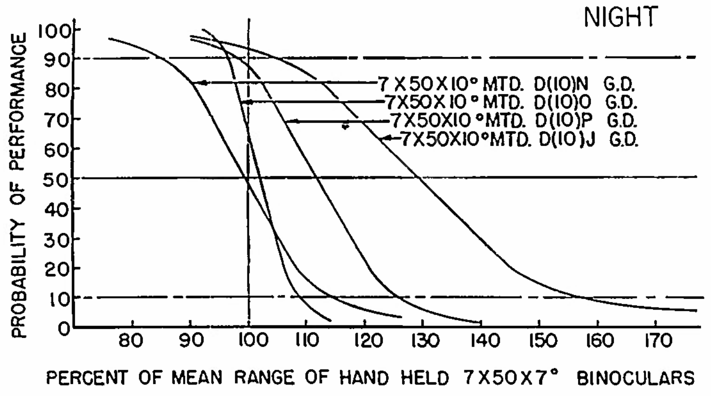
Figure A-6. The 7x50x10° binocular with the head-rest removed.



7 x 50 x 10°	RRP VALUES HAND-HELD	NIGHT GUN DECK	
SETS		PROBABILITY	
	90	50	10
Wg-1	85.7	99.9	113.0
Wg-2	79.2	95.0	112.0
Wh-1	83.9	102.2	120.6
Wh-2	79.0	93.0	108.0
Wi-1	83.2	93.8	103.8
Wj-1	92.0	97.0	103.2
(W(s)i-2)	Excluded.	Randomizing off.	
(W(s)j-2)	Excluded.	Randomizing off.	
W(s)i-3	93.8	104.9	117.5
W(s)j-3	80.0	89.3	97.0
Wz-1	80.1	100.0	119.1
Wz-2	79.2	94.7	106.2
Combined values for all sets of Night Gun Deck tests	99.0	103.5	108.0



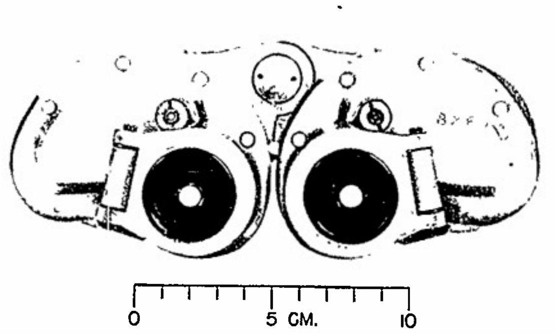
7 x 50 x 10°	RRP VALUES HAND-HELD	DAY GUN DECK	
SETS		PROBABILITY	
	90	50	10
wC	92.0	101.0	109.0
wB	91.0	97.5	106.5
Combined values for all sets	94.0	102.5	107.5

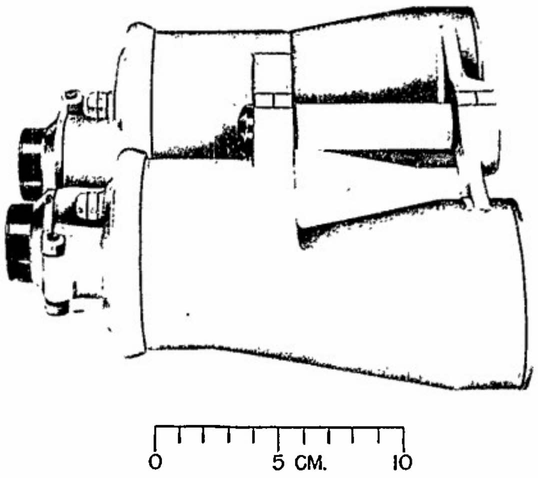


7 x 50 x 10°	RRP VALUES MOUNTED	NIGHT GUN DECK	
SETS		PROBABILITY	
	90	50	10
D(10)j*	102.7	128.9	160.0
D(10)n	84.9	99.8	115.2
D(10)o	96.3	101.7	109.1
D(10)p	102.6	116.5	130.7
Combined values for all sets	98.4	105.0	111.5

*Not included in combined values.

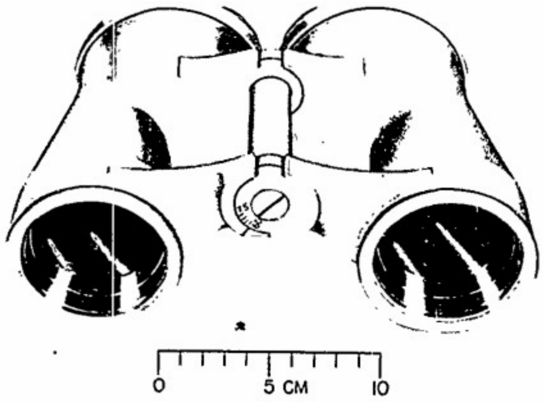
Figure A-6. (Continued) The 7x50x10° binocular with the headrest removed.

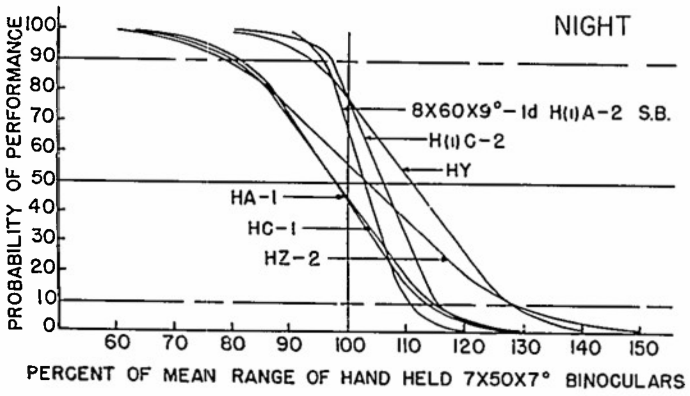




THE 8x60x9° BINOCULAR

OPTICAL SPECIFICATION	
Magnification	8
Diameter of Objective in MM	60
True Field Angle	8.85°
Apparent Field Angle	70.8°
Exit Pupil Diameter in MM	7.5
Eye Relief in MM	20.7
Light Transmission--Specified	-
--By test (at Penn State Optical Inspection Laboratory)	.65
Contrast Rendition--Day	97
--Night	92
Kinetic Definition Chart, Efficiency in %	66
Weight in Grams	3,170
Length of Instrument, CM	21.2





RRP VALUES

8 x 60 x 9°(- 1d Fixed Focus) NIGHT SIGNAL BRIDGE

SETS	PROBABILITY 90	 50	 10
HA-1	80.5	97.5	114.2
H(1)A-2	96.0	103.0	110.0
HC-1	79.8	97.5	114.3
H(1)C-2	96.0	106.0	116.0
HY	93.5	111.5	129.5
(HZ-1)	Insufficient Data		
HZ-2	78.0	104.0	130.0
Combined values for all sets	100.5	105.5	111.0

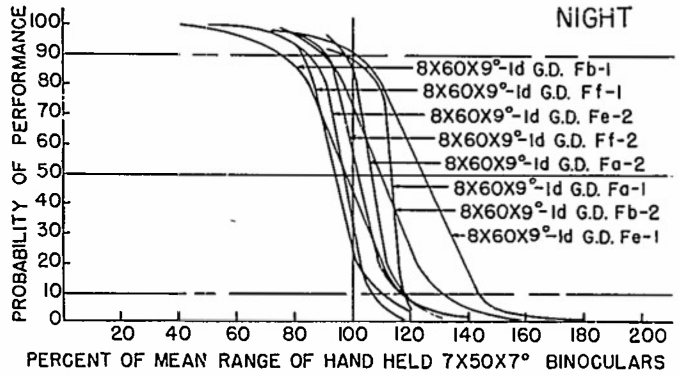


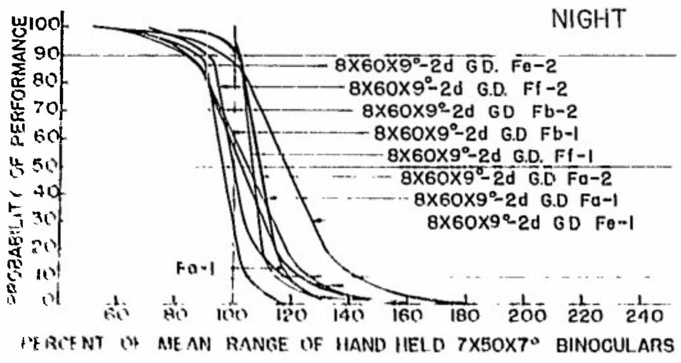
Figure A-7. The 8x60x9° binocular, a German instrument, which was tested at fixed focuses of -1 and -2 diopters.

RRP VALUES

8 x 60 x 9°(- 1d Fixed Focus) NIGHT GUN DECK

SETS	PROBABILITY 90	 50	 10
Fa-1	96.0	113.0	118.0
Fa-2	97.0	106.0	117.0
Fb-1	74.8	97.3	116.5
Fb-2	89.5	109.2	131.0
Fe-1*	100.5	124.2	143.2
Fe-2	85.0	97.0	106.2
Ff-1	82.5	93.2	110.0
FF-2	90.5	101.0	116.8
Combined values for all sets	98.5	103.8	109.0

*Not included in combined values.



FIELD TESTS OF OPTICAL INSTRUMENTS

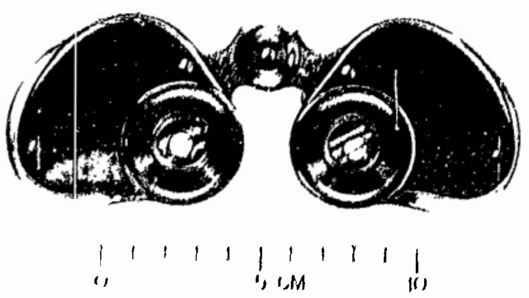
RRP VALUES

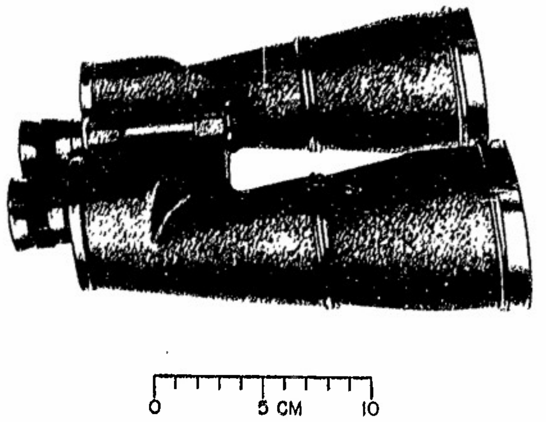
8 x 60 x 9° (– 2d Fixed Focus) NIGHT GUN DECK

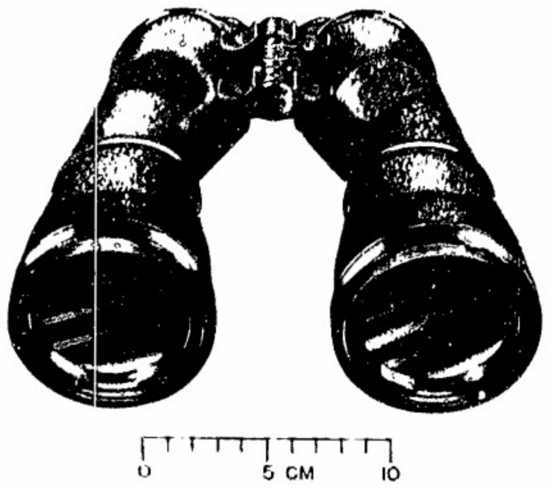
SETS	PROBABILITY 90	50	10
Fa-1	101.0	109.0	119.0
Fa-2	101.0	108.0	123.5
Fb-1	83.6	104.4	126.2
Fb-2	83.2	102.8	122.5
Fe-1*	97.0	118.5	142.5
Fe-2	86.2	96.2	104.5
Ff-1	101.3	106.5	114.5
Ff-2	90.5	100.0	117.8
Combined values for all sets:	101.7	105.9	110.0

*Not included in combined values.

Figure A-7. (Continued) The 8x60x9° binocular, a German instrument, which was tested at fixed focuses of -1 and -2 diopters.



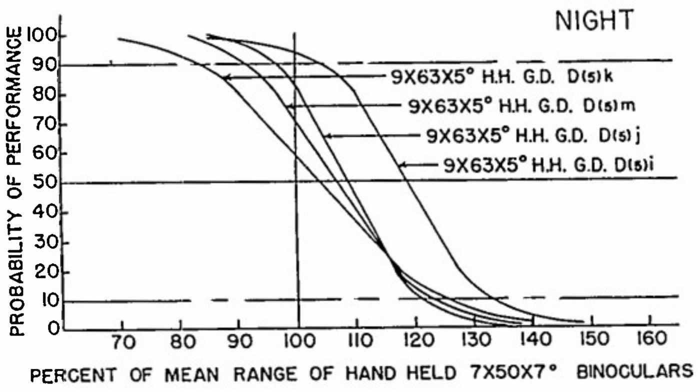




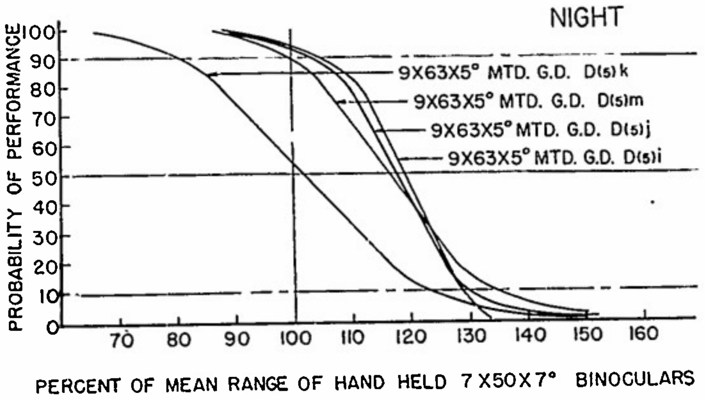
THE 9x63x5.7° BINOCULAR

OPTICAL SPECIFICATION

Magnification	9
Diameter of Objective in MM	63
True Field Angle	5.7°
Apparent Field Angle	51.3
Exit Pupil diameter in MM	7.0
Eye Relief in MM	13.5
Light Transmission--Specified	.78
--By test (at Penn State Optical Inspection Laboratory)	.72
Contrast Rendition--Day	96
--Night	94
Kinetic Definition Chart, Efficiency in %	74
Weight in Grams	1,700
Length of Instrument, CM	24.5



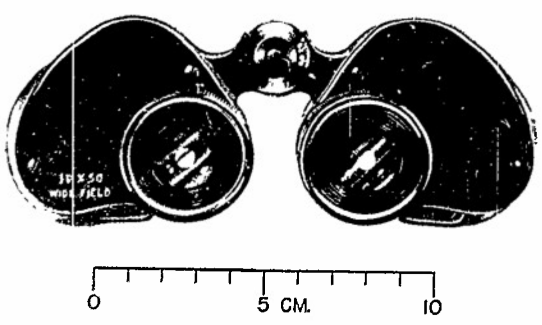
9 x 63 x 5.7°	RRP VALUES HAND-HELD	NIGHT GUN DECK	
SETS	PROBABILITY 90	50	10
D(5)i	104.3	119.0	133.0
D(5)j	96.9	109.0	116.9
D(5)k	84.0	103.8	125.6
D(5)m	91.9	107.0	122.8
Combined values for all sets	104.0	112.5	120.7

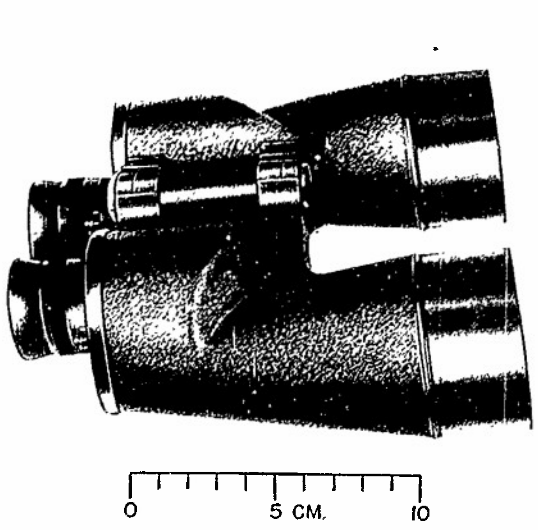


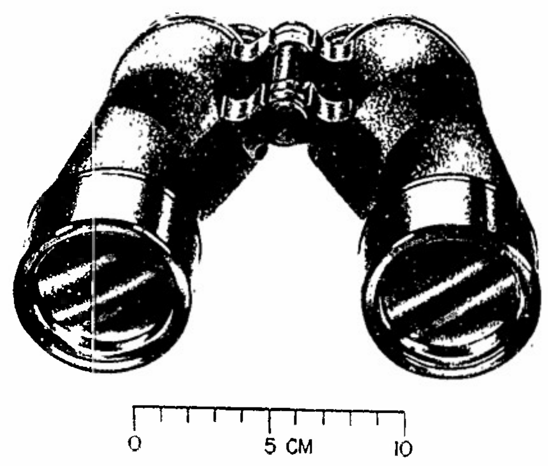
9 x 63 x 5.7°	RRP VALUES MOUNTED	NIGHT GUN DECK	
SETS	PROBABILITY 90	50	10
D(5)i	104.9	119.0	133.0
D(5)j	104.0	118.0	130.0
D(5)k*	81.0	102.0	124.2
D(5)m	99.8	116.7	135.5
Combined values for all sets	112.0	120.2	127.2

* Not included in combined values

Figure A-8. The 9x63x5.7° binocular.







THE 10x50x7° BINOCULAR

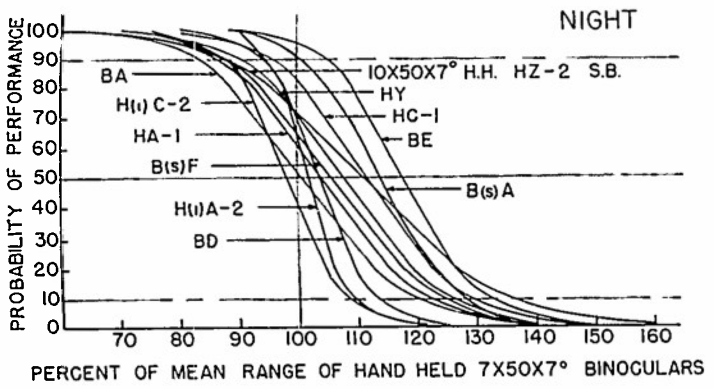
OPTICAL SPECIFICATION

Magnification	10
Diameter of Objective in MM	50
True Field Angle	7°
Apparent Field Angle	70°
Exit Pupil diameter in MM	5.0
Eye Relief in MM	14.5
Light Transmission--Specified	.77
--By test (at Penn State Optical Inspection Laboratory)	.76
Contrast Rendition--Day	98
--Night	91
Kinetic Definition Chart, Efficiency in %	69
Weight in Grams	1,290
Length of Instrument, CM	18.1

RRP VALUES

10 x 50 x 7° HAND-HELD NIGHT SIGNAL BRIDGE

SETS	PROBABILITY 90	50	10
BA	83.0	100.0	120.0
(BB)	Excluded.	Randomizing off.	
BD	94.5	104.0	113.3
BE	104.5	118.0	132.0
B(s)A	101.5+	115.5+	129.5+
B(s)F	88.0	106.5	124.0
HA-1	87.0	105.0	121.0
H(1)A-2	96.0	102.0	109.0
HC-1	96.0	112.5	129.5
H(1)C-2	88.0	97.5	108.8
HY	97.5	113.0+	132.0+
(HZ-1)	Insufficient Data.		
Hz-2	86.0	111.5	136.5
Combined values for all sets	101.2	106.7	112.0



RRP VALUES

10 x 50 x 7° HAND-HELD NIGHT GUN DECK

SETS	PROBABILITY 90	50	10
Hi	108.5	117.0	127.0
Hj	91.0	116.0	139.0
Hk	86.0	105.5	125.0
Hl	104.0	117.0	129.5
Combined values for all sets	109.0	117.0	124.0

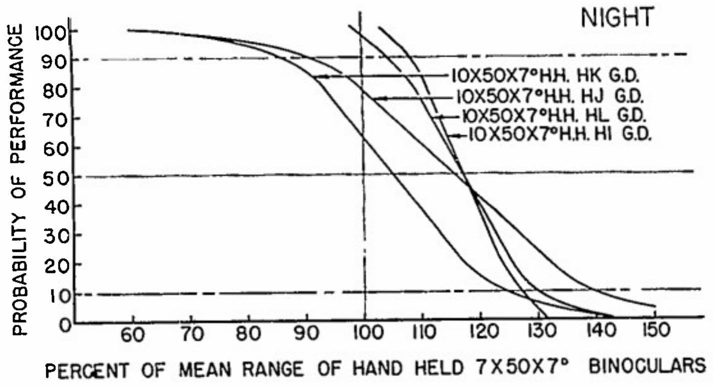
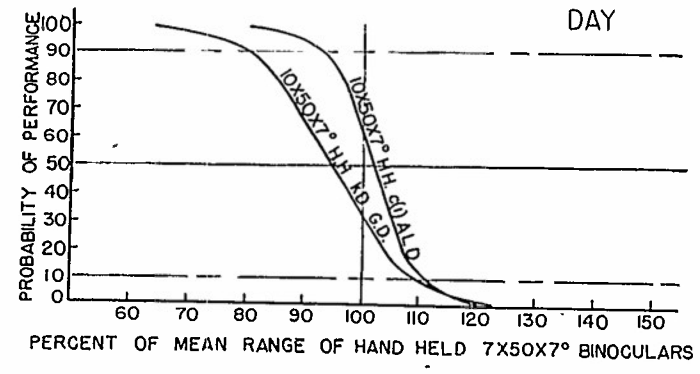
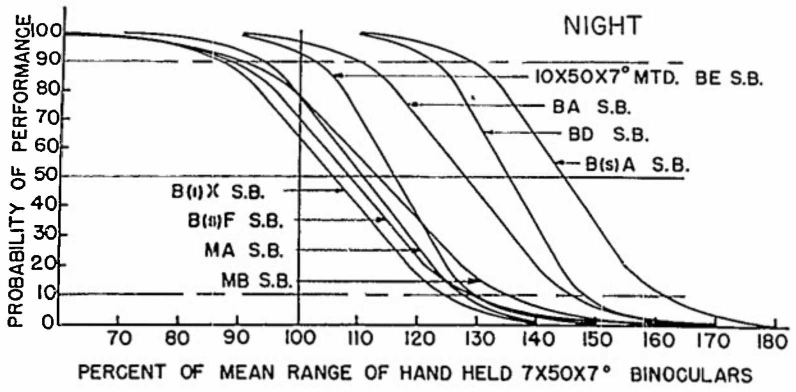


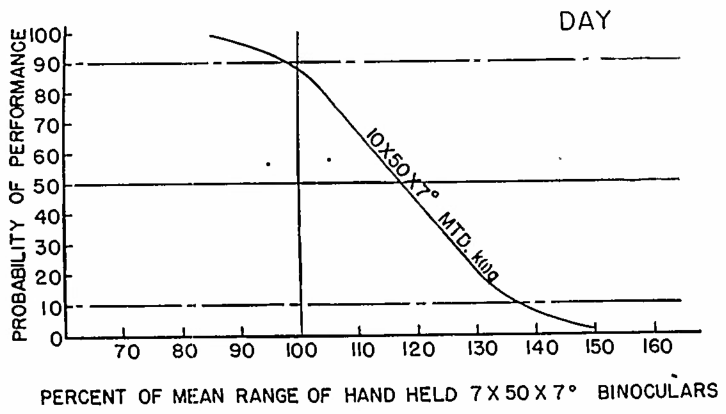
Figure A-9. The 10x50x7°, which performed well both hand-held and mounted.



10 x 50 x 7°	RRP VALUES HAND-HELD		DAY
SETS		PROBABILITY	
	90	50	10
C(1)A (Lower Deck)	93.0	102.0	111.0
kD (Gun Deck)	81.0	95.0	109.5
Combined values for all sets	90.5	100.2	108.0

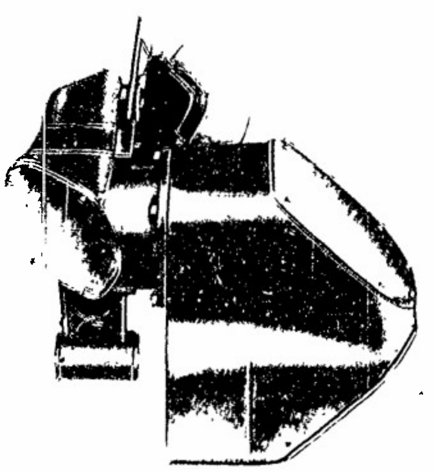


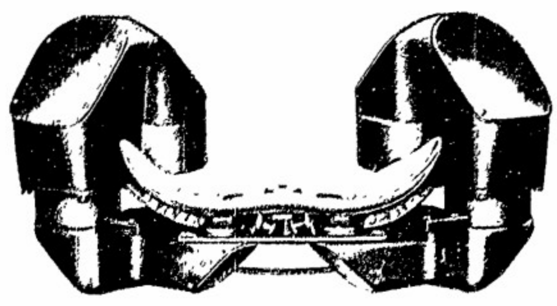
10 x 50 x 7°	RRP VALUES MOUNTED		NIGHT SIGNAL BRIDGE
SETS		PROBABILITY	
	90	50	10
BA	109.5	127.5	146.0
B(s)A	129.0	145.0	162.0
(BB)	Excluded.	Randomizing off.	
BD	122.5	135.2	148.5
BE	102.5	116.0	129.5
B(s)F	88.5	108.5	129.5
B(l)X	87.5	105.5	125.4
Ma	94.0	110.2	127.5
MB	88.0	112.0	135.8
Combined values for all sets	113.0	122.3	132.3



10 x 50 x 7°	RRP VALUES MOUNTED		DAY SIGNAL BRIDGE A
SETS		PROBABILITY	
	90	50	10
K(l)q	98.5	117.5	137.0

Figure A-9. (Continued) The 10x50x7° binocular which performed well both hand-held and mounted.

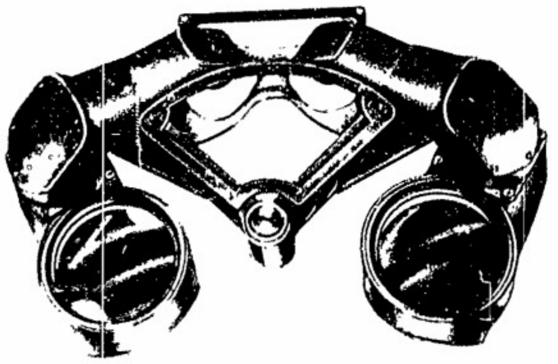


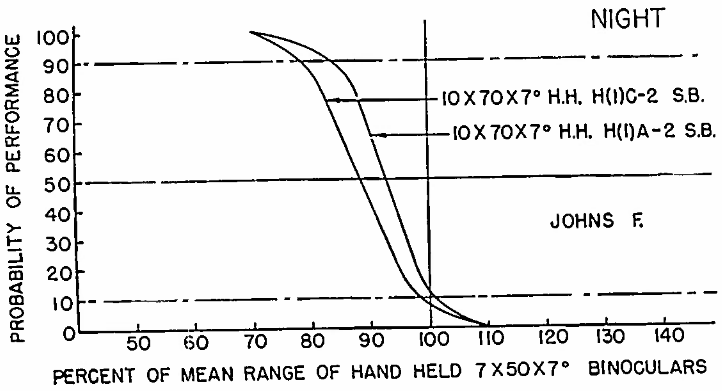


THE 10x70x7° BINOCULAR (JF)

OPTICAL SPECIFICATION

Magnification	10
Diameter of Objective in MM	70
True Field Angle	7°
Apparent Field Angle	70°
Exit Pupil diameter in MM	7.0
Eye Relief in MM	21.0
Light Transmission--Specified	-
--By test (at Penn State Optical Inspection Laboratory)	.40
Contrast Rendition--Day	95.
--Night	94.
Kinetic Definition Chart, Efficiency in %	
Weight in Grams	2,270
Length of Instrument, CM	17.0

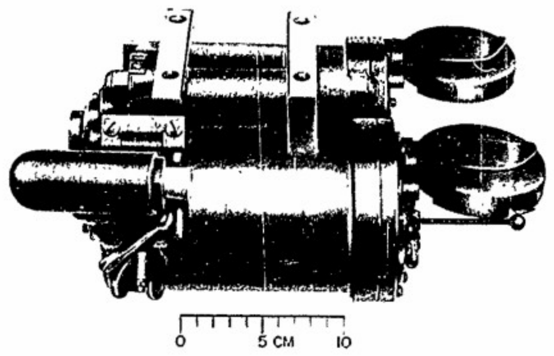


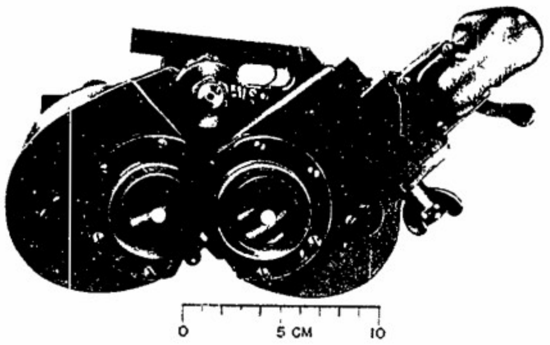


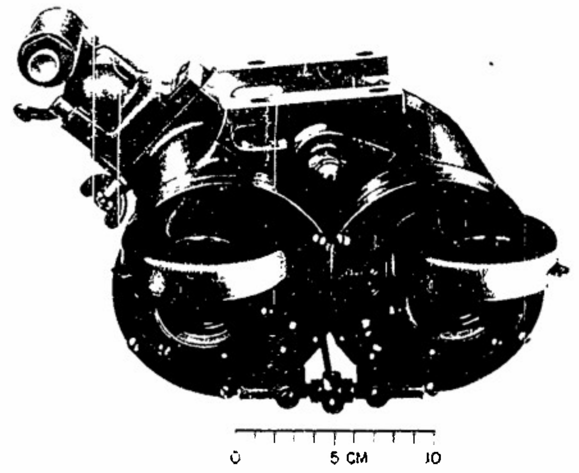
RRP VALUES

10 x 70 x 7° (Johnson Foundation) HAND-HELD		NIGHT SIGNAL BRIDGE	
SETS	PROBABILITY		
	90	50	10
H(1)A-2	85.0	92.5	100.5
H(1)C-2	79.0	88.5	98.8
Combined values for all sets	84.0	92.0	96.5

Figure A-10. The 10x70x7° folded binocular developed by the Johnson Foundation.







THE 6x50x7° BINOCULAR

OPTICAL SPECIFICATION

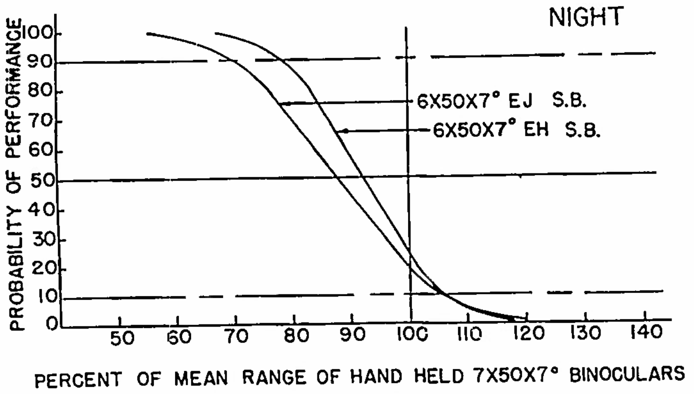
Magnification	6
Diameter of Objective in MM	50
True Field Angle	7°
Apparent Field Angle	42°
Exit Pupil diameter in MM	8.4
Eye Relief in MM	25.0
Light Transmission--Specified	.67
--By test (at Penn State Optical Inspection Laboratory)	.62
Contrast Rendition--Day	97
--Night	90
Kinetic Definition Chart, Efficiency in %	93
Weight in Grams	19,650
Length of Instrument, CM	24.0

RRP VALUES

6 x 50 x 7° MOUNTED NIGHT SIGNAL BRIDGE

SETS	PROBABILITY		
	90	50	10
EH	78.5	92.0	106.0
EJ	70.0	88.0	105.5
(Ep)*	Insufficient	Data:	Visibility
(Et)*	Insufficient	Data:	Visibility
Combined values for all sets	80.7	91.9	103.0

*Not included in combined values.



RRP VALUES

6 x 42 x 7° MOUNTED NIGHT SIGNAL BRIDGE

SETS	PROBABILITY		
	90	50	10
EH	76	90.5	104.5
EJ	73.5	90.0	106.0
(Ep)*	Insufficient	Data:	Visibility
(Et)*	Insufficient	Data:	Visibility
Combined values for all sets	73.4	88.0	101.0

*Not included in combined values.

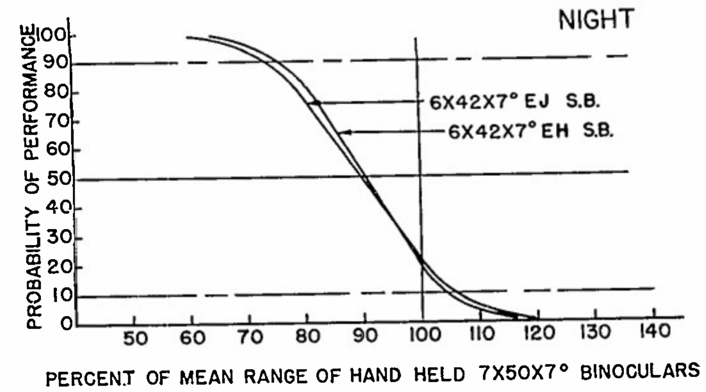
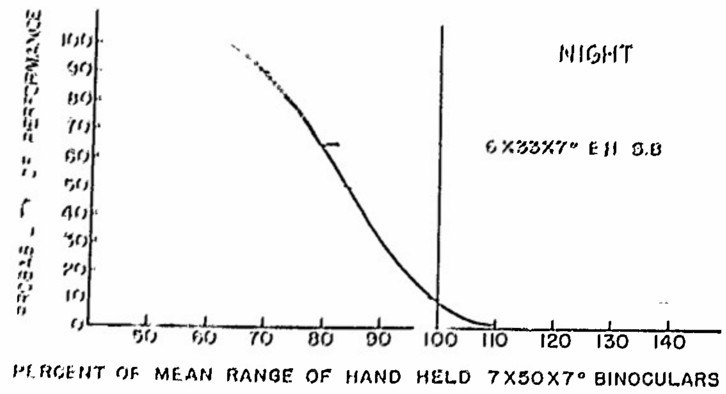


Figure A-11. The 6x50x7° mounted binocular. This instrument was also tested as a 6x33x7° and a 6x42x7° binocular.

6 x 33 x 7° RRP VALUES MOUNTED NIGHT SIGNAL BRIDGE

SETS	PROBABILITY 90	50	10
EH	69.5	84.5	99.5
EJ	Insufficient Data		
Combined values for all sets	Insufficient Data		



6 x 33 x 7° RRP VALUES MOUNTED NIGHT GUN DECK

SETS	PROBABILITY 90	50	10
(Ep)	Insufficient Data:		Visibility
(Et)	Insufficient Data:		Visibility

6 x 33 x 7° RRP VALUES MOUNTED DAY SIGNAL BRIDGE A

SETS	PROBABILITY 90	50	10
oL	84.0	103.5	120.5
oH	81.5	90.0	98.0
o(1)l	87.0	96.0	104.5
Combined values for all sets	86.5	94.0	101.0

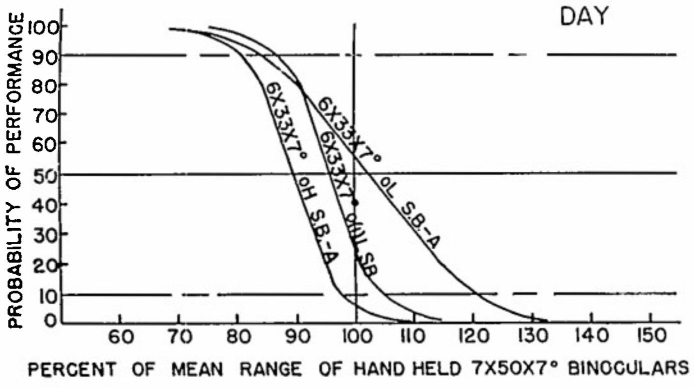
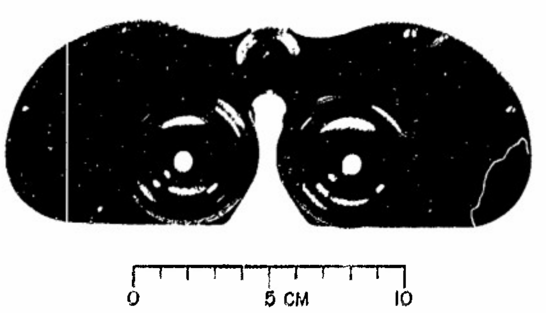
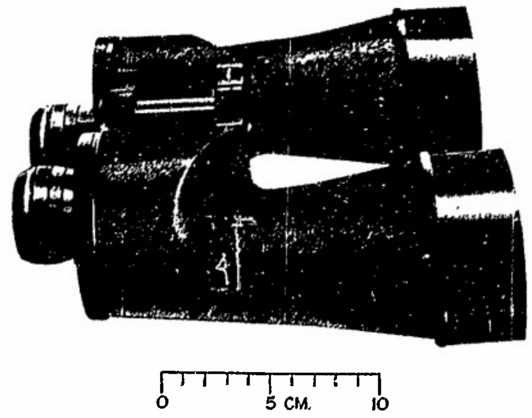
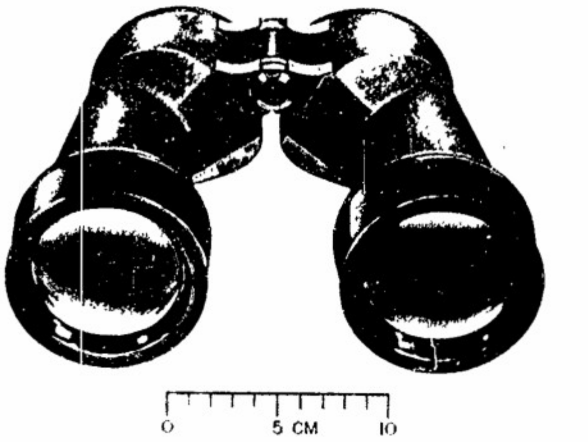


Figure A-11. (Continued) The 6x50x7° mounted binocular. This instrument was also tested as a 6x33x7° and a 6x42x7° binocular.

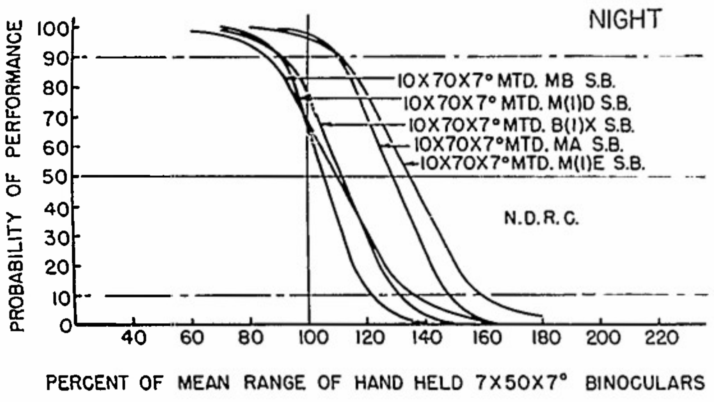






THE 10x70x7° BINOCULAR (NDRC)

OPTICAL SPECIFICATION	
Magnification	10
Diameter of Objective in MM	70
True Field Angle	7°
Apparent Field Angle	70°
Exit Pupil diameter in MM	7.0
Eye Relief in MM	21.0
Light Transmission--Specified	.74
--By test (at Penn State Optical Inspection Laboratory)	.66
Contrast Rendition--Day	90
--Night	82
Kinetic Definition Chart, Efficiency in %	77
Weight in Grams	3,690
Length of Instrument, CM	23.7

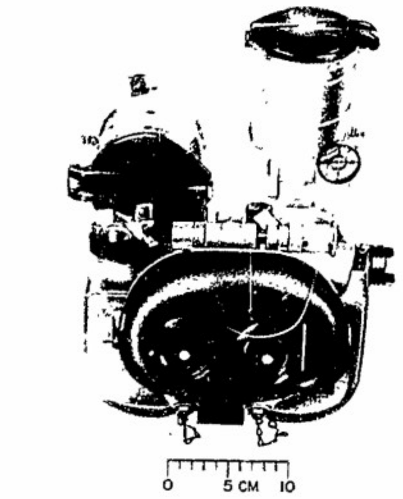


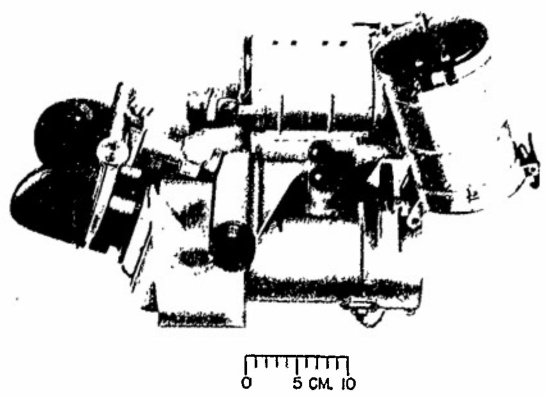
RRP VALUES

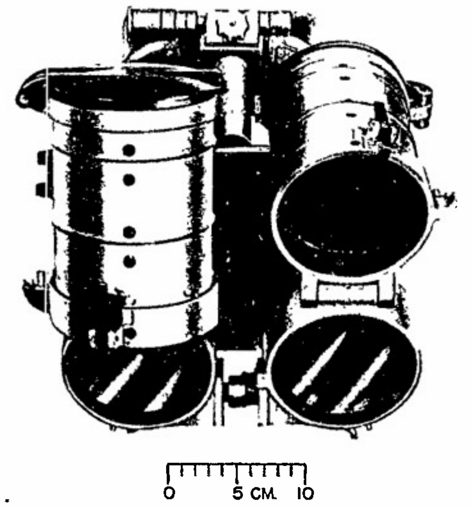
10 x 70 x 7° (NDRC) MOUNTED NIGHT SIGNAL BRIDGE

SETS	PROBABILITY 90	50	10
B(1)X	92.0	111.5	130.5
MA	110.5	129.0	147.0
MB	85.5	110.0	135.0
(M(1)D)	Excluded.	High winds.	
M(1)E	112.0	136.0	158.5
Combined values for all sets	106.0	119.5	132.5

Figure A-12. The 10x70x7° binocular developed by NDRC was tested in a mount.

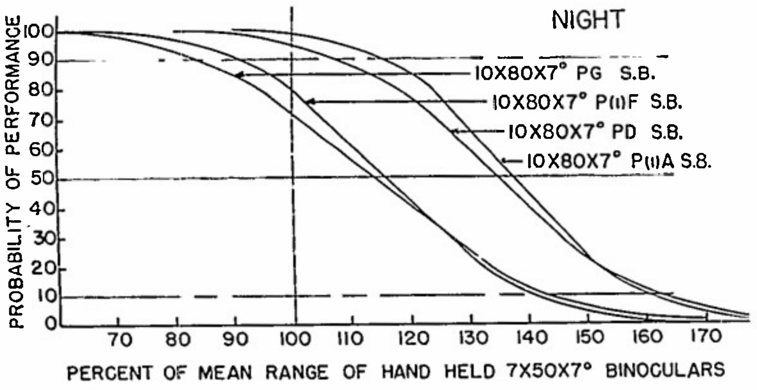






THE 10x80x7° BINOCULAR

OPTICAL SPECIFICATION	
Magnification	10
Diameter of Objective in MM	80
True Field Angle	7.04°
Apparent Field Angle	70.4°
Exit Pupil diameter in MM	8.0
Eye Relief in MM	25.5
Light Transmission--Specified	-
--By test (at Penn State Optical Inspection Laboratory)	.48
Contrast Rendition--Day	88
--Night	86
Kinetic Definition Chart, Efficiency in %	
Weight in Grams	13,200
Length of Instrument, CM	55.0



10 x 80 x 7°	RRP VALUES MOUNTED	NIGHT SIGNAL BRIDGE	
SETS	PROBABILITY		
	90	50	10
P(1)A	116.5	138.5	161.5
PD	108.0	135.0	162.5
P(1)F	91.0	116.0	141.0
PG	85.0	114.0	143.0.
Combined values for all sets	116.8	133.0	146.2

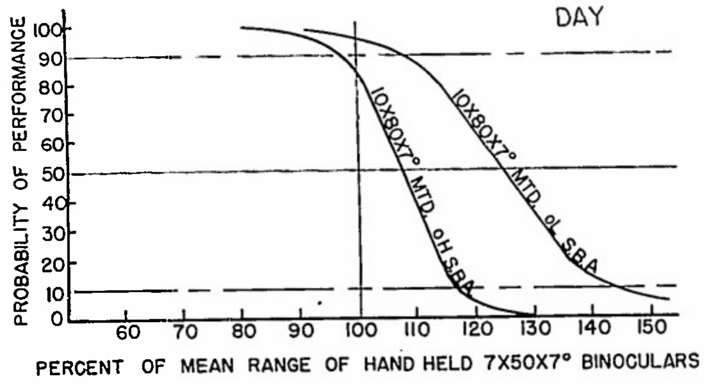
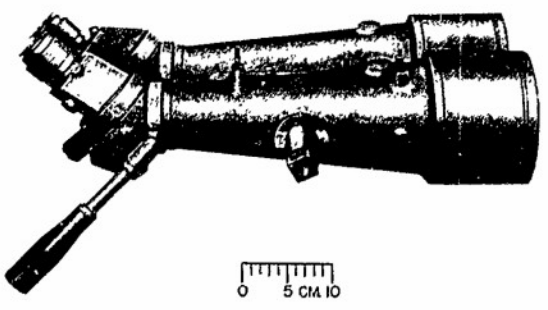
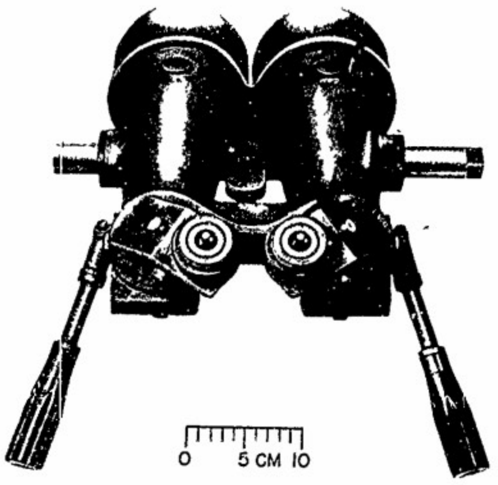
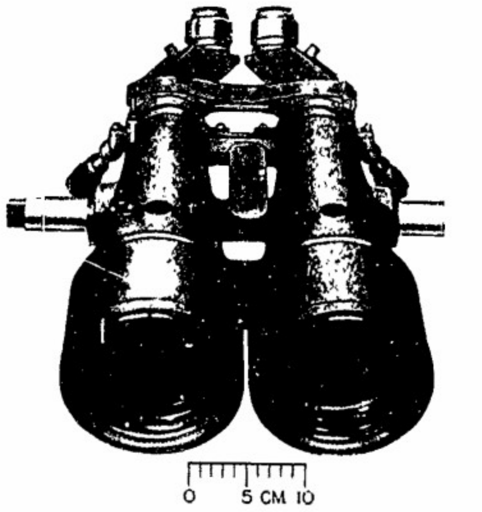


Figure A-13. The 10x80x7° mounted binocular was a German instrument. Note the large sunshades.

10 x 80 x 7°	RRP VALUES MOUNTED	DAY SIGNAL BRIDGE A	
SETS	PROBABILITY		
	90	50	10
oL	108.0	125.0	144.0
oH	98.0	108.0	116.5
Combined values for all sets	104.0	114.0	125.0







THE 20x120x3° BINOCULAR

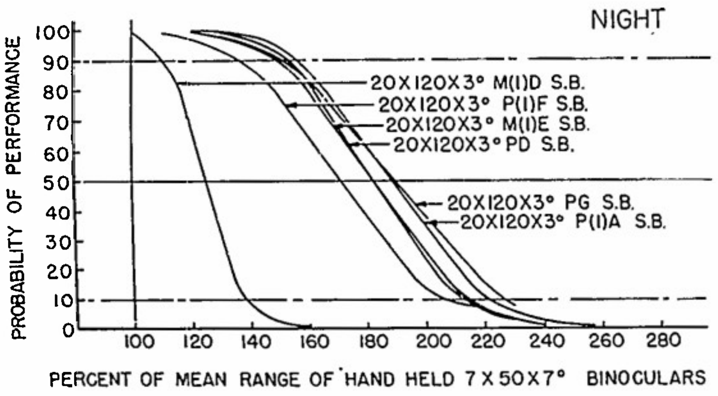
OPTICAL SPECIFICATION	
Magnification	20
Diametor of Objoctive in MM	120
Truo Fiold Angle	3°
Apparent Field Angle	60°
Exit Pupil diameter in MM	6.0
Eye Relief in MM	13.2
Light Transmission--Specified	.69
--By test (at Ponn State Optical Inspection Laboratory)	.61
Contrast Rendition--Day	96
--Night	94
Kinetic Definition Chart, Efficiency in %	
Woight in Grams	23,900
Length of Instrument, CM	59.5

RRP VALUES

20 x 120 x 3°	MOUNTED	NIGHT SIGNAL BRIDGE	
SETS	PROBABILITY		
	90	50	10
(M(1)D)	Excluded from final results. High winds.		
M(1)E	151.0	183.0	-
P(1)A	157.0	189.0	219.0
PD	153.0	180.0	213.0
P(1)F	137.5	171.5	-
PG	149.0	187.5	225.5
Combined values for all sets	170.0	188.0	205.8

RRP VALUES

20 x 120 x 3°	MOUNTED	DAY SIGNAL BRIDGE B	
SETS	PROBABILITY		
	90	50	10
pE	142.5	193.0	231.0
pF (See Appendix B)	106.0	133.5	162.0
Combined values for all sets	142.5	193.0	231.0



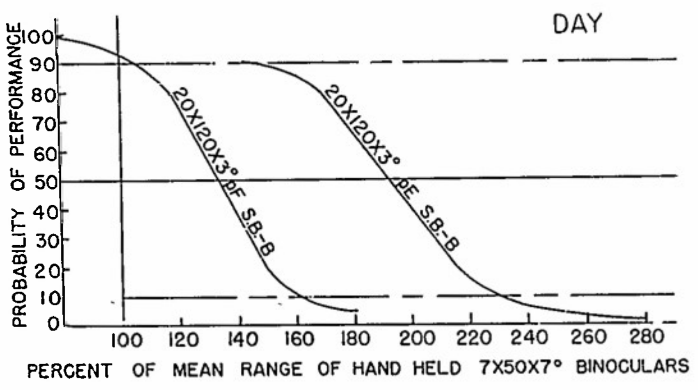
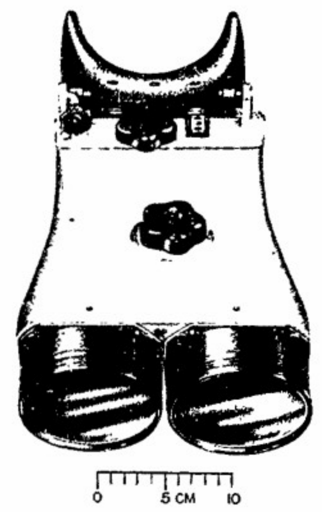


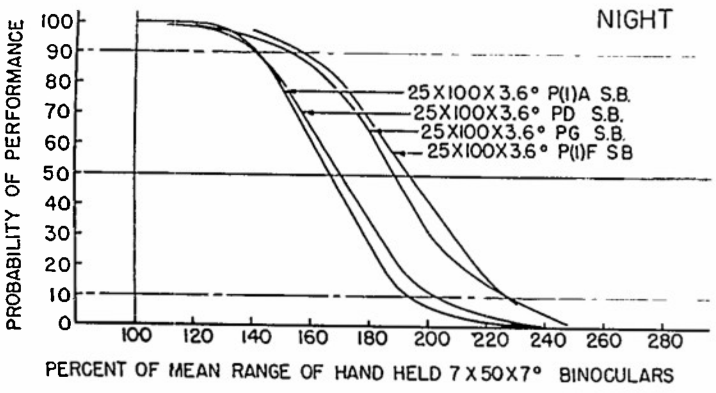
Figure A-14. The 20x120x3° mounted binocular.



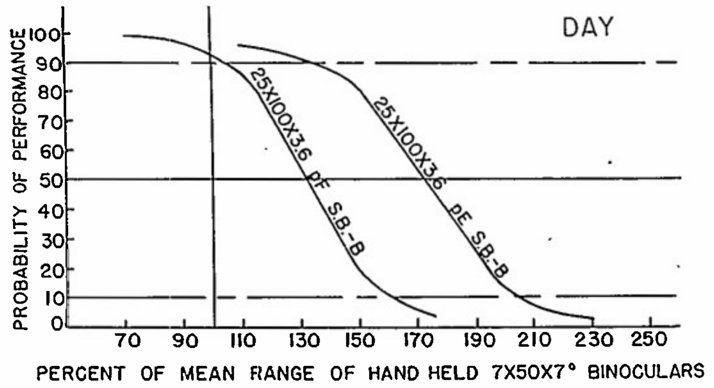
THE 25x100x3.6° BINOCULAR

OPTICAL SPECIFICATION

Magnification	25
Diameter of Objective in MM	100
True Field Angle	3.6°
Apparent Field Angle	90°
Exit Pupil diameter in MM	4.0
Eye Relief in MM	11.2
Light Transmission--Specified	-
--By test (at Penn State Optical Inspection Laboratory)	.65
Contrast Rendition--Day	94
--Night	92
Kinetic Definition Chart, Efficiency in %	
Weight in Grams	10,200
Length of Instrument, CM	70.0

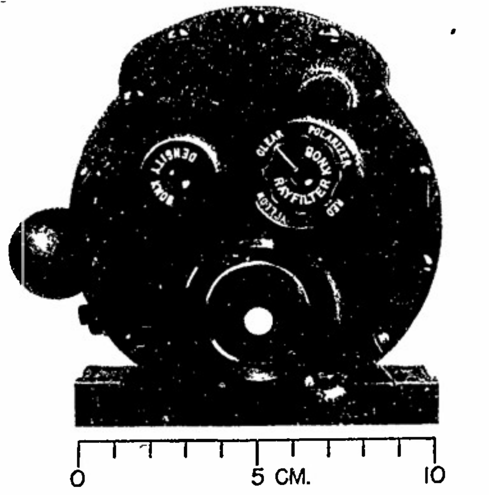


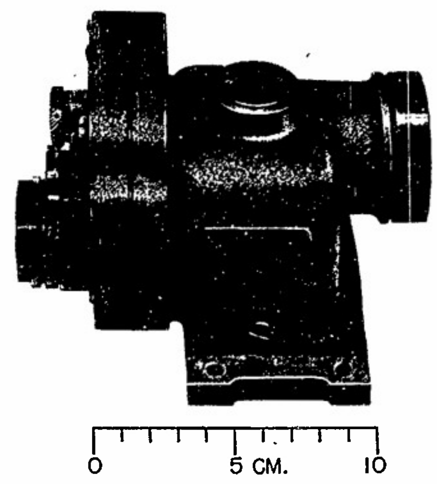
25 x 100 x 3.6°	RRP VALUES MOUNTED	NIGHT SIGNAL BRIDGE	
SETS		PROBABILITY	
	90	50	10
P(1)A	142.5	167.0	193.5
PD	141.5	170.0	208.5+
P(1)F	152.0	191.0	229.5
PG	156.0	191.8	228.0
Combined values for all sets	160.0	179.9	197.0

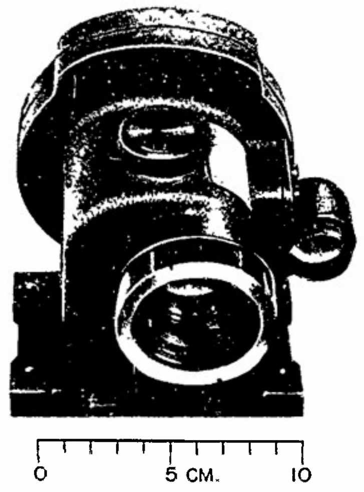


25 x 100 x 3.6°	RRP VALUES MOUNTED	DAY SIGNAL BRIDGE B	
SETS		PROBABILITY	
	90	50	10
pE	134.0	173.5	205.0
pF (See Appendix B)	105.5	132.5	162.5
Combined values for all sets	134.0	173.5	205.0

Figure A-15. The 25x100x3.6° mounted binocular was a German instrument.

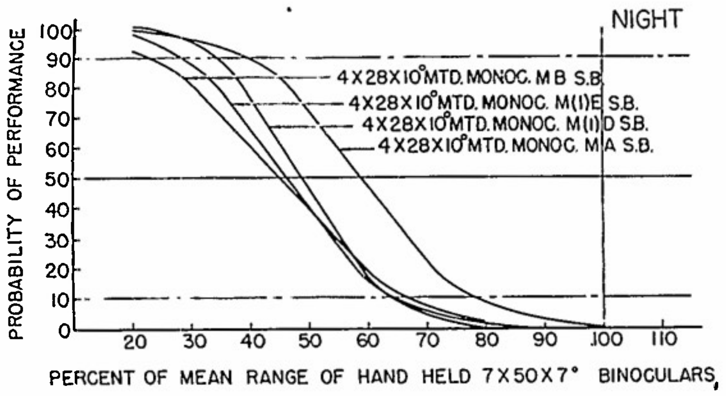






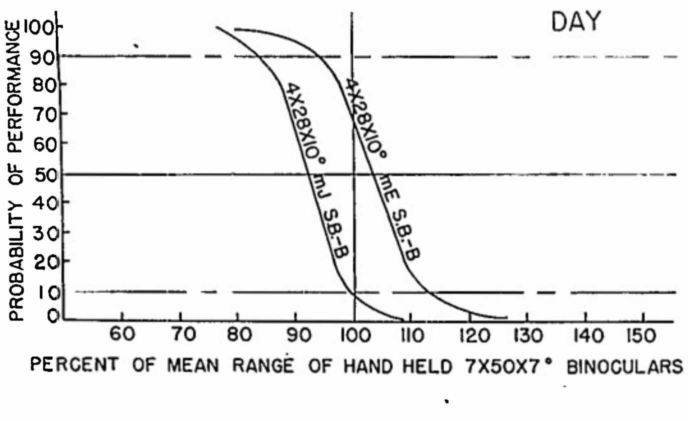
THE 4x28x10° MONOCULAR

OPTICAL SPECIFICATION	
Magnification	4
Diameter of Objective in MM	28
True Field Angle	10°
Apparent Field Angle	40°
Exit Pupil diameter in MM	7.0
Eye Relief in MM	33.5
Light Transmission--Specified	.69
--By test (at Penn State Optical Inspection Laboratory)	.61
Contrast Rendition--Day	95
--Night	85
Kinetic Definition Chart, Efficiency in %	89
Weight in Grams	4,220
Length of Instrument, CM	15.3



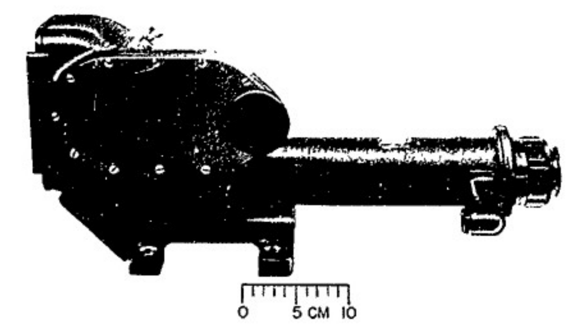
4 x 28 x 10°	RRP VALUES MOUNTED MONOCULAR	NIGHT SIGNAL BRIDGE	
SETS	PROBABILITY		
	90	50	10
MA	40.0	59.0	79.5
MB	23.5	45.0	67.5
(M(1)D)	Excluded.	High winds.	
M(1)E*			
Combined values for all sets	43.3	53.0	71.0

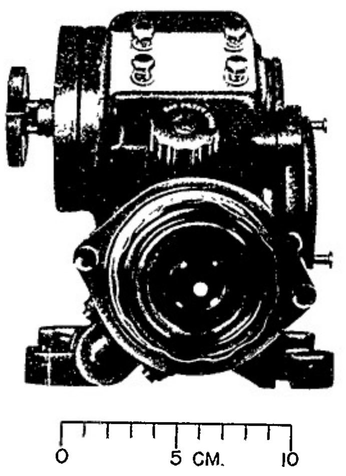
*Not included in combined values

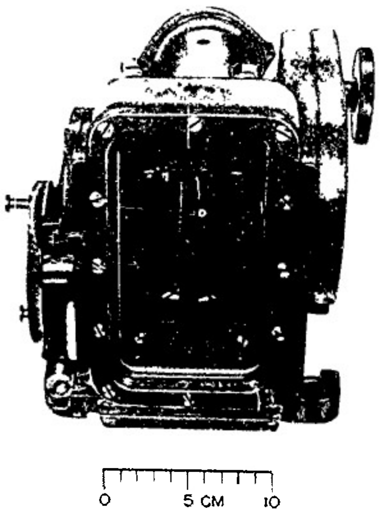


4 x 28 x 10°	RRP VALUES MOUNTED MONOCULAR	DAY SIGNAL BRIDGE B	
SETS	PROBABILITY		
	90	50	10
mE	94.5	103.8	113.0
mJ	84.0	92.5	100.0
Combined values for all sets	90.0	97.2	104.5

Figure A-16. The 4x28x10° mounted monocular.







THE 6x30x8.5° MONOCULAR

OPTICAL SPECIFICATION	
Magnification	6
Diameter of Objective in MM	30
True Field Angle	8.5°
Apparent Field Angle	51°
Exit Pupil diameter in MM	5.0
Eye Relief in MM	30.0
Light Transmission--Specified	.58
--By test (at Penn State Optical Inspection Laboratory)	.47
Contrast Rendition--Day	98
--Night	96
Kinetic Definition Chart, Efficiency in %	86
Weight in Grams	240,000
Length of Instrument, CM	53.6

6 x 30 x 8.5°	RRP VALUES MOUNTED MONOCULAR		NIGHT SIGNAL BRIDGE
SETS	PROBABILITY 90	50	10
MA	34.5	51.0	69.5
MB	18.0+	47.0+	74.5+
(M(1)D)	Excluded.	High winds.	
M(1)E*			
Combined values for all sets	39.0	53.0	66.0

*Not included in combined values.

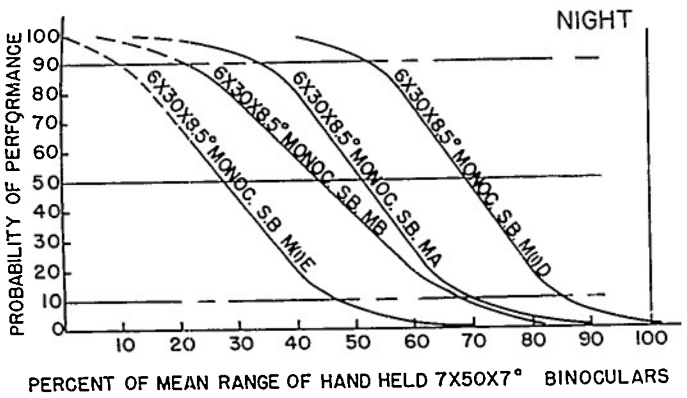


Figure A-17. The 6x30x8.5° mounted monocular.

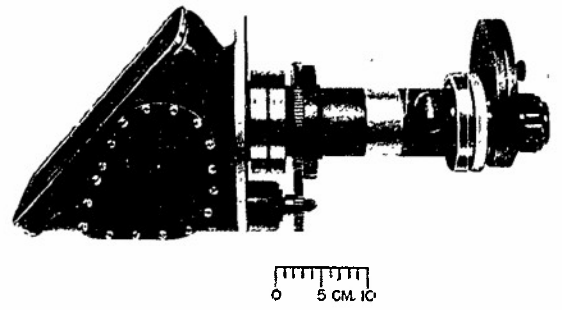
6 x 33 x 7°	RRP VALUES MOUNTED MONOCULAR		NIGHT SIGNAL BRIDGE
SETS	PROBABILITY 90	50	10
EM	83.0	98.0	110.5
EJ	60.5	78.0	95.5
(NO)*	Insufficient	Data:	Visibility
(NS)*	Insufficient	Data:	Visibility
Combined values for all sets	73.4	88.0	101.0

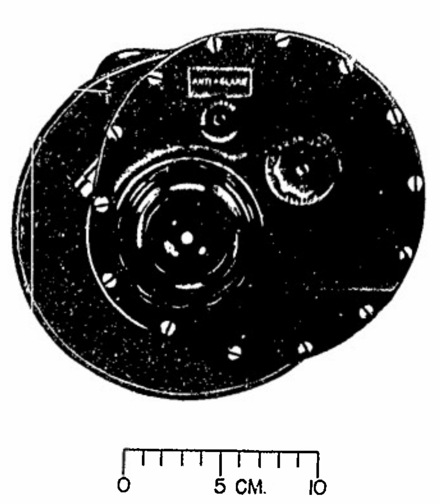
*Not included in combined values.

THE 6x33x7° MONOCULAR

OPTICAL SPECIFICATION	
Magnification	6.
Diameter of Objective in MM	33
True Field Angle	7°
Apparent Field Angle	42°
Exit Pupil diameter in MM	5.5
Eye Relief in MM	25.0
Light Transmission--Specified	-
--By test (at Penn State Optical Inspection Laboratory)	.56
Contrast Rendition--Day	95
--Night	89
Kinetic Definition Chart, Efficiency in %	
Weight in Grams	19,750
Length of Instrument, CM	24

Figure A-18. The 6x33x7° monocular. This instrument was a modification of the 6x50x7° shown in Fig. 11.

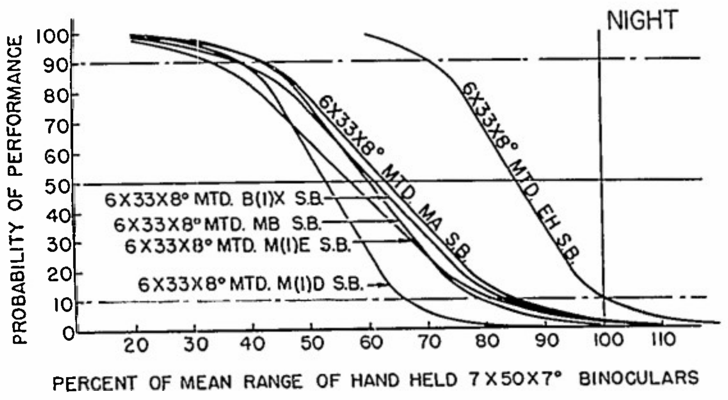




THE 6x33x8° MONOCULAR

OPTICAL SPECIFICATION

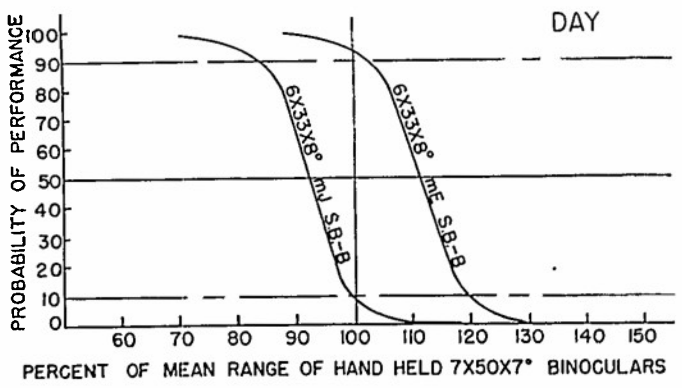
Magnification	6
Diameter of Objective in MM	33
True Field Angle	8°
Apparent Field Angle	48°
Exit Pupil diameter in MM	5.5
Eye Relief in MM	35.3
Light Transmission--Specified	.58
--By test (at Penn State Optical Inspection Laboratory)	.45
Contrast Rendition--Day	91
--Night	75
Kinetic Definition Chart, Efficiency in %	-
Weight in Grams	34,700
Length of Instrument, CM	62.4



RRP VALUES

6 x 33 x 8°	MOUNTED MONOCULAR	NIGHT SIGNAL BRIDGE	
SETS	PROBABILITY		
	90	50	10
B(1)X	42.0	60.0	79.0
EH	71.5	85.5	99.5
EJ*			
MA	42.3	63.0	84.0
MB	38.5	61.8	82.5
(M(1)D)	Excluded.	High winds.	
M(1)E	34.5	57.0	82.0
(No)*	Insufficient	Data:	Visibility
(Ns)*	Insufficient	Data:	Visibility
Combined values for all sets	53.8	64.9	75.0

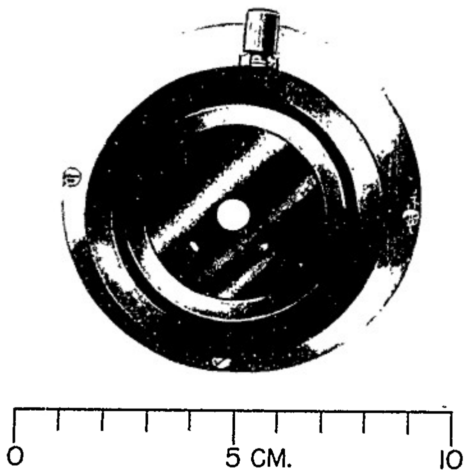
*Not included in combined values.

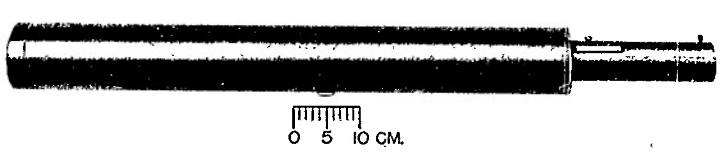


RRP VALUES

6 x 33 x 8°	MOUNTED MONOCULAR	DAY SIGNAL BRIDGE	
SETS	PROBABILITY		
	90	50	10
mE	103.0	111.8	119.0
mJ	84.2	92.5	99.0
Combined values for all sets	91.5	100.0	109.0

Figure A-19. The 6x33x8° mounted monocular.





THE 16x96x3.2° MONOCULAR

OPTICAL SPECIFICATION

Magnification	16	24
Diameter of Objective in MM	96	96
True Field Angle	3.16°	2.10°
Apparent Field Angle	50.6°	50.4°
Exit Pupil diameter in MM	9.6	9.6
Eye Relief in MM	34.0	34.0
Light Transmission--Specified	.77	.77
--By test (at Penn State Optical Inspection Laboratory)		*
Contrast Rendition--Day		*
--Night		*
Kinetic Definition Chart, Efficiency in %		*
Weight in Grams		7,750
Length of Instrument, CM		113.5

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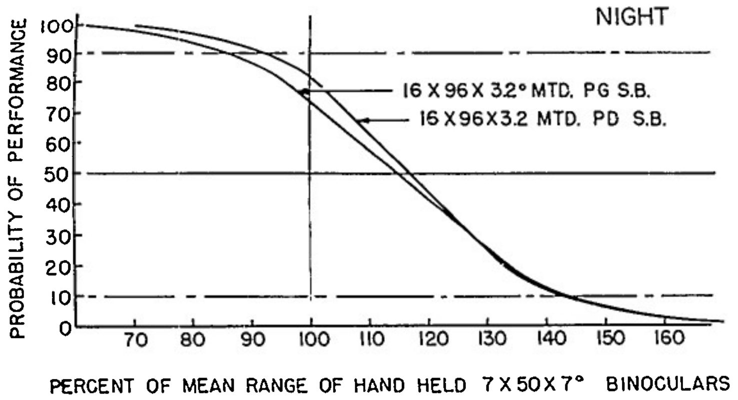
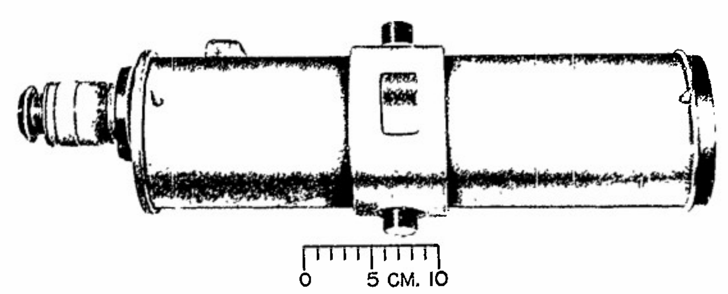
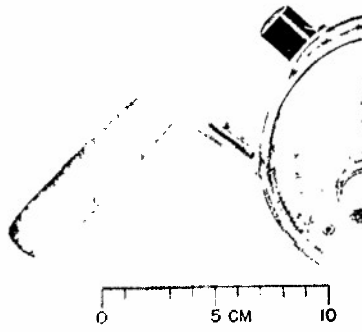
*Instrument damaged in shipment; measurement not possible.



16 x 96 x 3.2°	RRP VALUES MOUNTED MONOCULAR	NIGHT SIGNAL BRIDGE	
SETS	PROBABILITY		
	90	50	10
PD	93.0	117.0	142.5
PG	85.5	115.0	145.0
Combined values for all sets	93.0	117.0	143.0

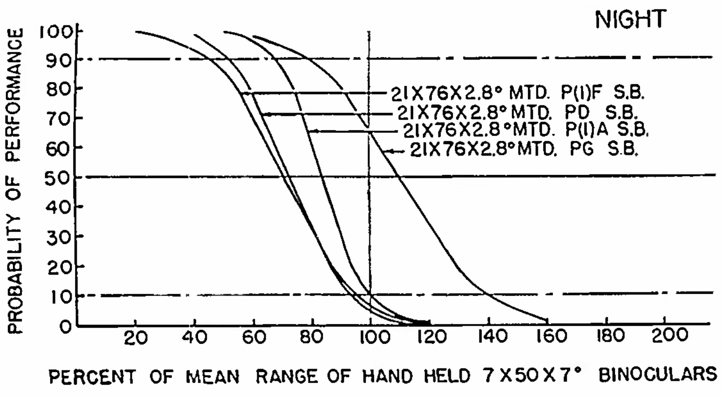
Figure A-20. The 16x96x3.2° telescope has an adjustable eyepiece so that it can also be a 24x96x2.1° monocular.



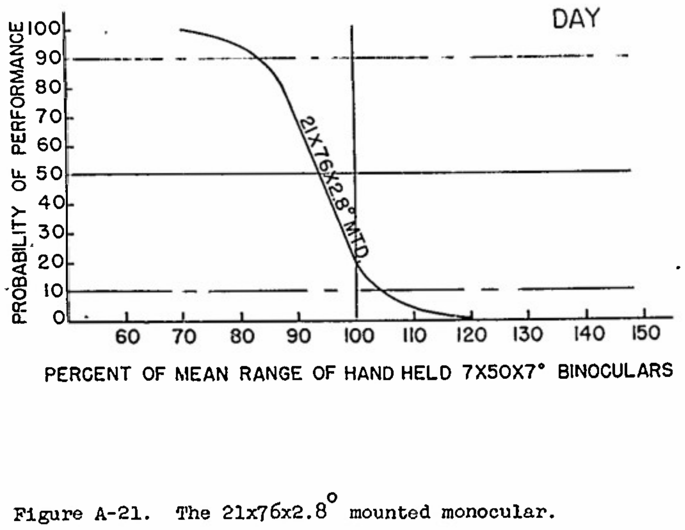


THE 21x76x2.8° MONOCULAR

OPTICAL SPECIFICATION	
Magnification	21
Diameter of Objective in MM	76
True Field Angle	2.8°
Apparent Field Angle	58.8°
Exit Pupil Diameter in MM	3.6
Eye Relief in MM	21.7
Light Transmission--Specified	.46
--By test (at Penn State Optical Inspection Laboratory)	.50
Contrast Rendition--Day	96
--Night	94
Kinetic Definition Chart, Efficiency in %	
Weight in Grams	9,400
Length of Instrument, CM	65.0

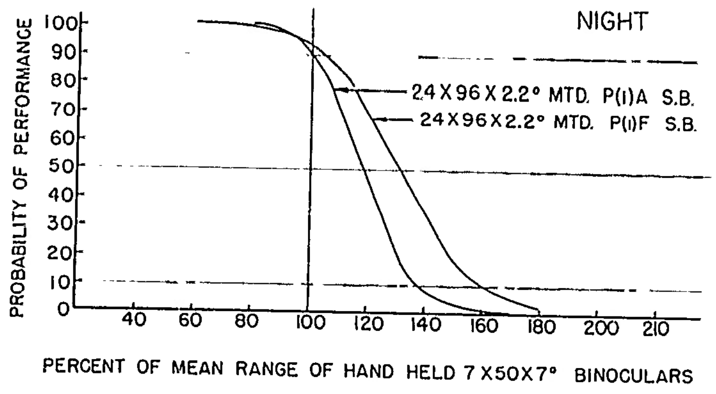


21x76x2.8°	RRP VALUES MOUNTED MONOCULAR	NIGHT SIGNAL BRIDGE	
SETS		PROBABILITY	
	90	50	10
P(1)A	69.0	84.5	100.0
PD	52.5	73.0	93.0
P(1)F	45.0	71.5	96.0
PG	80.0	110.0	139.0
Combined values for all sets	67.5	79.8	91.5



21 x 76 x 2.8°	RRP VALUES MOUNTED MONOCULAR	DAY SIGNAL BRIDGE A	
SETS		PROBABILITY	
	90	50	10
o(1)L	83.5	93.8	104.0

Figure A-21. The 21x76x2.8° mounted monocular.



24 x 96 x 2.2°	RRP VALUES MOUNTED MONOCULAR		NIGHT SIGNAL BRIDGE
SETS	PROBABILITY 90	50	10
P(1)A	101.0	119.0	138.0
P(1)F .	103.0	132.0	160.0
Combined values for all sets	111.3	125.2	145.5

Figure A-22. The 24x96x2.2 monocular. This is a modification of the 16x96x3.2° instrument shown in Fig. A-20.

APPENDIX B

APPENDIX B

Appendix B is a complete report on the experiment. In Part I, full detail of all procedures, both operational and statistical, is given, so that the techniques and methods may be evaluated in fine and so that such techniques as have been developed may serve to guide those who, at some later date, may attempt to perform a similar experiment.

Part II contains certain results not immediately relevant to the primary purpose of the experiment (which was to compare optical instruments).

More important, however, Appendix B presents in detail all results included in the report itself, and extends and clarifies each of them. An attempt has been made in preparing Appendix B to foresee questions and objections which may arise in the critical reading of the report, and to present the full information which may assist the technical reader in evaluating the experiment for himself.

For the convenience of the reader, the order of presentation of material in Appendix B roughly follows that of the report proper.

HISTORY OF THE EXPERIMENT AND INTRODUCTION

Since the beginning of the recent war, a number of problems in optical design have been continuously present. Decisions on matters of optical design have been required regularly in the procurement of binoculars, telescopes and optical fire-control apparatus. In the absence of definitive knowledge, decisions have been made on the basis of "experience" or (until recently) of incomplete laboratory work, the results of which are difficult to evaluate and apply in terms of the actual conditions of service. The Bureau of Ordnance has frequently found it necessary - and difficult - to adopt new optical designs in the absence of quantitative field data and to design new sights or other equipment without definitive and concrete evidence, theoretical or practical, as to the relative weight to be assigned such variables as magnification, exit-pupil diameter and field size.

Although military problems have stimulated a great amount of research in binoculars and other optical equipment, and many laboratories both in the United States and abroad have investigated one or another aspect of the problems raised, a remarkably small amount of experimentation has ever occurred under field conditions. The work of Hyde* and his associates in 1917-1918 stands almost alone, and its results are restricted in scope.

In the late war, only one attempt to

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* Hyde, E. P., Cobb, P. W., Johnson, H. M. and Weniger, W. The Relative Merits of Monocular and Binocular Field-Glasses. Proceedings of the Franklin Institute, Vol. 189 No. 1130-14, February 1920.

evaluate binoculars in the field was performed. This work, conducted aboard ship for the German Reichsmarine, consisted in crudely controlled evaluations by experienced personnel of a series of binoculars varying in magnification and exit pupil, and the conclusions were reached on the basis of remarkably unscientific data.

The present field experiment on binoculars and optical instruments developed out of a series of discussions in the Army-Navy OSRD Vision Committee in late 1944 and early 1945. At these meetings, representatives of the Bureau of Ordnance repeatedly raised certain problems of optical design to which satisfactory solutions had not been found. A sub-committee, consisting of the following, was formed:

Dr. C. W. Bray, Applied Psychology Panel, Chairman
Comdr. S. S. Ballard, Bureau of Ordnance
Lt. Col. F. S. Cranmer, Office of the Chief of Ordnance
Dr. Selig Hecht, Laboratory of Biophysics, Columbia University
Dr. Theodore Dunham, Jr., Section 16.1 (Optical Instruments), OSRD
Lt. N. E. Pulling, Bureau of Ordnance
Lt. Harry London, Bureau of Aeronautics
Lt. W. S. Verplanck, Medical Research Dept., S M Base
Dr. D. G. Marquis, Executive Secretary, ANCOSRD Vision Committee, Secretary

The following questions were placed before this committee:

1. Which of the following binoculars are best suited for hand-held use in detecting and recognizing surface and aircraft targets at night:
   (a) 7x50x7 standard binoculars
   (b) 7x50x10 standard binoculars
   (c) 9x63x5 standard binoculars
   (d) 10x50x7 standard binoculars

2. What are the relative advantages of the above instruments, and the following, for mounted rather than hand-held use:
   (a) 6x50x7 binocular
   (b) 6x33x8 monocular
   (c) 10x70x7 binocular
   (d) 12x60x3.3 binocular (German)
   (e) 20x120x3.3 binocular

3. How much advantage is gained by a binocular over a monocular instrument at night?

4. What diopter setting should be used in fixed-focus instruments which are to be used in the daytime and at night?

5. What advantage is gained in a mounted binocular telescope by an exit pupil larger than 7 mm.?

6. (a) Should the eyepieces of binoculars and telescopes be set at night one diopter more negative than daytime settings?

   (b) What loss in range of detection obtains at night when incorrect diopter settings are used?

7. How critical is precise interpupillary adjustment of binocular instruments at night?

8. What are the advantages gained by the use of head rests?

9. What loss in range of detectability at night is produced by the use of a dimly lit red crossline?

10. What are the contrast sensitivities and resolving powers of the dark-adapted eye across the field of vision?

In a series of meetings, the problems presented were carefully considered and formal answers based on laboratory and theoretical data were presented.*

In attempting to formulate these answers, it became clear that from the service point of view, a certain amount of field experimentation would be required in order to validate and supplement the laboratory work. It was therefore decided to undertake a large scale field experiment which would be designed for precisely this purpose and in which only experienced observers from the various Services and Research Laboratories would take part. A sub-group was charged with the responsibility of outlining the procedures of such an experiment. Their plan was completed, approved by the Subcommittee, and by the full Committee, and, eventually, presented to CominCh for action.

The difficulties encountered in the execution of such field experiments have usually been considered prohibitively great. Most derive from the essential impossibility of adequately controlling the many variables which influence the results.

Many of these variables are physical: factors of visibility, wind, of sky brightness, and of sea condition. Others stem from the physiology and psychology of the human animal. Beck has enumerated some 60 variables*, physical, physiological and psychological, which affect such performances, and of these, it is possible to control accurately only a fraction. In effect, then, to take such a problem out of the laboratory into the field initially commits the experimenter to the acceptance of a variability which may be so great that the effects under study are completely obscured by the effects of variables impossible to control adequately in the field.

The only hope of adequately controlling this variability, so that valid results may be secured, is to plan the experiment with that end in view, and then to supervise and control the execution of the plan in detail so serious sources of error are not inadvertently introduced by unqualified operational personnel.

Not only is there the expectancy of poor data, i.e., data showing no significant differences, but there are also the added problems ensuing from the complex arrangements required to perform a field test.

The problem of administration can not be met by reduction in the scale of the experiment. It is not advisable to perform a field experiment on a restricted scale: the variability, dictated by the lack of many usual controls, requires that a large number of observations be made. Further, the purpose of performing a field test requires that the test itself approximate as closely as possible the actual conditions, operations and performances met under actual field conditions.

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* Minutes and proceedings of the twelfth meeting 12 June 1945 of the Army-Navy NRS Vision Committee, pp. 20-26.

* Beck, L.H., An Experimental Investigation of Binoculars as an Aid to Night Visition. (PhD thesis, Department of Psychology, Brown University, May 1945.)

The question may arise as to why a field test should be performed at all if, at best, its results will be highly variable. There are several compelling reasons; they stem, paradoxically, from the very advantages which the laboratory enjoys.

The precise data obtained in the laboratory owe their excellence to the careful control of the relevant variables, and to the use of skilled, carefully trained observers, usually few in number and unrepresentative of the general population. For problems of theoretical importance, and for pure science, this is, indeed, as it should be. But when the problem under study is essentially practical, such as the present one, certain difficulties arise: the variables under control are abstracted from the situation itself; sky brightness with its variations owing to moon, clouds, aurora, etc., becomes the uniform and meticulously controlled and measured field brightness. Variations in haze and fog - the problem of visibility - are simulated by variations of target contrast which are not always easy to relate directly to the field conditions they purport to represent. The observations themselves are reduced to simplest terms, and the actual manipulation of the glasses themselves stripped so that the smallest demand is placed on the observer to do anything other than make a simple visual discrimination. To approximate non-visual field conditions in the laboratory, unwieldy apparatus is required which must be carefully designed to reproduce such variables as vibration, or roll and pitch.

When complete the laboratory data are definitive, and appear to answer clearly and unequivocally the type of questions posed. The difficulty arises in the application of the results to the operational situation. In the field, relatively inexperienced individuals are used, and they are an almost random sample of service population. Certain instruments may perform very well in a laboratory but are bulky and heavy. Aboard ship, visibility, vibration, roll and pitch, and the standing of long watches, may either reduce performance with one instrument or, with some other instrument, may be offset by the skills acquired by an experienced OD or lookout.

To apply conclusions reached in the laboratory to the field, one may either make the best possible guess, on the basis of information otherwise at one's disposal, or formulate and solve the problem mathematically, or perform a field test on items sufficiently representative of the laboratory data. In the absence of field validation* of a particular item, its probable validity may be estimated on the basis of comparable laboratory findings which have been field checked.

The first of these procedures is the easiest, and for many problems may suffice. The second may be a more scientific procedure but can yield even less reliable results, since tacit assumptions may enter. The conclusions reached by either method are still subject to experimental test. The third alternative, the field test, alone produces results which are dependable. Not only may laboratory findings be validated, but also the adequacy of theoretical treatment may be tested. The use of a field test by no means precludes simultaneous logical or mathematical treatments.

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* By determination of validity is meant the measurement of the accuracy with which a laboratory finding may be repeated in the field under conditions for which it was expected to apply.

It was on the basis of these considerations that the experiment reported upon in the present report was undertaken.

With these considerations in mind a program designed to meet the need for information was set down and submitted to CominCh.*

The program was activated on August 24, 1945, with the ordering to the U. S. Submarine Base of the DE Mason by CominCh letter.** Two weeks later, the U.S.S. Peary relieved the Mason***, and on September 4 the first trials were run.

As the work progressed, with experience and preliminary analysis of the data collected, with new questions raised by BuOrd, and with the exigencies of demobilization, certain modifications were necessarily made in the original experimental design. These changes were, however, not drastic, and the program was carried through as planned in all essentials.

The original field tests were planned in six parts, as follows:

a. Optical instruments for night use : shore and floating targets.
b. Optical instruments for day use : shore and floating targets.
c. Optical instruments for day use: aircraft targets.
d. Daylight sky scanning procedures.
e. Use of color and neutral filters for haze penetration.
f. Miscellaneous experimental problems.

Of these, parts a and b were completed. Parts c and d were dropped owing, in the former case, to difficulties in arranging coordinated operations with aircraft during the period of demobilization, and in the latter, because of the termination of the war, and with it of the suicide aerial attack (Kamikaze) problem. Of the several items combined under f, some were assimilated in a and b, some were performed separately, and some were cancelled. Part e will become the subject of a separate report.

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* Sub Base Confidential letter NB7/S71-8/ L5(MR) Serial 2722 of 30 July 1945 with enclosure "Proposals for Field Test of Optical Equipment".

** CominCh confidential dispatch 131322 of 13 August 1945.

*** CominCh confidential dispatch 23194 of 23 August 1945.

THE CHARACTERISTICS OF TELESCOPES WHICH AFFECT TARGET DETECTION

In order to make clear the problems facing those who design terrestrial telescopes, both monocular and binocular, a brief treatment of significant factors will be presented.

Such optical instruments are designated in terms of three figures. The first of these gives the magnification or number of times the system magnifies the linear dimensions of the target. The second is the diameter of the objective lens, or entrance pupil, in millimeters, and the third is the angular diameter of the field which is seen through the instrument, in degrees. The quotient obtained when the second is divided by the first of these, yields the exit pupil, the diameter in millimeters of the beam of light which leaves the binocular, and may enter the eye when it is held in the correct position.* The exit pupil constitutes an index of the brightness of the retinal image obtained, and hence of the telescope's utility at night. These figures give data significant from the point of view of vision, as well as information on the general size of the instrument. A wide objective lens, for example, when associated with high power, indicates that the instrument designated must be large and heavy. Similarly, larger field sizes require larger prisms, and consequently a wide and heavy instrument.

This nomenclature does not exhaust the list of important variables, nor does it explain the role of each, and the problem it presents to designers.

Magnification: Magnification increases the range at which a target may be seen by night or by day. By day, it permits otherwise invisible or indistinguishable targets to be seen by increasing the size of the image falling on the light-sensitive retina sufficiently so that the image becomes larger than the limiting 'grain' of the retina (which would otherwise make targets smaller than approximately 0.4 minutes of arc invisible). At night, under low levels of illumination, this grain is even coarser. But, the night advantage given by magnification stems from another physiological property of the eye, which plays a more important role by night than by day. The retina functions in such a way that it is more sensitive to large illuminated areas than to small. Against equally bright backgrounds, a large area may be dimmer or appear in lower contrast than a smaller area, and yet be more readily visible. The limits of area and brightness within which this is true are relatively restricted under high illumination, but under low illumination, they are wider. To be equally visible with a large area, covering up to 20 to 30 minutes of arc, a small area must be brighter by a factor equal to the square of the ratio of the diameters. Thus, by increasing the area over which its image falls, magnification may serve to render visible an object which would otherwise not be seen.

Exit Pupil: Exit pupil offers an index of the amount of light that an optical instrument will gather and send into the eye to provide a retinal image.*This is of very great importance at night, when all the light possible must be used, since the more light, the smaller and the less contrasting may be the targets which the eye can detect. The maximum value of the brightness of the image which an optical instrument can put on the retina is the brightness of the target as seen by the eye alone. No binocular can 'gather' light to produce an image brighter than that seen by the unaided eye. This is because the pupil of the eye acts just as does the diaphragm stop of a camera. At night it is fully expanded. But it will not allow to enter it a beam of light any wider than its own diameter. Consequently, no matter how much light a very large objective lens may be able to gather, the effective objective lens is always equal* to the product of the magnification of the instrument and the diameter of the observer's pupil, and any increase beyond that in the diameter of the objective lens is wasted. When it is considered that in the case of the unaided eye, an image of unit linear dimensions is illuminated to a brightness made possible by the diameter of its objective lens, which is the pupil diameter, and that, in the case of an M power binocular, an image M times greater than unity in linear dimensions is illuminated to a brightness made possible by an objective lens M times the pupil diameter, it will be seen that at best, the brightnesses of the two images are equal, although one image covers M^2 the area of the other. In practice, the image obtained with the telescope will always be less bright than that with the naked eye, since there is an inevitable loss of light in the optical system (which will be discussed in a subsequent paragraph).

Thus, although a large exit pupil, up to the limits of the size of the observer's pupil when it is fully expanded, gives substantial benefits at night, it is unnecessary during the day, when the observer's pupil is contracted and blocks from the eye most of the light provided by the telescope's exit pupil.

Light Transmission: Light transmission is the percentage of the total image-forming light falling on the objective lens of an instrument which is transmitted through the instrument and is not lost by reflection or absorption in passing through the optical system. Like exit pupil, it is of most importance at night, when all the light possible may be utilized. It presents certain problems, many of which have been solved by the use of magnesium fluoride, and similar lens coatings, which have the property of markedly reducing losses by reflection, and which consequently may increase the transmission of an instrument by as much as 50%.

Contrast Rendition: Contrast Rendition is a property of optical instruments which has only recently been studied, and which has proven of very great importance in determining the visual efficiency of a telescope. It is "a measure of how nearly an image of an object formed by an optical instrument resembles the object with respect to brightness contrast." It is defined as follows:

$$CR = \frac{C_1}{C_o} \times 100$$

where C_1 equals image contrast, and C_o equals object contrast.

Contrast is one of the most important factors in the determination of the visibility of a target, and is defined by the following equation:

$$C = \frac{B_b - B_t}{B_b} = \frac{\Delta B}{B}$$

where B_b is the absolute brightness of the background, and B_t that of the target.

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* More precisely, exit pupil diameter is the diameter of the image of the objective lens formed at the eyepiece.

* The brightness of the image is a function of the square of the exit pupil diameter. Thus the image produced by a telescope with an exit pupil four millimeters in diameter is sixteen times brighter than that produced by a telescope with an exit pupil one millimeter in diameter.

* This assumes, of course,, perfect alignment of the binocular with the eye.

The significance of the factor Contrast Rendition and its interrelationships with magnification, exit pupil, and transmission for the use of optics at night may be understood if it is recalled that in determining the visibility of a target at night, the three most important factors are Ω , the solid retinal angle subtended by the target, B, the brightness of the background of the target, and ΔB, the difference between the brightness of the target and its background. $\Delta B/B$ is, as defined above, the contrast of the target. When binoculars are used, Ω is, of course, determined only by the size and range of the target, and M the magnification of the binocular. The values at the retina of B, ΔB, and $\Delta B/B$ vary not only with the corresponding values of the target, but also with the transmission of the binocular, with exit pupil, and with the Contrast Rendition. This is a variable independent of the others, whose magnitude is a function of the ratio of the brightness of the scattered* light to the brightness of the target. Since the visibility of a target varies considerably with the contrast, it is evident that any differences in the Contrast Renditions of optical instruments will be reflected in differences in the ranges at which targets may be detected with them.

Contrast Rendition (CR), then, plays a very important role in determining the visibility of a target through an optical instrument. It is now under intensive study at the Optical Inspection Laboratory, Pennsylvania State College, where the design factors which determine the CR of optical systems are being determined. In effect, a glass of poor CR, in which stray light is scattered across the image of the target and so decreases the value of the contrast, displays the effects of what may very properly be called a built-in fog.

Resolving Power: Resolving Power is the ability of an instrument to measure very small angles, or to distinguish very fine lines. It is closely comparable to the visual acuity of the eye. In daytime, it is of course of the greatest importance that the system have a resolving power sufficiently great so that the limiting factor in visibility is the resolving power of the eye, and not that of the instrument. At night, this factor is of little significance, since the acuity of the eye is so poor under low levels of illumination that it cannot distinguish in performance between a glass of very poor resolving power, and one of good.

Field Size: Field size owes its importance, not to the properties of the eye itself, but to the mode of use of the instrument. Provision of a large field improves greatly, in both speed and efficiency, the procedure of scanning by which the instrument is used in search, and also the spotting of a target by an observer, to whom the location of a target has been reported. An instrument of small field is extremely difficult to keep trained on a target, especially in the presence of roll and pitch.

Of these properties, certain of them are not 'incompatible'. They do not require any changes in the size or weight of an instrument, but rather present engineering difficulties in the techniques of design and manufacture.

These are Contrast Rendition, Resolving Power*, and Transmission. Since this is the case, it is not the business of this experiment to study them.

The other three, however, Magnification, Field Size, and Exit Pupil, are in many respects incompatible, i.e., it is impossible to have an instrument with the most favorable values of each. Thus, although a 30x240x10° might sound like a good instrument, it is a manifest impossibility, since the product of magnification and field size, which is the apparent field, is greater than the visual field of the eye, which is approximately 100°. In practice, the apparent field seldom exceeds 75°, although it is understood that some instruments have been built with apparent fields as great as 90°. But even if the instrument is reduced to 30x240x2°, it is still huge, expensive and heavy. It is necessary to establish which must be cut, to make the most efficient instrument: magnification or exit pupil. What is the optimum value of magnification? How much can be sacrificed in exit pupil to gain this magnification? Is it advisable to increase exit pupil beyond the average pupil diameter? Will gain or loss result from replacing a 7x50x7° by a 10x50x7°? These are the practical questions which must be considered by those engaged in the writing of specifications and in the procurement of both binocular and monocular telescopes. Their answers must satisfy the other requirements of size, weight, and cost. Decisions must be made, too often on the basis of scanty or indecisive laboratory data, or worse, on the basis of hunch or personal preference.

BASIC EXPERIMENTAL DESIGN

In order to test specific instruments and provide a field evaluation of the factors in design, a series of experiments was performed in which the selected instruments were compared with the standard hand-held 7x50x7° binocular for efficiency in spotting and identifying a series of targets of varying characteristics. Observers placed on the bridge and gun decks of a DE spotted and identified these targets as the DE made an approach run towards them. The range at which this became possible with each instrument was recorded. From these ranges the final results are derived and conclusions drawn with respect to the instruments.

The primary difficulty in this experiment is the great variability encountered in the data because the control of the relevant variables cannot be directly achieved. The design of the experiment must therefore be such that these sources of variability can be taken into account, and their effect on the variables being measured eliminated insofar as possible.

The problem is not only one of taking into account this variability; but also of providing for the comparison of all the instruments under investigation with one another, so that their relative merits may

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* That is, non-image-forming light due to internal reflections and similar factors

* It should be noted that distinct losses in resolving power are usual in the periphery of the field of a wide-field instrument.

be assayed.

Analysis of the variables which enter into the performance of an optical instrument tested in an experiment such as this shows that, with two exceptions (to be noted later), they fall into three categories:

(a) those associated with the instrument, e.g. its power, light transmission, exit pupil, weight, contrast rendition, etc.

(b) those associated with the conditions of its use, i.e. with the approach run (such as sky brightness, visibility, sea condition, course, target).

(c) those associated with the observer, e.g. retinal adaptation, visual acuity, pupil diameter, skill, recorder, etc.

The first step is to reduce the differences among men, and among runs. If the men are brought to roughly equivalent performance by means of a careful training program, and if all are well motivated and in good physical condition, they will be less variable and consequently will give more homogeneous data. An attempt was made to reduce variability by control of these factors. Similarly, certain standard conditions and procedures for execution of runs were set, so that the variation produced by differences among the condition of use would be reduced. Two set approach courses were maintained and deviation from them avoided. Operations were restricted to those nights when there was no moon. The observation vessel made all runs at standard speeds* (except when speed was a variable under investigation), and the targets were maintained as constant as possible from run to run. Standardized procedure have been utilized wherever possible. Such reduction in variation is not, however, sufficient. It is necessary to plan so that this reduced variability, too, can be partialled out.

On a single run, the range at which a particular discrimination ** is made will depend on the efficiency of the binocular, on the identity and state of the individual using the binocular, and on particular circumstances of the run. No information at all is yielded on the binocular by itself. If six men use six different binoculars on one run, the run itself is eliminated as a source of variability; all binoculars have been tested under the same conditions. But there is still no basis for the evaluation of the binocular alone, only for the evaluation of the performance of observer and binocular together.

If one observer uses a different glass on each of six runs, the observer is eliminated as a source of variability but the variability associated with the runs confuses the comparison between glasses.

The Latin Square provides a statistical design and procedure which permits isolation of the variabilities attributable to differences among binoculars, men, runs, and the remaining variability inherent in the experimental technique. Consequently, it disassociates the performance of a binocular from run conditions and observer differences. Applied to the present problem, where a maximum of six instruments can be employed simultaneously from a given height of eye, the Latin Square required that the six instruments be compared with one another over six runs. On each run one of the six observers must use a different instrument according to a predetermined randomized plan which ensures that no observer uses the same instrument twice. Three instruments may similarly be compared over three runs, with three observers.

Such a Latin Square schedule of runs is presented in Table B-1, in which the six runs are numbered 1 through 6 and the six instruments lettered A, B, C, D, E and F. The manner in which the six observers, a, b, c, d, e and f, rotate at random in the six runs from instrument to instrument is indicated. The first row and first column of observers were distributed in an order determined by tables of random numbers; however the observers are allocated to the remaining cells by rotation, meeting the requirement that an observer appear only once in each column and each row. Different randomized patterns were generated for the different comparisons of groups of six instruments.

The Latin Square design insures that a valid comparison on each discrimination may be made among six instruments in six runs, or three instruments in three runs. The variability attributable to runs, observers and experimental error may be evaluated separately from that attributable to the instruments tested. Consequently, in any set[*] of six runs, as many sample performances may be obtained as there are discriminations which all six observers are able to make, so that the data become more reliable. The results of two or more sets of six runs, utilizing the same instruments may be combined, thus attaining a yet higher reliability. The provision must always be made that the basic Latin Square design be followed - that six observers, using six instruments, act together over six runs, according to the prearranged schedule.

TABLE B-1

LATIN SQUARE PLAN FOR USE OF SIX INSTRUMENTS BY SIX OBSERVERS OVER SIX RUNS

Runs	Instruments					
	A	B	C	D	E	F
	Observers					
1	b	e	a	c	d	f
2	d	f	b	e	a	c
3	e	a	c	d	f	b
4	f	b	e	a	c	d
5	a	c	d	f	b	e
6	c	d	f	b	e	a

On Run 1, observer b uses instrument A. On Run 2, he uses instrument C, and so on.

A similar 9-celled schedule may be made up for the comparison of three instruments with one another.

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* The standard speeds employed in the experiment are specified later. They are not identical with the technical naval "Standard Speed".

** Used throughout this report to mean the sighting of a given target, to a given criterion of seeing.

[*] Set refers to a six-run comparison of six instruments, or a three-run comparison of these.

The Standard Instrument: Even with the Latin Square design, one cannot place all instruments on a comparable basis without one basic instrument common to all sets. Such a reference point provides a means whereby the relative performance of binoculars may be evaluated in a standard fashion. The instrument selected as a standard was the 7x50x7° binocular, hand-held, since it is the most familiar instrument, and since more is known abouts its performance both in the laboratory and in the field than any other. The 7x50x7° HH binocular, then, was included in every set.

The Remaining Sources of Variability: All but two sources of variability within such an experiment fall into one or another of the three categories noted. The first of these is the position of an instrument on the bridge; this is a non-instrumental source of variability which remains confoundsd with the binocular differences. Special analyses have been made of this factor, and are reported elsewhere. It does not constitute a major problem.

The second source of variability is more serious. This is the interaction of the instrument with the observer or with the condition of the run. Interaction exists where the performance of one instrument relative to another differs consistently from one observer to another. Interaction also exists where one binocular excels another in good weather, but is inferior in hazy or windy weather. It is necessary to perform separate experiments if these possibilities are to be explored. Such an experiment on interaction was performed, and the results are reported elsewhere in this report.

TEST PROCEDURE

Operating Area:

All operations were carried out in Gardiner's Bay, in the waters of the eastern end of Long Island Sound.

Horizon: When preliminary surveys of the area were made in June and July 1945, the horizon in the area included approximately 90 degrees of land-sea horizon, free from lights, and the same extent of sky-sea horizon, similarly free from interference. The lights of the remaining 180° of horizon were not numerous or troublesome, and did not interfere with the operations planned. However, following V-J Day, and with the advent of nights of exceptional visibility, more and more lights appeared, and the question was raised of the extent to which such lights might invalidate the data obtained at night. As a consequence, one course was changed, and a conference was immediately held including both staff members and a group of eight of the visiting observers with scientific backgrounds. It was the conclusion of the meeting that these lights could in no way invalidate the findings, but that it would be desirable to analyze the data with respect to visibility, so that if any effect of the lights occurred, it could be detected. This analysis was made, and is presented elsewhere in

this report.

Visibility and Sea Conditions: This area was also considered suitable in that representative visibility and sea conditions might be encountered, and that weather would permit a sufficient number of observations to be made. This expectation was not met with respect to sea conditions; on only one, or at the most, two operating days was there any appreciable swell producing roll and pitch in the observation vessel. Visibility conditions encountered were indeed representative. Operations were performed on several nights of unlimited visibility, when lights at extreme ranges were visible, and on nights when operations were necessarily terminated, since the principal target was barely visible at 2000 yards, and no others could be detected. During the night operating period, on few nights only were operations suspended because of the weather. Visibility did not vary so extensively during the day operations. Since these were considered of secondary importance to the night work, they were put off until late November and early December, when no days of exceptional visibility were encountered, and when, on several mornings, considerable atmospheric refraction was evident, thus making impossible the detection or identification of targets at extreme ranges.

The course: All operations centered about a ruin, at 41° 08' N and 72° 09' W, which served as primary target, and upon which secondary targets were placed. Observations were made as the observation vessel, a destroyer-escort approached this object on predetermined courses.

Night Courses: Figure 5 presents the operating area, with the night courses.

Three courses were followed for night observations. The first of these approached the ruin directly from approximately 7000 yards, holding a course of 210 T.* Characteristically, while the range was closing, the course presented the fort and targets against a distant land background, which was not visible to the observers until the range to the fort had closed considerably. In any event, the targets appeared in slightly lower contrast on this course than on the other. The course also had the disadvantage that within a few degrees of the port bow there was a flashing buoy, 600 yards north of the fort, which distracted the observers during the September runs, and consequently may have interfered with the first two discriminations required of the observers. During the October, November and December observations, measures were taken which effectively minimized this problem. When the range had closed to some 1000-2000 yards, the observation vessel turned, and approximated a course 270 T, which headed it toward a target vessel stationed several thousand yards beyond the turning point, which it approached to some 1000 yards. This course was utilized throughout the observations.

The second course approached the fort from the west southwest on a course 055 T. The fort and targets appeared against a clear sky-sea horizon. When the range had

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* Course 210 T came close to constellation rock buoy and is referred to as constellation on data sheets.

closed some [illegible] to [illegible] yards, the DE turned north, and when opposite the buoy mentioned above, turned east and approached a second target vessel, a submarine moored some [illegible] yards beyond the buoy. Toward the end of the September series, a new, and unfamiliar light appeared on the horizon, and interfered with observations made on this course. The course was accordingly abandoned on 4 October 1944, and a new one substituted for the remainder of the night observations.

The day course selected corresponded closely to the [illegible] one and differed only in that [illegible] from a more northerly [illegible], so that the fort was approached on the course [illegible] T.

[illegible] the DE making a [illegible] following course [illegible] T. [illegible]

[illegible] However [illegible] of some [illegible] procedure was [illegible] the DE [illegible] because [illegible] the schedule [illegible]

The [illegible] ranges of the [illegible] depended on the [illegible] and the [illegible]

ment of the O D* Ideally, each run (one complete course) would begin at a point from which the fort was invisible to all observers, irrespective of the binoculars employed. The distance from the fort varied between 9000 and 4000 yards, with the visibility. However, in many cases, OD's manoeuvered the ship so that she was ready to start a run at less than this extreme range. In order to avoid losing the 20-25 minutes which would be required to bring the ship about, and into her proper position, the run was begun at that point.

The closest range to which the fort was approached was determined by the range from the fort to the buoy noted above, on course [illegible] T. Again, ideally, a turn would bring this buoy close aboard, and observation of the fort could continue until the range had closed to [illegible] yards. However, even under the best of visibility and sea conditions certain of the OD's were reluctant to come so close, and none of the OD's would approach so close in poor visibility, or in the presence of wind. Although the depth of the water on [illegible] T permitted closer approaches, turns on this course were made to correspond with those of [illegible] T.

The approach to the fort was made [illegible] except on [illegible] when a speed of [illegible] knots was made [illegible] maximum [illegible] of the vessel. After the turn was made speed was [illegible] and a speed of [illegible] knots was [illegible] and it was [illegible]

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* [illegible] of the Deck

at which the target vessels were approached.

Day Courses:

Figure 6 shows the day course, which began at a point just south of East Point, Fisher's Island, and ran 239 T, holding the fort just to the port of the bow. When the range had closed to approximately 8000 yards, the DE turned and proceeded down the course 210 T, the same as that followed at night. This course was planned to begin at 25,000 yards, so that the fort and its targets would be beyond the horizon. However, atmospheric refraction was such that it was seldom necessary to go to this range. Speed was maintained at 12 knots, which shortened the time required for a run, without producing vibration noticeably greater than that encountered at 9 knots.

The Fort and Other Targets:

Fort Tyler: The principal target in the experiment was Fort Tyler, an abandoned fortification, several thousand yards off the northern end of Gardiner's Point. A concrete structure, it presents a target 234 feet long and 20 feet high from course 210 T and 220 feet long from 065 T. The thick walls provided a large platform on which other targets were erected, and the inner court provided shelter for the target crew. Figure 1 and Figure 7 show the fort as it appeared when the DE approached. The fort is referred to as Target One.

Supplementary Targets - Night Observations:

Selection: The other targets were selected on the basis of the trial runs performed in July and August preceding the experiment. Targets of these sizes were found to come into visibility successively from a range of some 4500 yards to 1000 yards. During the night experiments, owing to the inability of the observation vessel to come sufficiently close, many of the smaller targets were never sighted except on nights of exceptional visibility, and even then, they often were not observed through the less efficient instruments. The targets were chosen so that some were of high contrast and some of low, and so that both positive and negative contrast could be observed.

Target Two: The second target, used in the September runs, was the beach, the islet on which Fort Tyler is constructed. This target was dropped when analysis of the data showed that it differed in no significant manner from the fort as a target, and merely repeated observations on it.

Target Three: This target was a radar reflecting screen, erected on top of the fort by Harbor Defense, Long Island Sound, U. S. Army, for the purpose of providing a calibrating range. It is made of a timber framework, constructed of 2' x 4's and it is covered with heavy Cyclone wire-fence fabric, painted orange. The target presented to an observer is sixteen feet in height and sixteen feet broad on course 210, and thirteen feet broad on course 065, presenting an area of 257 and 210 square feet, respectively. Except for the fort, this is the only target which varied in apparent size from course to course.

Target Four: This target consisted of a pipe framework on which a strip of black-painted canvas was rigged to form a cylinder eight feet in diameter and eight feet in height. The framework was twelve feet high, so that the base of the cylinder stood four feet above the top of the fort and cleared the parapets which might otherwise obscure part of it. The device of employing a cylindrical target ensured that the image of the target was always a square, irrespective of the bearing from which it was approached. Target four stood at the western end of the fort, and appeared to the right of the radar screen on course 210, and to its left on 065.

Target Five: was a duplicate of Target Four, placed at the opposite end of the fort.

Target Six: was similar in construction to Targets Four and Five, but the diameter and the height of the canvas cylinder was six feet, and the over-all height of the framework twelve feet. It was placed between the radar screen and Target Five.

Target Seven: was an eight by eight foot frame over which was stretched canvas painted white. Two were used, one on each side of the fort. It rested against the weathered concrete of the wall of the fort and was placed normal to the course on the destroyer escort approaches.

Target Eight: This target appears on the data sheet but it was not used, since it was impossible to keep it intact.

Target Nine: was a drum target, like Targets Four, Five and Six. Its height and diameter were four feet, and its tall framework, set on the south-east parapet of the fort, raised it sufficiently high so that it cleared the other targets and was not obscured on either course.

Target Ten: was a wooden "flagpole", two feet wide and fifteen feet in height, with an eight foot extension six inches in width.

Supplementary Targets - Day Observations:

For the day observations, additional targets were set up. Each of these consisted of acuity targets of the proportions 7x7. Four strips of wood or of canvas backed by wood of the proportion 7 : 1 were mounted parallel to each other. The background appeared between the stripes. These targets could be turned so that the stripes were either horizontal or vertical.

(A) (Placed between 5 and 6 of the night series on the data sheet.) Over-all dimensions of this target were 7' x 7'. It was painted black, and placed on top of the fort.

(B) (Placed following 8 of the night series on the data sheet.) This target was the same as A except that all its dimensions were exactly half of those of A.

(C) (Follows B on the data sheet.) The over-all dimensions of this white-painted target were 7' x 7'. It hung against the concrete wall of the fort.

(D) (Follows C on data sheet.) The dimensions of this were half those of C above. Otherwise, it corresponds exactly with C.

(E) (Follows Target 10 of the night series.) Over-all dimensions half of that of B above. Otherwise the same.

(F) (Follows E on data sheet.) Dimensions are half of those of D above; otherwise the same.

Accurate dimensions and other data on the targets are given in Table B-2.

General Notes on the Targets:

Target Variations: It must be stated that on all the runs, all targets were not always in position. It proved much more difficult than anticipated to keep them in operating condition. All the artificial targets except the radar screen and "flagpole" were damaged at least once during the observations, and many had to be replaced and rebuilt several times. Since the fort was inaccessible except by landing craft, it was occasionally impossible to make the full

TABLE B-2

DIMENSIONS AND CONTRAST OF TARGETS

Target	Length or Width, Feet	Height, Feet	Length, Yards	Height, Yards	Area Presented to Course 210 T (Sq.Yds.)	Area Presented to Course 065 T (Sq.Yds)	Contrast
1. Fort (Basic) 210 T	234.25	18.3-19.1	78.0	6.2-6.3			
065 T	222.00	18.3-19.1	74.0	6.2-6.3			
Sloping Top		1.5- 2.3		0.50-0.75			
Parapets 210 T	15.2-19.1	4.6-5.0	5.1-6.3	1.5-1.7			
065 T	26.7	4.6-5.0	6.9	1.5-1.7			
Total					552.1	487.6	0.75
2. Beach around Fort		NOT	USED				
3. Radar Screen (210 T)	16.00	16.00	5.33	5.33	28.39		0.41*
(065 T)	13.00	16.00	4.33	5.33		23.10	0.41*
4. 8'x8' Black Drum	8.00	7.62	2.66	2.54	6.76	6.76	0.95
5. 8'x8' Black Drum	8.00	7.62	2.66	2.54	6.76	6.76	0.95
6. 6'x6' Black Drum	6.09	7.24	2.03	2.41	4.89	4.89	0.95
7. 8'x8' White Flat	8.00	7.62	2.66	2.54	6.76	6.76	2.60
8.		NOT	USED				
9. 4'x4' Drum	4.00	4.00	1.33	1.33	1.77	1.77	0.95
10. Flagpole Base	14.48	1.90	4.82	0.63	30.81	30.81	0.75*
Flagpole Top	8.00	0.57	2.66	0.19			
Supplementary Day Targets							
A. 7'x7' Black Striped	6.86	0.76**	2.28	0.25	2.31	-	0.95
B. 42"x42" Black Striped	3.50	0.50	1.17	0.17	0.78	-	0.95
C. 7'x7' White Striped	7.24	1.15	2.41	0.38	3.69	-	2.60
D. 42"x42" White Striped	3.50	0.50	1.17	0.17	0.78	-	2.60
E. 21"x21" Black Striped	1.75	0.25	0.58	0.08	0.19	-	0.95
F. 21"x21" White Striped	1.75	0.25	0.58	0.08	0.19	-	2.60

* Approximato Value, contrast actually lower. See text.
** Refers to strip width.

repairs in time for the next run. As a consequence, Target Five was often not in place, since it had to serve temporarily in lieu of a destroyed and unrebuilt Target Four. Targets Six, Seven and Nine were also occasionally absent. The absence of these targets, however, was not critical, since they were not frequently sighted.

In late November, all the drum targets were destroyed by an extremely severe windstorm. Since there was not time to manufacture more frames, rigged square targets presenting comparable areas to the observers were substituted for the remainder of the experiment. Targets Four and Five varied on some nights in another respect: stiff breezes made it impossible to hold the canvas in place at the top of the frame, so that the 8' x 8' drums began on the top of the fort itself. This had the unfortunate result that part of the targets were obscured behind the protruding parapets.

On the basis of experience in the present experiment, the necessity of building targets as sturdy as possible is strongly urged; they should be able to withstand winds of high velocity, and must be designed with this in mind. No matter how carefully they are constructed, duplicates should be immediately available.

Search Targets: During the night observations, two naval vessels also served as targets. These were a fleet-type camouflaged submarine which lay hove to at a position 6000 yards due south of Little Gull Island, with a heading of 000 or 180. This vessel was a "search" target, on course 065, when it appeared against a clear sky-sea horizon. The other "search" target was a submarine chaser (SC) which lay hove to at a position 4500 yards bearing 160° true from Oyster Pond Reef Light. It served as a target vessel on course 210 T. The use of these targets was not successful during the September series, largely because the submarines employed were R-type vessels, small and relatively difficult to handle. For this reason, and so that data could be obtained comparable to those collected by the Camouflage Section of BuShips for cross-checking, fleet-type submarines were substituted for the older ships.*

The Observation Vessel: Posting of Observers

The observation vessel was the U. S. S. ROBERT E. PEARY, DE 132, under the command of Donald R. McKinley, Jr., Lt. Comdr. USNR, until 28 November when he was relieved by M. M. Gantar, Lt. Comdr. USN.

Night observations were made from the signal bridge and the number two gun deck and by day the lower deck was also utilized. See Fig. 9.

In order to accommodate the observers and mounts, the two 24-inch searchlights were removed from their platforms on the port and starboard side of the signal bridge, and two 20 mm. mounts were removed forward. In accordance with BuShips specifications the E & R Department, U. S. Naval Submarine Base, New London, Conn. placed, on the two searchlight platforms, and at positions evenly spaced across the forward area of the signal bridge, six Mark 51 Director mounts. On the windscreen for-

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* Cominch restr. ltr. FF1/S71-8 Serial 7102 dated 7 September 1945.

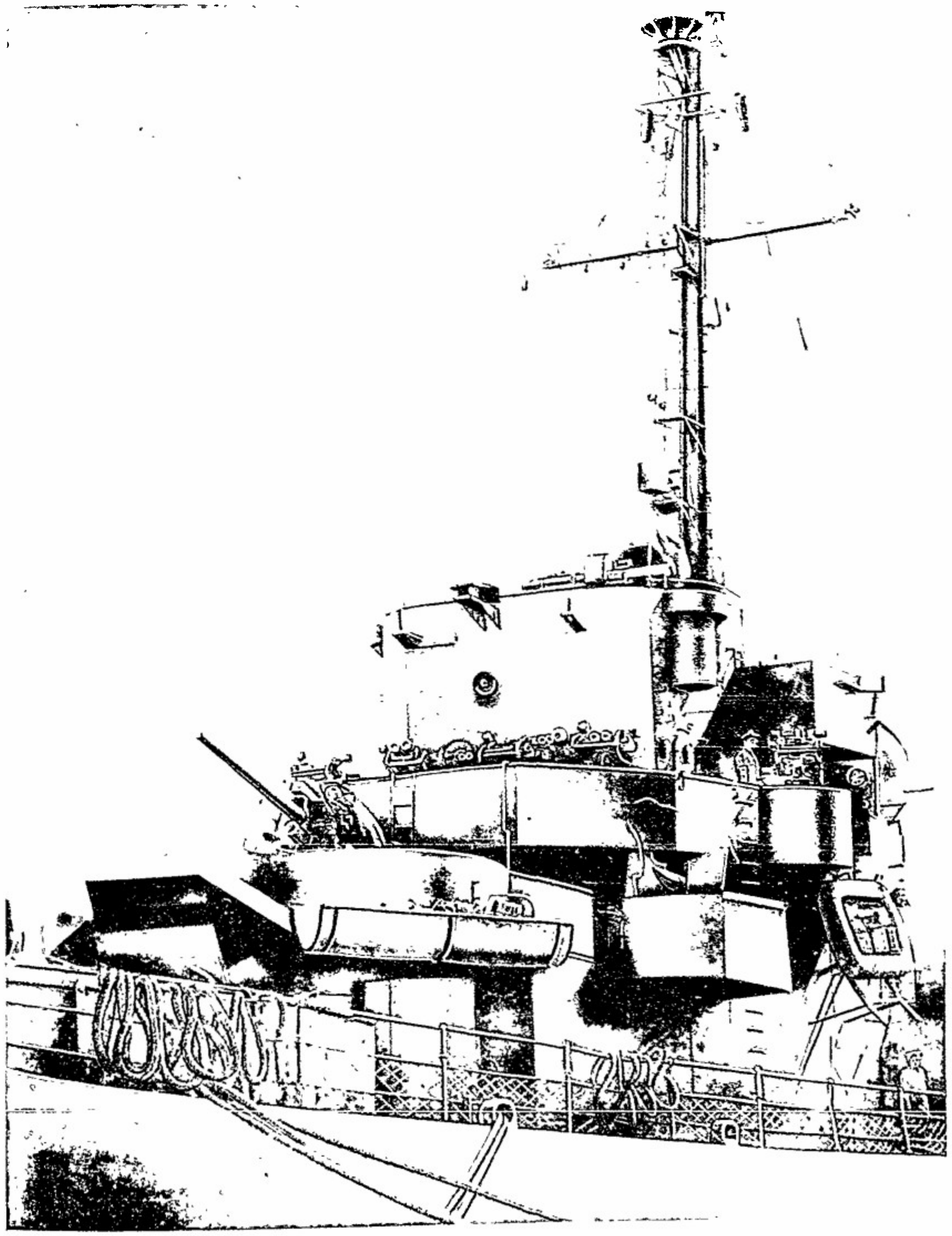

Figure B-1. General view of Destroyer-Escort, showing location of mounts and observers.

ward of these mounts, bases were provided for a vibration-free alidade (Eastman Kodak) and for a BuShips Mk 5 Alidade. A series of adapters was constructed for the director mounts, so that the various instruments employed in the experiment could be properly mounted on them.

Provision was also made on the number two gundeck for the placement of the vibration-free alidade on the port, and a Mark 5 Alidade on the starboard side.

Figure B-1 is a shot of the DE with the mounts in place, showing their disposition and the observation posts. Figures 15 and 16 of the report are close-ups of a Mk 51 Director Mount and a Vibration-Free Alidade, each fitted with a binocular, and show the mode of use and placement of these mounts.

During night observations, running lights were turned off, the navigation bridge blacked out, the flying bridge darkened, and the ship forward of frame 45 darkened, with spaces where work had to proceed rigged for red, so that a minimum of light could distract or interfere with the dark adaptation of the observers. Slight interference from the red-illuminated CIC, where certain unavoidable but dim sources of white light remained, was felt by the observer on the starboard searchlight mount. This interference, such as it was, was not so much from the source of light, as it was from the unavoidable traffic between the signal bridge and CIC or the flying bridge.

Stationing of the Men. During the night runs 6 observers were stationed on the signal bridge and three * on the number two gundeck. For the day runs, an additional three men were placed on the lower deck, forward of the Number One gun.

Signal Bridge: On the signal bridge an observer occupied each of the searchlight platforms. The remaining four were placed, when using hand-held binoculars, along the forward rail, at intervals of 5½ feet. During the trials of mounted instruments, observers were posted at the four director mounts which were aligned at evenly spaced intervals across the bridge, and at the two on the searchlight platforms. Positions were numbered from 1 through 6, going from port to starboard. The height of eye was 32' and put the observers approximately level with the targets on the top of the fort. The signal bridge did not provide good shelter from wind.

Gun Deck: Three men were stationed on the number two gundeck, one well to the port, one forward as near amidships as the bow would permit, and one on the starboard side. These positions are referred to as 7, 8 and 9, respectively. The height of eye was 25' and put the observers on a level with the top of the fort. Wind presented less of a problem on this level than on the signal bridge.

Lower Deck: The lower deck was used only during the day runs, and the three observers stationed here occupied positions corresponding to those on the number two gundeck, and numbered 10, 11 and 12, respectively. The height of eye was 20' It should be noted that this position was not satisfactory for observations. It received not only wind but also spray, since the DE headed almost directly into the wind during the day runs. As a consequence, the men were forced to seek shelter, and could not maintain the targets under continuous observation, as was desirable.

Observers:

The original plan of the experiment envisaged the use of a relatively large number of civilian and military observers of technical qualifications, and of a smaller number of highly trained enlisted men. Neither expectation was completely fulfilled.

(A) Enlisted Men: A total of 64 men served as observers throughout the experiment. Of these, 15 men, all experienced quartermasters or signalmen from the Surface Fleet, reported for duty before V-J Day. These men underwent an extensive training program which included a full course of lookout training (if they had not had it previously), special training on the night lookout stage, and training under low levels of illumination on a scale model of the fort and its targets, using binoculars. They received thorough instruction on binoculars, on night vision, and on the purpose of the experiment, so that they were thoroughly familiar with their duties.

As a final step in training, they all served in the later preliminary observations, so that they were thoroughly indoctrinated in every phase of the procedure.

Finally, all received a series of tests, which it was hoped might correlate with their skill as observers. These tests included the RPA Adaptometer, the Royal Canadian Navy Adaptometer, and the Orthorater. Interpupillary distance was measured with the NDRC interpupilometer, and the observers used this value at all times in adjusting the binoculars. Record was also made of their GCT scores, their age and experience as lookouts.

With the announcement of demobilization plans after V-J Day, it was possible to muster one 6-man section (Section A) from the fifteen. This group served through the experiment, and its performance was characterized by low variability.

The remaining 49 observers were submarine men who were due to be discharged in a period of 2-3 months, and who were accordingly assigned to the experiment after leaving the ships on which they had been stationed. The majority of those had had lookout training, and had also stood lookout duty aboard ship. It was possible to give those reporting in earlier in the experimental period special training similar to that accorded the earliest group. The later arrivals, however, had what was considered the barest minimum of such training; it was occasionally necessary to employ a man as observer within two or three days after he had reported and, consequently, his training was almost exclusively limited to watching the collection of data for one night, and making dummy runs on another. It was possible, however, to give almost all men the complete battery of tests.

Motivation of Enlisted Men: After V-J Day, serious difficulties of motivation arose. The men, all short timers, had no particular interest in doing a good job, and, in many

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* No observers were stationed on the gundeck during the September series.

cases, no interest in the problem. It was therefore necessary to handle observers very carefully, to ensure that the results would not be invalidated by carelessness, casualness, or lack of cooperation in any form. This problem was met, and apparently solved, by openly asking for their cooperation, when the experiment and its nature was explained to them; by ensuring that their conditions of living were the best possible with respect to rest, chow aboard ship, foul weather gear, etc., and finally by assisting them in every possible way to achieve such personal ends as rapid discharge.

Despite these efforts, one or two men failed to cooperate. As soon as this was evident, they were relieved of duties as observers, and were assigned to the bridge crew, transferred, or detailed as compartment cleaners. The result of this program and policy was that the experiment ran into remarkably little difficulty owing to poor cooperation from the observers.

Officer-Observers: The experimental plan included the use of a number of line officers with sea experience as observers. One six-man section of officers, all qualified in submarines, and including two Commanding Officers and a prospective Commanding Officer, were scheduled. On one night they made two runs. On the next, operations were cancelled owing to weather. No effort was made to re-schedule them, so that they could complete a set of six runs, since the experience of the night during which they did observe indicated that unsatisfactory data would be obtained from them. It was not possible for them to readjust from the responsibilities of their daily work to rather special demands placed upon observers, who must follow a relatively simple, but unalterable routine.

It is possible that a group of junior line officers, with sea experience, and with no collateral duties might have yielded satisfactory data.

Technically Qualified Officer and Civilian Observers: Both the experimental plan and the hazards of the weather made it impossible to utilize a large number of technically-skilled observers, who had duties elsewhere. In order to observe in the experiment for two operational nights, it might be necessary to spend as much as a week at New London, owing to the possibility of cancelled operations. The result was that a total of only 7 civilians, from various university laboratories performing research on night vision or binoculars, and 5 technically trained Naval staff officers, could be included as observers. These men offered the fullest of cooperation, and yielded data of considerable interest, which are reported herein. They received an intermediate amount of training, and test scores were obtained on them as well. In general, however, they showed clear evidence of the lack of practical experience in handling binoculars, and in making observations at night. With few exceptions, all the enlisted personnel had such practical experience.

No technical personnel was used during the day observations. Observer personnel is listed in Appendix D.

SCHEDULING AND ORGANIZATIONAL PROCEDURES

General Problem: The Latin Square design requires that six observers make together a set of six runs using six different instruments, or three a set of three runs using three instruments. Upon this requirement the scheduling of all operations depended. In laying out the schedule for operations over several days, the first consideration is the maintenance of the integrity of the Latin Square design. It was never possible for a six-run set to be completed on any one night, although this was frequently done for three-run sets. Consequently, after the first runs of a set were made, the highest priority in operations for ensuing nights was allocated to the completion of the sets only partly run.

Observer Sections: Since the statistical design of the experiment required that six observers make a set of six runs together on the signal bridge, and that three men make sets of three runs together on the number two gun deck, the observing crew was organized into six-man and three-man sections. In order to eliminate fatigue from lengthy observations, the policy was established of scheduling these sections to observe on alternating runs. As a consequence, two 6-man sections and 2 3-man sections would be scheduled for any one night. Each man in each section was scheduled to work with a man from the opposite section, to form an observer-recorder team which remained intact at least until both sections had completed their total of 12 runs, and until both 3-man sections had completed the same number of runs. The policy of alternating runs ensured not only that fatigue from observation would not become too great, but it also served to ensure that, with unavoidable exceptions, a six-run set would be composed of runs on the same course, 065 T or 210 T, and on the same target vessel.*

A second form of alternation was also followed: During the night observations, the men obtained all their rest during the daylight hours. The preliminary experiments showed that this could not be continued day after day; the men showed signs of exhaustion. Since every available night without a moon had to be used for observations, it was clear that a second alternation was necessary: four sections to go out, and four to stay ashore on each night of observations. For this form of alternation, it was found most satisfactory for one set of sections to go out on two successive nights, and to stay ashore for the next two successive nights. This procedure succeeded in providing the experiment with an alert group of observers at all times.

Another limitation placed upon scheduling also arose from fatigue. It was never

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* During the day observations, when at least 40 minutes elapsed between runs, it was not necessary to alternate, and the same observers made all of a day's runs. The recorders on these had no other duties. This was a fortunate circumstance since at the time the day runs were made there were not sufficient experienced observers to maintain alternation.

possible to schedule routinely a section for more than four runs as observers for any one night. In exceptional instances, five might be made. Six were impossible; the observers were unable to function efficiently beyond five runs, and on five they could observe only occasionally.

Number of Runs per Night: In order to minimize variability and to ensure that all our data were taken under homogeneous conditions [illegible] the use of night vision, runs were scheduled only for those periods of each night when there was no moon, and the sky brightness was relatively constant (approximately [illegible] log [illegible]). So that no errors would be made runs were scheduled only for the period between (1) fifteen minutes after the termination of astronomical twilight, or one half-hour after moonset, whichever was later, and (2) one half-hour before moonrise or fifteen minutes before morning astronomical twilight, whichever was earlier. As a consequence, the number of nights per month on which runs could be made was sharply limited, with a practical limit of 10. In addition, it was necessary to provide time for the observers to mess at some point during the night's operations.

Instruments: The final problem of scheduling was that of instruments: the correct instruments had to be aboard, and the proper mounts or accessories provided. In general the effort was made to keep at a minimum the number of instruments used on any one night, to avoid the necessity of changing mounts during a night's operations.

Scheduling: The limitations set upon scheduling by observers, nights and instruments provide problems enough; the hazards of weather or loss of a night's operations for other reasons made the problem so much the more complex. It was never possible or advisable to lay out schedules more than a day in advance. Suffice it to say that, with the occasional requirement of completing several sets of runs within a short time, a night's schedule might, and occasionally did, become very complex indeed, with, perhaps, all four 6-man, and all four 3-man sections out simultaneously, and with several shifts of instruments and mounts necessary. Occasionally, too, an observer was ill or missed the ship. Under such circumstances, it became necessary to compromise with details of the experimental plan. Thus, many sets of runs include some on course 210 T and some on 265 T, thus increasing the variance. In four instances, one observer shifted identity during a set of runs.* In some instances, too, several weeks elapsed before a set of runs could be completed.

In view of the complexity of the schedule for any one night, it was determined to minimize the possibility of error by giving to each observer a card on which was typed his own schedule for the night, with his instruments, station and recorder for each of the night's runs clearly stated. As cross-check, each supervisory staff member had a complete schedule of the night's operations and at the end of each run, there was entered in the log complete data on the observations

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* This is undesirable since it adds to observer variance. However, it does not invalidate the basic differences among instruments.

of that run.

The success of the whole procedure, of the precautions taken, and of the high degree of cooperation from the men is attested by the fact that on only one 6x6 set, BB, and two 3x3 sets, W(s)1-2 and W(s)j-2, was there failure of the prearranged schedule, with the result that the data had to be discarded.

General Procedure: A day's routine included the following activities:

(a) Preparation of the night's schedule and schedule cards.

(b) Preparation for the night's runs: check of instruments to be used and their serial numbers; check of equipment (e.g. clipboards, data sheets, flashlights, etc.); installation of adapter mounts on DE, preparation of muster lists, check with target handlers* the targets available; brief of target vessels as necessary, brief of supervisory and bridge crew.

(c) Muster of observing section, obtain focuses for instruments new to any observer; report aboard U.S.S. Peary, depart for operating area.

(d) Break out gear for night; distribute schedule cards; brief CO on any special problems; arrange chow; meet LCM for transfer of personnel as necessary; distribute foul weather gear as necessary.

(e) Supervise and check of all runs made; fill in weather sheets; provide chow.

(f) Secure operations and gear; arrange data.

(g) Return men to base; deliver data to statistical department; enter into log any action required of shore staff.

The staff required to handle these procedures was not inconsiderable in size. Besides the shore-based staff, duplicate staffs were needed for DE operations, just as duplication observation sections were required. The staff found to function most efficiently is outlined with their duties:

Shore Staff:

Officers:
(1) Oin-C (staff) general coordination and direction.
(2) Asst. O-in-C (line) Executive Officer, detail of operations.
(3) Head of Statistics - schedule, direct statistical staff, and plan.

Enlisted Men:
(1) Property
(2) Yeomen
(3) Statistical assistants (5)
(4) Two target crews, of 3 men each

Operational Staff (Duplicated):
(1) Staff Officer, in charge of night operations.
(2) Line officer assisting staff officer.
(3) CPO - Assistant to officers; supervisory, in charge personnel.
(4) Quartermaster - general assistant, keep log, check data sheets, weather sheets.
(5) Talker - radar record sheet, announcements and call of marks over loudspeaker system.
(6) Signalmen) May be provided by
(7) Radarmen) observation vessel.

Staff personnel is listed in Appendix D.

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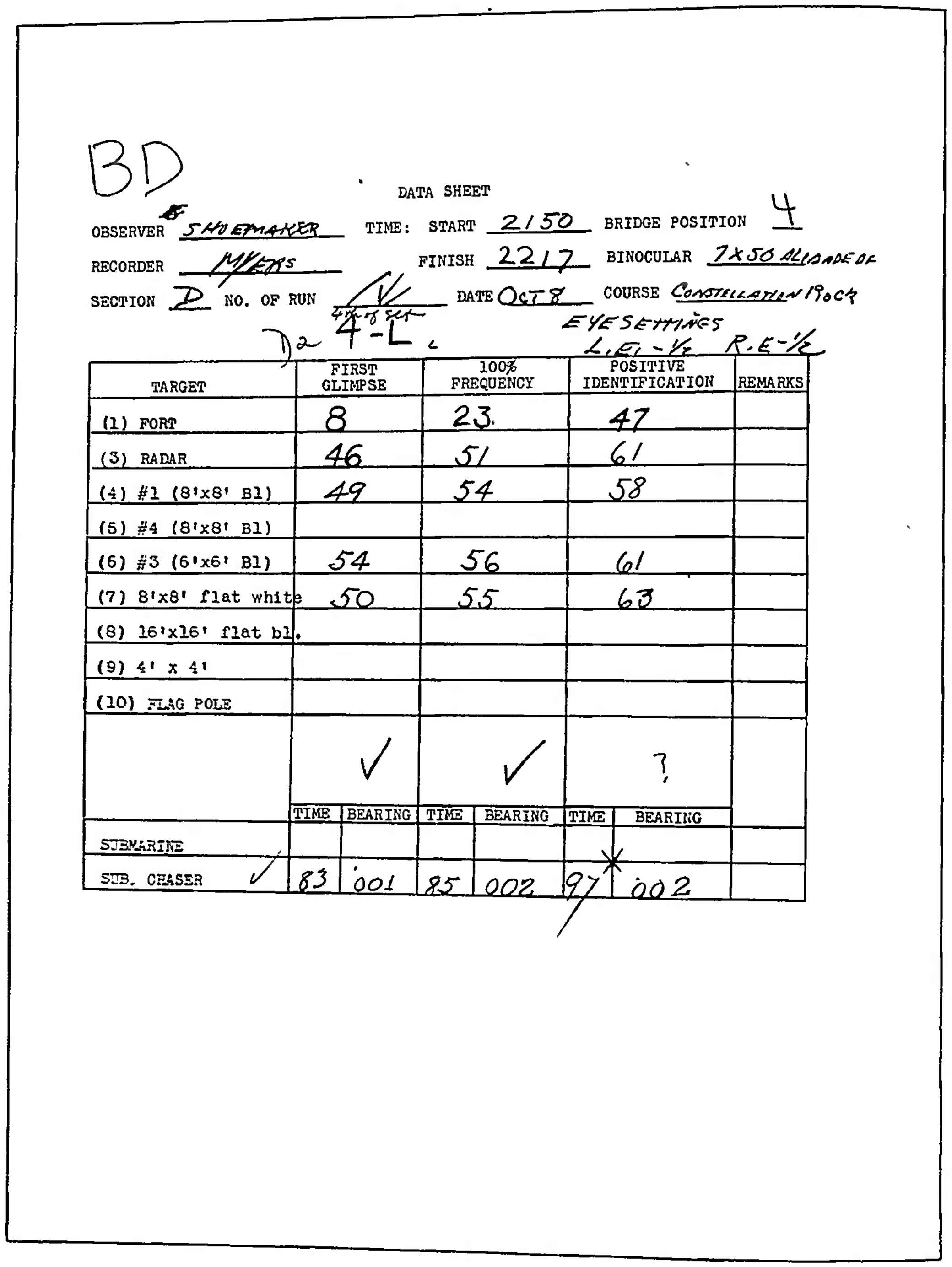
* The crews which handled the targets were based at Fort Terry, HDLIS, Plum Island, N.Y. All communications with this group was by phone, or by means of the LCM which operated for them.



BD

DATA SHEET

OBSERVER SHOEMAKER TIME: START 2150 BRIDGE POSITION 4

RECORDER MYERS FINISH 2217 BINOCULAR 7x50 ALIDADE OF

SECTION D NO. OF RUN ✓ DATE OCT 8 COURSE CONSTELLATION ROCK

4th of set 4-L D2

EYESETTINGS L.E. -1/2 R.E. -1/2

TARGET	FIRST GLIMPSE	100% FREQUENCY	POSITIVE IDENTIFICATION	REMARKS
(1) FORT	8	23	47	
(3) RADAR	46	51	61	
(4) #1 (8'x8' Bl)	49	54	58	
(5) #4 (8'x8' Bl)				
(6) #3 (6'x6' Bl)	54	56	61	
(7) 8'x8' flat white	50	55	63	
(8) 16'x16' flat bl.				
(9) 4' x 4'				
(10) FLAG POLE				
	✓	✓	?	

	TIME	BEARING	TIME	BEARING	TIME	BEARING	
SUBMARINE							
SUB. CHASER ✓	83	001	85	002	97	002	

Figure B-2. Sample Data Sheet. The mark numbers for each target and each discrimination were noted on such sheets.

PROCEDURE: THE COLLECTION OF DATA ON EACH RUN

Ten minutes prior to the beginning of each run approaching the fort, a warning was delivered over the public address system of the observation vessel, announcing the number of the run about to begin. A five-minute warning was announced after the proper intervals. These warnings enabled the observers and recorders to check their schedule cards to determine what their duties were on that run, the instrument each would use or record for, and its position on the bridge. The men were able to take their stations, check the identity of the instrument, adjust and clean their instrument, and fill in the heading of the data sheets. It also provided an opportunity for supervisory personnel to check the positions taken against the schedule sheet.

Basic Data Sheets: These data sheets (Fig. B-2) provided basic information in the heading (observer's name; time, number, date and course of run; identification of the instrument, its position, and the focus employed). Entry of the observations themselves required the recording of the mark number (number of fifteen second intervals since the beginning of the run as announced over a loud speaker to the bridge from CIC) at which the observer was able to see each target according to each of the three following criteria of seeing:

(A) First Glimpse (G): when the observer first was able to see the target momentarily, only to have it fade out.

(B) 100% Frequency (100): when he was able to see a target in the correct position all the time, without fading, and

(C) Positive Identification (PI): when he was able clearly to identify the target by its characteristics as known by him.

The use of these "criteria of seeing" provided for the collection of data roughly corresponding to the "frequency of seeing" curves of the laboratory, and covered the subject's perception of a target from none whatsoever, through the first vague and evanescent view, and the stage of appearance as an amorphous blob to perception sufficiently clear so that it was unmistakable in identity. The data sheets were filled in by the recorder, who always served with the same observer throughout a set of six runs, and who observed on alternate runs. A red flashlight was employed on night runs.

Range Determination: As soon as the observation vessel was in position to begin a run, this was announced over the ship's communication system to CIC. From there, word was relayed to the bridge together with the time, date, course and number of the run about to commence. The beginning of the run was then announced, a stop-watch was started, and thereafter, sharp on the fifteen second mark, the mark number was announced over the loud speaker. At alternate mark numbers, the range and bearing of the fort were determined by radar and entered on a range sheet (Fig. B-3, opposite the number of the interval. At mark zero, the DRT began to operate, and a tracing of the course, again with fifteen second intervals marked and numbered, made as a double check on the radar ranges, which were occasionally found to be in error.

Observations of the fort and its targets began with the announcement of the beginning of the run on the fort, and were continued intensively until the DE had approached the fort to the closest range, and had turned to such an extent that the fort was no longer visible to the observer at the entrance port (on course 065 T) or starboard (on course 210 T) stations. When this occurred, "end of run on fort" was announced, and the observers were able to relax until the observation vessel was headed properly for the search problem to begin. When she was in position for search, "beginning of run on SC" (or S/M) was announced, radar ranges to the target vessel were taken, and observations began in the sector in which the target vessel was located as announced by CIC. Method of entry of data on search corresponded exactly to that employed on the other targets.

When all observers had been able to positively identify the target vessel, or when her position obscured her to the extreme port or starboard observer, the end of run and the time were announced and recorded on the data sheets. The observers then filled in the comment sheets (Fig. B-4), on which they rated the instrument which they had just used.

Data sheets were then collected and checked in CIC to assure that none was missing, and that the headings were complete and accurate. On every third run and at every change of weather "weather sheets" were filled in by a quartermaster, and sky and sea brightness, as measured by an O'Brien Low-Level Illuminometer, was recorded.

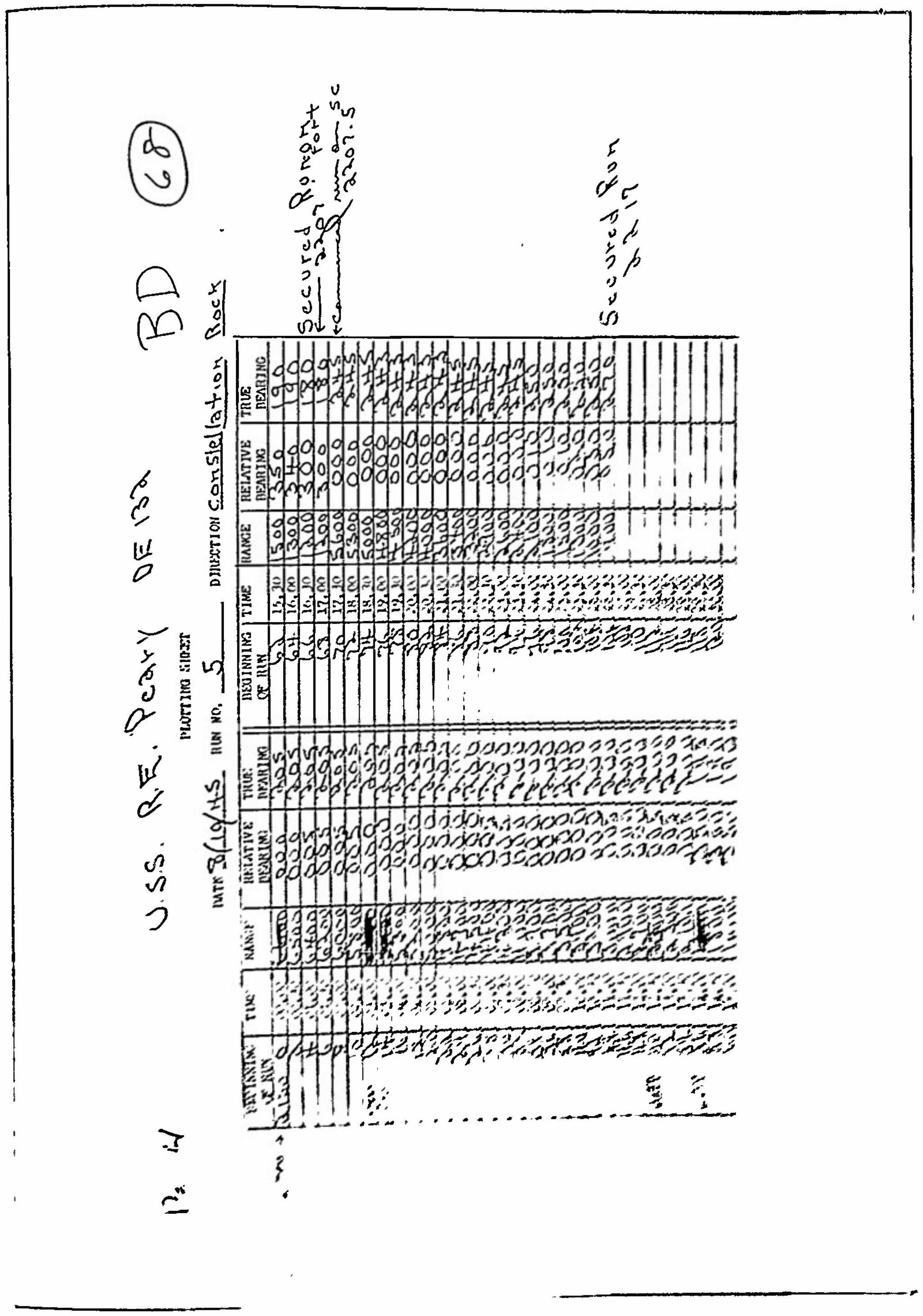
A run-by-run log was kept, entering all pertinent data on each run, together with notes of any communication with the target vessel, the crew on the fort, or with the base.

Each run required from 35 to 50 minutes, depending upon the range at which the visibility required that it start. Typically, an interval of 15 minutes intervened betwen runs.

Notes on the Collection of Observational Data:

Some comment and explanation must be made on certain phases of collection of the data, so that it may be more readily interpreted.

Prompting: Early experience with the technique, during the preliminary runs, showed that subjects would often forget to report on some target to some criterion of seeing, with the result that many blank spaces appeared in the data sheets, even though it was evident that the observer had made the observation, but had failed to report it Since this happened even with experienced observers (but to a lesser extent than with those with less training), it was considered essential that the recorder remind the observer of what targets he had reported, and what targets, due to become visible within a thousand yards or so, had not yet been mentioned. Considerable differences appeared among the recorders in the amount of assist-



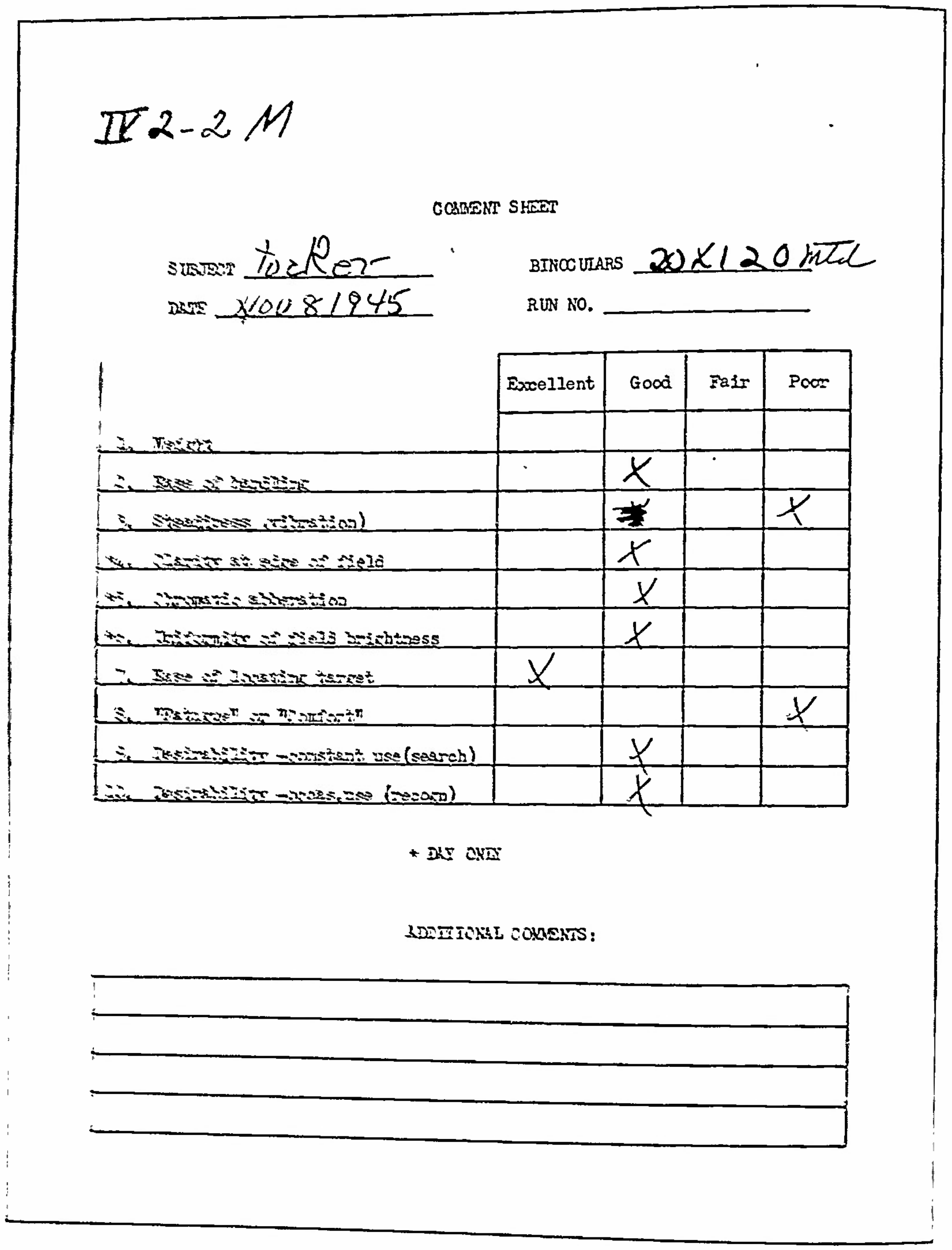
U.S.S. R.E. Peary DE 132 BD (68)

PLOTTING SHEET

DATE 3/10/45 RUN NO. 5 DIRECTION Constellation Rock

BEGINNING OF RUN	TIME	RANGE	RELATIVE BEARING	TRUE BEARING	BEGINNING OF RUN	TIME	RANGE	RELATIVE BEARING	TRUE BEARING
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	15.30	5500	350	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	64	16.00	5300	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	16.30	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	17.00	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	70	17.30	5600	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	18.00	5300	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	18.30	5000	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	19.00	4800	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	19.30	[illegible]	[illegible]	[illegible]

Secured Report Fort
Secured Run



IV 2-2 M

COMMENT SHEET

SUBJECT Tucker
DATE Nov 8 1945

BINOCULARS 20x120 Mtd
RUN NO. ____

	Excellent	Good	Fair	Poor
1. Weight				
2. Ease of handling		X		
3. Steadiness (vibration)				X
*4. Clarity at edge of field		X		
*5. Chromatic aberration		X		
*6. Uniformity of field brightness		X		
7. Ease of locating target	X			
8. "Fatigue" or "Comfort"				X
9. Desirability - constant use (search)		X		
10. Desirability - occas. use (recogn)		X		

* DAY ONLY

ADDITIONAL COMMENTS:

Figure [illegible] Comment Sheet. At the end of the run the observer rated the instrument on the [illegible] of the comment sheet

ance given; some were extremely conscientious, and others remained almost mute, and required prompting in turn by the supervisory staff. Since, in a set of runs, observer and recorder served as a team, the effect of differences in prompting methods is balanced out so that the performance of a binocular as measured by the observations is not invalidated by it. Careful note of the behavior of observers and recorders made it clear that observers did not report targets merely because they were reminded of them; observers, when prompted, at first would reply "No" and if a target was reported immediately after prompting, usually said something such as "I just got it".

Communication between Observers: With six observers on the signal bridge, and three on the gun deck, the question arises of the extent to which the report of one observer might influence that of another. Where one observer can hear another make a report he might make the same report at the same time, irrespective of whether he had seen the target or not. Since the construction of shields between observers was not possible, other means of reducing this hazard were sought. Two-way sound-powered phone systems between observers and recorders were rigged out, but proved to be unsatisfactory in that they were distracting, interfered with the use of some instruments, and constituted a hazard on the darkened bridge. The methods of controlling this factor which proved satisfactory were (a) the motivation of the observers themselves, who were typically too busy with their own observing and reporting to pay attention to what was going on about them, and (b) close supervision, which kept the voices of both observers and recorders low so that it was not easy to overhear the conversation, and which maintained the recorder in close proximity to the observer. Interference between subjects, then, remained a problem, but it was reduced to a minimum.

In any event, observer interference may be checked statistically, and information on this is presented elsewhete in this report.

Routinization of Report: The possibility has been mentioned that, by this technique, the observers might learn to report a given discrimination (i.e. sighting a given target to a given criterion of seeing) on the basis of the mark number announced over the loudspeaker. This possibility may be discounted since the same mark number was associated with a wide variety of ranges (owing to the different positions from which a run might start) and, consequently, with a wide variety of targets, and since, with poor visibility, the ranges at which various discriminations were made shifted proportionately.

It would require very careful thought and a few calculations to figure out the proportional shifts to be made, if observations were to be made on the basis of the mark number announced.

Supervision: Several supervisory personnel were necessary at the observation posts. Their manifold duties included not merely verification of and correction of improper behavior of the observers and recorders (use of a loud voice in reporting, not paying attention to business, elimination of extraneous conversation, proper maintenance of a binocular as hand-held, etc.), but also check of position of binoculars, use of lens paper, and proper filling-in of data sheet headings.

THE INSTRUMENTS TESTED AND SETS PERFORMED

The original program called for the testing of approximately 12 instruments. At the termination of the September experiments, however, it was evident that the data obtained were of such quality that more instruments could be included in the experiment without limiting the value of the data on any of them. Accordingly, additional problems were added to the program, and new instruments were added, either on request of BuOrd, or on the basis of statistical requirements.

The sets run were designated by two letters: the first, referring to the instrument compared, is capitalized for night observations and is lower case for day; and the second, referring to the section of men serving as observers, uses capital letters for 6-man night sections and for day sections, and in lower case letters for 3-man gun deck night sections. A subscript numeral to the first letter indicates that that set differs in one instrument from others with the same letter designation. A parenthetic subscript "S" denotes a set of runs as one made at high speed. The final numeral, which appears after some sets, indicates that the set was repeated one or more times, using the same section of observers. The list of sets of runs made by night and day appear in Table B-3 and in full detail in Appendix C.

Table A-1 lists the instruments, showing the manner in which each was used, and the number of sets in which it appeared. Appendix A illustrates them, lists their specifications, and names the sets in which each was tested.

The initials HH after an instrument indicates that the instrument was tested "Hand Held" - the observer, standing, held the instrument to his eyes, and had no elbow rest or other support to assist him. This duplicates the most familiar manner in which binoculars are used. (Fig. 16.)

HHR means "Hand-Held-Rested". Here, the observer was free to seek any support which satisfied him. He was free to sit on the deck and rest the binoculars on the deck-rail, to sit and rest his elbows on the rail, to lean back and support his elbows on his chest. Any activity he chose to reduce vibration, or to render observations less fatiguing was acceptable.*

MTD, mounted, means that the instrument was rigidly fixed in either a Mark 51 director mount, or in a Mark IV Alidade. Both of these mounts provide for easy manipulation of the instrument in question, but both are mechanically so constructed that vibration of the ship is transmitted to the binocular.

The 7x50x7° VFA is a standard 7x50x7° instrument which is suspended, within a small housing, from a series of free-balancing contacts (in each dimension) such that little or no vibration is transmitted to the binoculars from the ship. In this anti-vibration alidade mount, developed by NDRC, the binocular still retains its own critical vibration.

TABLE B-3

SUMMARY OF SETS OF COMPARISONS

A. Night Observations

Code Letter	Comparison	Runs in Set	Number of Sections & Repetitions by Each Section
H	Hand-held binoculars	6	3x2; 1x1
M	Low-power mounted instruments	6	4x1
P	High-power mounted instruments	6	4x1
B	Type of mount (9 knots)	6	5x1)One section in common
B(s)	Type of mount (17 knots)	6	2x1
I	Interaction: Observer-Binocular	12	1x1 (double section)
V	Variability of 7x50x7°	6	2x1
E	Exit pupil series	6	2x1
H	Hand-held binoculars	3	4x1
F	Fixed Focus (-1d; -2d)	3	4x2
A	Head rests	3	4x2
W	Wide-field binoculars (9 knots)	3	3x2
W(s)	Wide-field binoculars (17 knots)	3	2x3
D(5)	Field Size and Mount (5°)	3	4x1
D(10)	Field Size and Mount (10°)	3	4x1
D(12)	Field Size and Mount (12°)	3	4x1
N	Prism telescope	3	2x1
E	Exit pupil series	3	2x1

(Table continued on next sheet)

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* Occasionally, there is some internal evidence in the data that observers in less easily supervised positions tended to make any "HH" instrument "HHR". This was especially true with presence of wind, when the men tended to keep low, behind the rail. This was, however, no problem in general.

TABLE B-3 (CONTINUED)

B. Day Observations

Code Letter	Comparison	Runs in Set	Number of Sections & Repetitions by Each Section
b	Type of mount	3	2x1
p	High-power mounted instruments	3	2x1
c	[illegible] monocular	3	3x1
w	Wide-field binoculars	3	2x1
k	1[illegible]-power binoculars	3	2x1
n	Low-power mounted instruments	3	2x1
o	Low-power mounted instruments	3	2x1; 1x1

Summary of Night Operations

Type of Set	Total	Invalid	Reported
12-run	1	-	1
6-run	26	3	23
3-run	48	10	38

Total Runs: 177

Total Sets: 62

Summary of Day Operations

Type of Set	Total
3-run	16

Total Runs: 13

Total Sets: 16

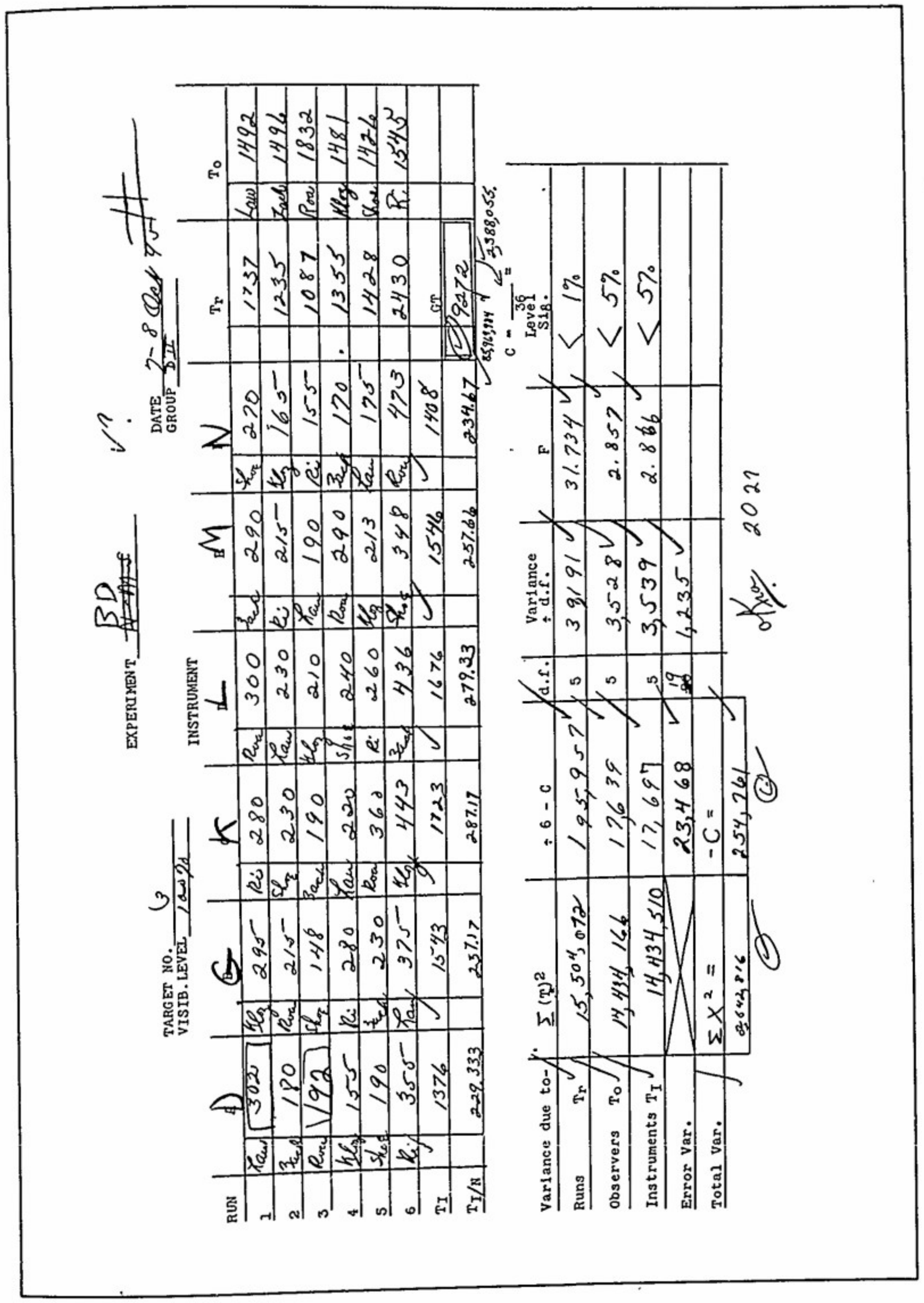
STATISTICAL TREATMENT OF THE DATA

The treatment of the data, designed to establish the differences among binoculars, followed a carefully planned and standardized pattern, which provided for several checks of accuracy. Early stages were performed at the Submarine Base, and the later phases at the Department of Psychology, Yale University, under the immediate direction and supervision of Dr. Charles E. Osgood.

I. Preparation of the Data for Statistical Treatment:

At the end of each observation period, the individual observation data sheets and comment sheets, logs, and range sheets, and DRT plots for each run were delivered to the statistical group and their treatment begun next morning. Each observational data sheet incorporated in its heading identifying material. These sheets were first checked by name of observer, run, and instrument against the schedule to ensure that the correct randomization had been followed. The sheets were then coded and arranged by set designation, run and instrument.

The raw data which appear on the sheet (Fig. B-2) consist of mark numbers indicating the number of 15-second intervals between the beginning of the run on the fort and the time at which the observer reported the



EXPERIMENT BD ~~[illegible]~~

TARGET NO. 3

VISIB. LEVEL 1 mi

DATE GROUP 7-8 Oct 45 D II

INSTRUMENT

RUN		D		G		K		L		M		N	Tr		To
1	Law	302	Klg	295	Ri	280	Rou	300	Zack	290	Shes	220	1737	Law	1492
2	Zack	180	Rou	215	Shes	230	Law	230	Ri	215	Klg	165	1235	Zack	1496
3	Rou	192	Shes	148	Zack	190	Klg	210	Law	190	Ri	155	1087	Rou	1832
4	Klg	155	Ri	280	Law	220	Shes	240	Rou	290	Zack	170	1355	Klg	1481
5	Shes	190	Zack	230	Rou	360	Ri	260	Klg	213	Law	175	1428	Shes	1426
6	Ri	355	Law	375	Klg	443	Zack	436	Shes	348	Rou	473	2430	Ri	1545
TI		1376		1543		1723		1676		1546		1408	GT 9272		
TI/N		229.333		257.17		287.17		279.33		257.66		234.67			

85,963,984

C = $\frac{\quad}{36}$ = 2,388,055.

Variance due to-	Σ(T)²	÷ 6 − C	d.f.	Variance ÷ d.f.	F	Level Sig.
Runs Tr	15,504,072	195,957	5	39,191	31.734	< 1%
Observers To	14,434,164	17,639	5	3,528	2.857	< 5%
Instruments TI	14,434,510	17,697	5	3,539	2.866	< 5%
Error Var.		23,468	19 ~~20~~	1,235		
Total Var.	ΣX² = 2,642,816	−C = 254,761				

2021

Figure B-5. Computation Sheet. The data on each discrimination of each target was entered on a computation sheet, and the F-values computed.

discrimination on which the entry is made (that is, reports seeing a certain target to a given criterion of seeing: first glimpse, 100%, or positive identification). For illustration, on the data sheet given in Fig. B-2, observer Shoemaker reports 100% seeing on target 3 (radar screen) at 51 (during the 52nd fifteen-second interval * since the beginning of the run).

The second step in the preparation of the data for statistical analysis was to translate these mark values into corresponding range values. Synchronously with every time-mark, it will be remembered, the range and bearing of the fort from the DE was recorded. These values were determined by radar. Since the approach of the DE on the fort was remarkably constant in speed and since the radar ranges were usually highly reliable, the radar ranges were used directly, and the DRT plot used only to correct the occasional irregularities which appeared in the radar record. The DRT plots were also used to obtain ranges to the target vessels, on those runs where all radar ranges were taken on the fort.

The mark-values were translated into corrected radar ranges and entered on 6x6 (or 3x3) data sheets on which the Latin Square analysis was performed for each discrimination. These sheets (Fig. B-5) were used for all subsequent statistical computations. Space on these computation sheets was provided to indicate the experimental series, the target, the criterion of seeing, data and group (code mark of set). Each range value entered on this sheet represents the performance of a given subject (initialled in small cells) using a given instrument (columns) on a given run (rows). Space is provided on these sheets for run, observer, and instrument totals, (T_R, T_O, T_I) and for the complete statistical analysis through the determination of the level of significance of the obtained F-values.

Some Basic Problems in Treatment of the Data:

Before presenting a detailed statement of the statistical treatment which was employed, several basic considerations must be presented and clarified.

I. The Distribution of the Data: Other things being equal, data on the ranges at which a given target may be seen are logarithmically distributed. Essentially, measurement is made of a visual angle, which is a trigonometric function of the range. Since the data are of this nature, then, unless the distribution of visual angles at threshold is itself logarithmic, all data should be treated in terms of log range. There is ample evidence that this is true; first, the variability of the range is a function of the range, and second, the differences in range obtained with various instruments are also proportional to the range.

However, further analysis has shown that, within any set of runs, it is not possible to determine whether statistical treatment of ranges themselves, or of log ranges is to be preferred; the data are too few in number to permit a choice to be made. Indeed, in the analysis of variance made on each set, this is a matter of indifference; it does not depend upon the usual assumption of normal distribution of the data.

Evaluations of "t" and its probability, however, do require that one deal with normal distributions. It may be, consequently, asked whether it is justifiable to apply normal curve statistics to data which theoretically (if not practically) are logarithmically distributed. It is believed that this is justified because:

(1) the data within any set are so few that it is impossible to determine whether a larger sample of them would be normally or logarithmically distributed.

(2) the difference in findings is slight, and the error introduced, if any, is conservative. This is demonstrated by the findings on one set which was treated both ways.

(3) the treatment of the data themselves, without conversion, permitted a considerable and necessary saving of time.

(4) the essentially logarithmic nature of the distribution and the proportionality of differences to ranges is taken into account by the summarizing procedures which are based upon percentages of the standard 7x50x7° ranges obtained with each of the instruments.

(5) finally, when the full distribution of range values is obtained on one target, and subjected to analysis, it is seen that while the statistical constants of the logarithmic values describe the data better than those of linear values, the actual difference found is small.*

The basic treatment, then, has been applied to linear ranges. Some of the special treatments, however, have been applied to log ranges, as a matter of convenience.

Reference Instrument

Since all-over weather and observer conditions varied markedly from square to square, it is necessary to have some basic standard to which the absolute ranges obtained with various instruments on different sets might be related. The standard 7x50x7° HH binocular was included in every set in the experiment, and the range value achieved with it served as the reference level with which the performance of the other instruments is compared. All final results on each set are reported in terms of the ranges obtained with any instrument expressed as a percentage of the range obtained with the standard instrument. The probability that these values express the performance of the instrument is plotted on probability paper and the result is referred to as Relative Range Performance Curve for that set. The .50 intercept reflects the most probable performance of a given instrument in relation to the 7x50x7° binocular.

Losses of Data

It was necessary to discard certain data. Data on three entire sets, BB, W(s)1-2 and W(s)j-2, had to be discarded because of failure of randomization in planning

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* In the September night observations, 30-second marks were used, but they were changed to 15-second marks for the remainder of the experiment in order to obtain more sensitive measurements.

* This is, of course, in part determined by the visibility conditions under which the data were collected.

tion of values for runs, instruments and observers and the final summations into the grand total (GT). These operations check directly since $\sum T_R$, $\sum T_O$, and $\sum T_I$ must all equal the same value (GT). Secondly, all instrument totals were divided by 6 (number of runs) to give the mean ranges for instruments. Thirdly, the correction factor ($\frac{GT^2}{N}$) was determined. Means and correction factors were done separately by each of two operators in order to provide an independent check.

(3) Sum of Squares: The summing of squares ($\sum T_R^2$, $\sum T_O^2$ $\sum T_I^2$, and $\sum X^2$) was done on calculators on which the entire process of squaring and accumulating is automatic upon entry of values. This machine also gives the direct total of the values entered, which, as on each summation of squares, should equal GT.

(4) Variance and F-Values: The remaining completions on the computation sheets ($\sum x^2$ [illegible] d.f. and the determination of F-values)* were also done independently by two different statistical operators, and the probabilities of these F values were determined by reference to the F-tables given in Snedecor.*

(5) Final Re-check: A final check of the above computations was made by having two operators re-check the degrees of freedom and the divisors, and also repeat the final computations by formulae which essentially reversed the procedures already followed. This last step was designed to pick up any constant errors.

Significance of Differences Among Instruments:

The central problem for which these experiments were designed was to determine the magnitude and significance of differences in performance of the instruments used. The F-tests made above, which appear in Appendix C, provide an over-all estimate of the significance of difference among runs, observers and instruments, but they provide no evaluation of the magnitude of the differences between individual instruments.

Therefore, the next step in the statistical treatment was to estimate, for each discrimination, the significance of the difference between the mean range for each [illegible] instrument and the mean range for the standard 7x50x7° HH, by determining the t-value of the mean difference.

In order to utilize the precision (reduction of variability) obtained by the analysis of variance already made, it was necessary initially to treat each discrimination individually.* For a given set and discrimination (e.g., for Set MA, 3, Glimpse), the best estimate of the variance of the mean range for any instrument (σ^2_M) is derived from the remainder, or error, variance as determined in the Latin Square analysis, symbolized as EV. EV is an estimate of the experimental error after the variability due to runs, observers and instruments has been removed. Substituting this value in the usual formula for the sigma of the difference between the two means, the following equation is obtained:

$$\sigma D = \sqrt{\frac{EV}{n_1} + \frac{EV}{n_2}}$$

in which EV is the error variance for the square and n is the number of items entering into each mean. Since n_1 and n_2 are always equal (either 6 or 3), the formula becomes:

$$\sigma D = \sqrt{\frac{2\ EV}{n}}$$

and the required t-value is determined through the usual formula

$$t = \frac{D}{\sigma D}$$

in which D is the obtained difference between the 7x50x7° HH mean range and the mean range for any other instrument employed in that set. The probability that the null hypothesis is tenable is found by consulting a t-table.

This method of determining the significance of results is necessary if the refinements of the analysis of variance are to be utilized, but it gives only a limited estimate of the relative performances of the instruments tested. The results obtained are not easily interpretable by others than skilled statisticians, and even they would have difficulty with the approximately 1000 "t" values obtained in this manner.

Combining and Summarizing the Results

In order to present the results in an easily comprehensible manner,* further use was made of the t-test. The usual null hypothesis (that there is no difference) is only one of an infinite number of hypotheses that may be evaluated by the t-test. The hypothesis that there is a 10% difference, or that there is a 25% difference, and so forth, may be tested. This becomes clearer if the formula for t given above,

$$t = \frac{D}{\sigma D}$$

is transformed into the more general and theoretically useful form

$$t = \frac{M_T - M_O}{\sigma D}$$

in which M_T is the hypothetical mean of the population and M_O is the obtained mean. The question then becomes one of the probability that the given obtained mean could have been drawn by chance from a population having the given hypothetical mean.*

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* In analysis of variance, the ratio of the [illegible] attributable to one of the factors under investigation to the error variance, [illegible] the variance which is not attributable to any of the variables investigated, is termed F. The value of F determines whether the [illegible]

* Snedecor, G. W. Statistical Methods Collegiate Press Inc., Ames, Iowa [illegible]

* Results in separate discriminations cannot be combined in the usual manner of summing squares since the necessary assumption of independent samples is not met. Generally, high correlation exists between discriminations, approximating .80 for "adjacent" discriminations and being somewhat lower for others.

* At the well-conceived insistence of Lt. Comdr. N. H. Pulling of BuOrd.

**Obviously, then, the smaller the value of p, the more significant is the obtained difference. Throughout this report, p is given wherever possible, so that the reader may evaluate the significance of differences reported.

In applying the formula to these data, M_T is the obtained mean for the standard 7x50x7 HH for a given set and M_O is the obtained mean for another test instrument on the same set. The t-test then gives the probability that the mean for the test instrument could have been obtained from a sample of a population having the same mean as the standard. For example, if M_T is 1000 yards and M_O 1100 yards, then the t-technique gives the probability that, a difference as great as 100 yards in range will be obtained in the absence of a basic difference in the efficiency of the two instruments, i.e., by chance alone. If this probability is only .01, then there is adequate reason to discard the hypothesis that the test instrument is no better than the standard.

If the performance of the standard instrument is allowed to assume values of 80%, 90%, 110%, 120%, and so on of its obtained value, it becomes possible to compare the performance of the test instrument with each of these hypothetical performances, and to determine the probability with which the null hypothesis may be rejected for each.

When a series of these percentage hypotheses for a given instrument on a given set is tested, the [illegible] best estimate of the standard error of the difference, based on the error variance of the set and the M_T obtained mean ranges for the given test instrument [illegible], and only M_T [illegible]. Thus a series of t-values can be obtained for various magnitudes of $M_T - M_O$ with a constant S.E. To the extent that distribution of 't' approximates a normal distribution* these values fall along a straight line when plotted on probability paper. Because of this a great deal of labor was saved, since only two percentage tests were needed to locate the line. The points used were 100% (equivalent to the usual null hypothesis) and either 120% or 80%, depending on whether the obtained mean range for the test instrument was greater or less than the obtained mean range for the 7x50x7 HH standard.**

Such a plot as this makes it possible to state the probability that a given instrument will perform at ranges equal to or greater than any given percentage of the range obtained with the standard 7x50x7° HH binocular. Figure B-6 presents an example of such probability plots for the 7x50x7° VFA as it functioned in relation to the 7x50x7° on set BD. Each line on this graph represents the results for a single discrimination (e.g. for target 3, 100% frequency of seeing). It will be noted that the lines representing different targets and levels have varying slopes. The slope is a function of the magnitude of the standard error of the difference which may vary with the mean range so that the greater the magnitude

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* For this particular purpose the approximation of the distribution of 't' to a normal distribution is adequate where N is [illegible] or greater. In the case of the [illegible] analysis, there were between 12 and [illegible] degrees of freedom. In the case of the [illegible]'s, the degrees of freedom are only [illegible] in number and straight-line plots on probability paper could only be made between [illegible] and [illegible], the function being approximately linear between these limits.

** For ease of consideration for the statistically untrained readers, the probability scale of the graphs has been reversed, so that the results may be uniformly interpreted in terms of the probability that the relative range performance is at least as good as that shown.

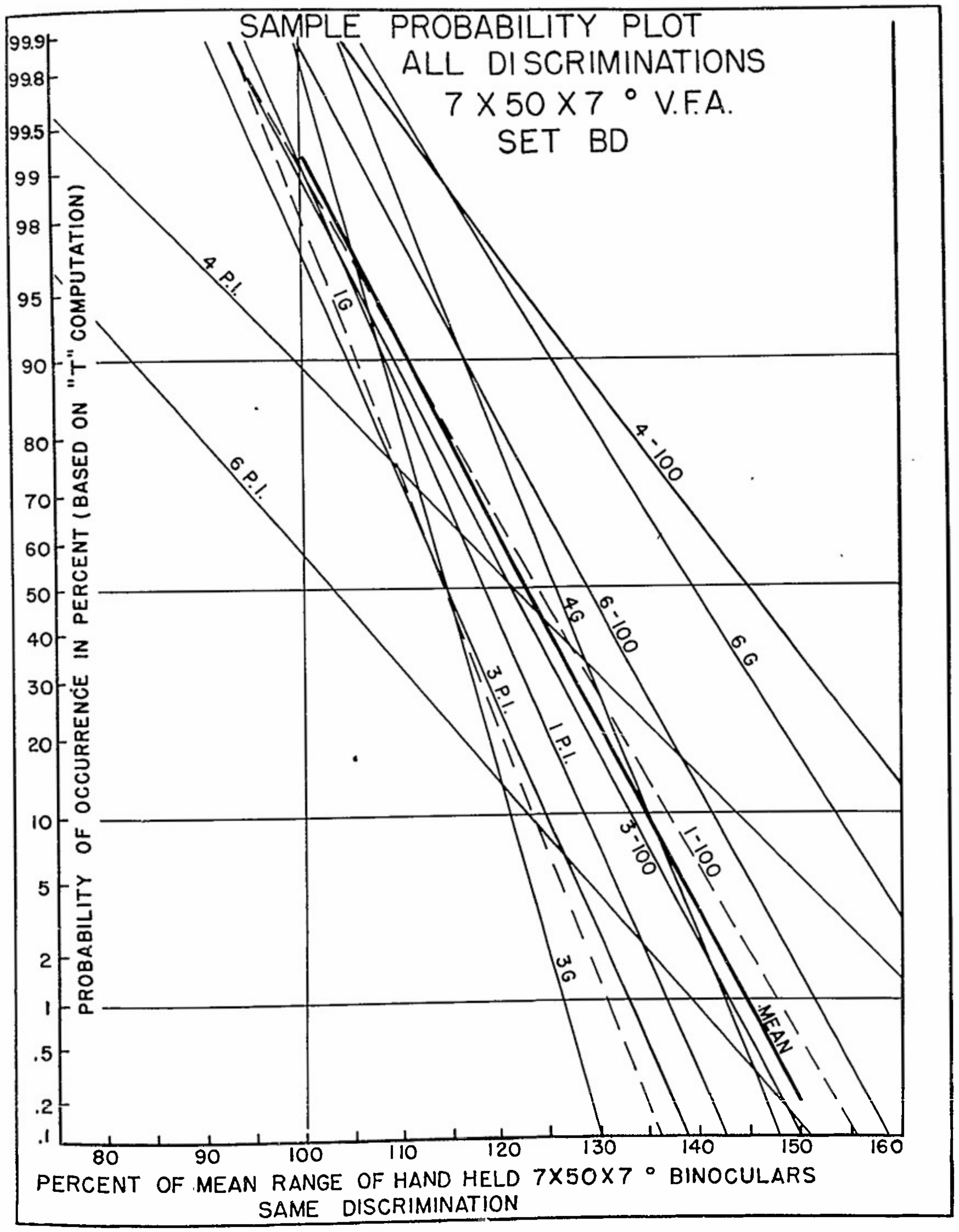

Figure B-6.

of σD the less the slope, and the greater the mean ranges the greater the slope. In most such plots, the slopes for Target 1 (Glimpse and 100%) are much steeper than the slopes of the other lines. This is a finding common to nearly all instruments on all sets, and is probably due to the fact that runs often started short and that these discriminations involve a search problem where the smaller targets do not. For this reason, in the summating procedures, Targets 1 G and 100% have been omitted from the analysis. They are, however, discussed with the data on search, which they closely resemble, in relative ranges, slope, and instrumental findings.

Derivation of the Relative Performance Curves for Each Set:

The next step in the statistical procedure was to combine the various estimations of an instrument's performance from all discriminations in a given set into a single most representative expression. The usual method of combining probabilities is inapplicable since it assumes that the probabilities to be combined are based on independent estimations. The procedure followed was to average the t-values mathematically determined by the values of p for a given relative performance of the instrument in question. Referring again to Fig. B-6, the t-values corresponding to the probability of 110% of the mean 7x50x7° were averaged, and likewise those for 120% and so on. When these average t-values were determined, their probabilities were determined and the final combined probability curve for the set drawn from these new probability values. T-values rather than probability values were averaged because averaging of probabilities would minimize the importance of extreme values. This method of combining by averaging is a conservative one, in that it assumes a perfect correlation among the individual targets and levels. Actually, the correlations run at .80 and below. Thus, to the extent that there is independent variation among targets, the significance of the results is underestimated.

Each of these combined curves represent a satisfactory though conservative estimate of the performance of an instrument in relation to the standard for a given set The combined curve is then transferred from probability paper to a linear grid and yields a curve approximating a typical sigmoid function. The Relative Range Performance curves in Appendix A present the performance of each instrument on each of the sets of runs in which it appeared, as determined by this procedure.

Final Relative Range Performance Curves:

A final summation of these data is possible which takes into account the consistency of results obtained with the same instrument on different sets employing different subjects and different runs. In this summation, the usual technique of combining probabilities can be used since each set represents an independent estimate (different subjects and runs) of the performance of the instrument in question. The actual method involves multiplication of individual probabilities, and determination of the probability of a resultant as described in Lindquist.*

The probability values summated in this final analysis were obtained from the relative range performance curves representing, for each set, the best estimate of performance based on all discriminations. These relative range performance curves thus represent the best over-all estimate of each instrument's performance based on findings of the whole experiment. The value of the X-intercept of these curves, at $p = .50$, is defined as the Relative Range Performance (.50RRP), and is used throughout the tables.

In this summation, results from 6x6 and 3x3 night sets are separately presented, because the number of degrees of freedom differs widely so that the estimates of significance varied, and also because systematic differences in range appeared between the result obtained at the two observation positions. The results for night speed runs are also treated separately, since they constitute a separate investigation. All day data were combined wherever possible, regardless of observation post, since no systematic inter-deck differences appeared, and all were obtained in 3x3 sets.

Curves for seven individual sets, all on different instruments, were also dropped from the combined sample, since they gave atypical results, which seemed to indicate the operation of some as yet unidentifiable factor. One whole set, MD, was dropped from final summation, since the results, attributable to an extremely severe wind, were also anomalous.*

The increased precision obtained by this final summation is indicated in the slopes of the RRP curves, which are steeper than those of the curves for individual sets from which they were derived. This increase in precision is due to the combining of independently obtained estimates of significance.

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* E. F. Lindquist, Statistical Analysis in Educational Research. Houghton Mifflin Co., 1940, p. 46.

* In this set, all instruments except the 7x50x7° performed very poorly. The 7x50x7° was in a position where it could have been used HHR, which is invalid as a standard. Final evaluation of these data must wait upon further analysis of the results.

SUMMARY OF OPERATIONS

The schedule of the field trials was designed to include five basic experiments, and a series of miscellaneous trials. It was originally planned that all experiments requiring joint operations with the destroyer-escort could be completed by 27 November, and that shore trials could be run simultaneously.

The beginning of demobilization made it impossible to meet this schedule, since, at times when it had been anticipated that day runs could be made, it was necessary to recruit and train new subjects. Although it was possible to complete satisfactorily the basic trials of binoculars and optical instruments at night, day operations were limited in number, and it was not possible to perform those experiments requiring joint operations with aircraft. The importance of these trials, however, had diminished greatly with the end of the war.

A summary of successful operations is given in Table B-4.

TABLE B-4

SUMMARY OF SUCCESSFUL RUNS
IN EACH MONTH

A. Night Operations

Month	Successful Operating Nights	Successful Runs
September	6	39
October	7	59
November	8	61
December	2	18
	Total	177

B. Day Operations

Month	Successful Operating Days	Successful Runs
November	2	6
December	3	7
	Total	13

Night Operations:

During the period 4 September to 9 December 1945, the moonless period was sufficiently long to permit operations to be scheduled on 51 nights. On 23 of the 51, operations were carried out; operations were cancelled in the remaining 28 because of weather (19), of mechanical breakdown of necessary equipment on DE 132 (4), or for other reasons (5).

(a) Of the 19 cancellations because of bad weather, one was occasioned by heavy sea and high wind, which made operations impossible by wetting the lenses of the instruments in use, and the remainder by rain or fog. On one or two nights, operations had to be suspended earlier than anticipated because of lowered visibility. In general, the time lost because of unsatisfactory weather was less than had been anticipated.

(b) Mechanical failure of the gyro-compass and of the radar of the DE 132 occasioned the loss of four nights of operation.

(c) Other losses were due to such factors as breakdowns and "disappearance" of the LCM, which was required for the target crew to perform night operations, to urgent and reasonable request by the CO of the PEARY for liberty for his men, and to the Army-Navy football game, when all operations in the area were cancelled.

Day Operations:

Successful day operations were performed on 5 days. Of the other possible dates on which day operations might have been run, 10 of them were lost because of weather. The remaining time of the 110 days through which the PEARY was assigned was spent as follows: indoctrination of PEARY-6; installation of mounts-7; absence of PEARY for Navy Day-8; training runs-12; no operations scheduled (holidays, weekends, engine trouble, refuelling, etc.)-11.

The scant number of days on which it was possible to perform day observations necessarily limited the amount and consequently the precision of the data obtained.

The day observations were made in late November and early December. During this period, the weather in the operating area was characterized by an early morning haze which limited visibility to some eight miles during the whole morning period, and also by a serious atmospheric refraction, which even more severely limited the ranges at which observations could be made. As soon as the fort and its targets became visible out of the haze, it had the appearance of a tall rectangle with broad vertical stripes. In any event, it was impossible to discriminate among the targets in any way, or to separate them from the striped appearance of the fort itself, under conditions of such extreme distortion. As a consequence, all the discriminations which were made at these ranges were not only made almost simultaneously but also were quite meaningless.

The general condition of observations during the day runs must also be considered. The days were cold, and the observation vessel was headed almost directly into the wind. Sustained observation through the sixty minute runs was almost impossible from the exposed observation posts, and frequent interruptions occurred while the men turned their backs to the wind, or bent down behind the rail. This problem was most acute on the lower deck, where spray often came over the bow, wetting the men and their instruments, and requiring time out to clean lenses.

To what extent these factors account for the relatively poor showing of binoculars by day is not known. However, despite the difficulties and the limited number of data, the results are considered to be sound.

RESULTS, PART I. METHODOLOGICAL PROBLEMS

The section to follow will be of limited interest to those primarily concerned with the problems of optics. The results reported cover four types of analysis of the data which are necessary for the proper evaluation of the findings on instruments (reported in RESULTS, PART TWO). The first of these analyses establishes that the basic procedure of requiring observers to report in terms of three criteria of seeing leads to valid results, and is suitable for the purpose of the experiment. The second establishes whether it is possible to extrapolate from the findings on a particular instrument of a given type to others of the same design, and gives data on the variability to be expected in the performance of a single type of instrument. The third tests the importance of observation position in determining the performance of an instrument used in that position, and throws some light on the effect of the reports of one observer on those near him. The last describes an experiment. It establishes that one binocular will not perform equally well for all those who use it, but will be better or worse than another, depending on the user. This result has consequences not only for the validity of the present results, which are based on the performances of observers, but also for binocular procurement, and the selection of personnel.

THE CRITERIA OF SEEING

The basic method employed in collecting data is essentially a novel one. It requires the acquisition by the observer of certain skills in observation and reporting. If this acquisition is not successful, results based upon them are necessarily vitiated. Therefore, the first analysis to be presented is designed to determine the efficacy of the use of the "Criteria of Seeing".

On each run, each subject was called upon to report when he was able to see each target to each of three criteria of seeing. The concept of criteria of seeing is fundamentally based upon the probability of seeing curve which describes the frequency with which a visual stimulus is effective when its intensity is near the sensory threshold.

First Glimpse: "First glimpse" is defined in terms of a low frequency of seeing. Below the 50% threshold, but near it, a target will appear to come and go, and no stable view of it can be obtained. In field observation, a target may be seen momentarily as a single "blob" and then fade out, not to appear again for some time. This is considered to correspond roughly with the lower limb of the frequency of seeing curve, as it is obtained in laboratory determinations of the threshold.

100% Frequency: "100% Frequency" is defined in terms of a high frequency of seeing. At a very high frequency of seeing, the target will be seen continuously as a vague blur, and will no longer seem to come and go. It is not identifiable at this level of visibility.

Positive Identification" The report "positive identification" is given when the observer is able to state unequivocally the identity of the target. It requires that the target appear as more than a vague blur, that it possess definite characteristics of shape, brightness, size or position. Obviously, each observer is free to set up his own standards on which to base this report, but he must be consistent in reporting "positive identification" on the same basis from run to run.

Analysis: There can be no question that the attempt to indoctrinate our observers to report the set of targets in terms of these three "criteria of seeing" involved certain calculated risks; failure of the men to assimilate these criteria or to adhere to them consistently would yield highly variable data, obscuring any positive findings and possibly yielding misleading results. With the risks in mind, training on the criteria of seeing was designed to set up, for each observer, a stable basis, as uniform as possible from observer to observer, for each of the three judgments, and to maintain them consistently throughout the whole series of observations.

In analysis of the data to determine the effectiveness of the use of these criteria. a variety of methods and statistical treatments have been employed.

Analysis of Variance: The first analysis, based upon the results of the observer sections, is designed to yield unequivocal answers to the following questions:

(1) Do the members of one observing section maintain from run to run the same standards in reporting targets to each of the three criteria of seeing?

(2) Do members of two different sections employ the same standards in reporting targets, i.e. are their criteria of seeing the same?

To answer these questions, a series of analyses of variance have been set up which make use of the data employed in our basic comparison of optical instruments. As a means of filling in missing values in the original Latin Square analyses, mean differences in range between levels of seeing for all targets on a given square were determined. This procedure is described on page 134. Since the absolute magnitude of these mean differences between levels of seeing is dependent to a considerable extent on weather conditions, instruments, etc., ratios of the mean range for one level compared with another were employed, i.e. M 100% / M Glimpse. Thus the range at which 100% seeing is reported is determined as a proportion of the range at which targets are just glimpsed.

Two such ratios were determined for each set of squares: 100/G and PI/100. To the extent to which these ratios are constant for the same group of observers functioning at different times, it may be assumed that their standards of judgment have remained constant. To the extent that these ratios are the same for different groups of observers, it may be assumed that essentially similar standards of judgment were maintained by the different groups.

Randomized block designs for two variables were utilized in this analysis, one variable being the order of sets (i.e., 1st set, 2nd set, etc.) and the other being groups of observers (i.e. group A, group B, etc.) Thus two sources of variance could be isolated, that attributable to variation in standards with time (or practice) and that attributable to differences among groups of observers, and the significance of these sources of variance could be tested against the remainder variance.

Since groups of subjects differed in the number of sets in which they participated, separate analyses had to be made for various equivalent groups. Table B-5 indicates the groups used, the number of of sets run (order variable) by each group, the degrees of freedom entering, and the F-values resulting from the analysis of variance.

These analyses of variance lead to several conclusions which are based upon the data presented in Table B-5, A and B.

(1) The data for the 100/G ratios give no suggestion whatever of any consistent differences, either with practice, or among groups of observers. Indeed, of the 6 values of F pertinent here, five are below 1.0, indicating that the differences were even smaller than those most likely to appear by chance in the absence of any

TABLE B-5

ANALYSIS OF VARIANCE--CRITERIA OF SEEING

A. 100%/Glimpse Ratios

Group	No. Repetitions	Degrees of Freedom Orders	Groups	Error	F-Values Orders	Groups
A, D, E	3	2	2	4	0.140	0.280
b, i, j	4	3	2	5*	0.371	0.726
a, c, d, f, g, h, k	2	1	6	6	0.090	3.091

B. Positive Identification/100% Ratios

Group	No. Repetitions	Degrees of Freedom Orders	Groups	Error	F-Values Orders	Groups
A, D, E	3	2	2	4	0.463	3.250
b, i, j	4	3	2	5*	1.829	4.000
a, c, d, f, g, h, k	2	1	6	6	1.375	1.375

*In these analyses, one value had to be filled in by the method reported in Snedecor ("Statistical Methods", Collegiate Press, Inc., Ames, Iowa, 1938) and hence one degree of freedom is subtracted from the error term.

consistency.

(2) The data for the PI/100 ratios do give some suggestion of a consistent difference among groups of observers. None of these three F values reach the 5% level of statistical significance, but the three taken together suggest the presence of some consistency, indicating that the observers may differ among themselves in the PI criterion. This difference also appears in the reports of the observers, which will be reported later. But again, as in the case of the 100/G ratios, there is no indication of the appearance of significant differences in these criteria with practice; they remained stable.

(3) The F-values for variance among groups are consistently higher than those for variance among orders. This suggests that differences between observers in standards of judgment are somewhat greater than differences in the same observers through time, and consequently that data from an individual may show high reliability. Since these analyses relate to groups of observers rather than individuals (such estimations being more crucial to the final results reported), it is impossible to isolate the individual variability by this statistical technique.

Correlation Analyses: Further analyses of criterion data were made in order to throw more light on the reliability of reports, and in order to provide a basis on which these data might be compared with others.

(1) Establishment of ratios of criteria of seeing to one another.

(a) Variability of ratios of criteria of seeing (all instruments):

TABLE B-6

MEAN FILL-IN VALUES

(Absolute, by sets; N = 56)

		Mean	SD
1.	$\frac{G}{100}$	1.252	0.102
2.,	$\frac{100}{G}$	0.808	0.056
3.	$\frac{PI}{100}$	0.642	0.090

r_{12} = -0.08 r_{23} = 0.05

Computed Ratio: $\frac{PI}{G}$ = 0.519

Table B-6 gives the mean ratios G/100, etc., as determined on all targets in each set, and the intercorrelations of each with values obtained by adjacent observers.

The low intercorrelations between the correction factors derived from the same set of runs indicate that the values of the ratios vary from set to set in a random manner, and not systematically. This indicates that the ratios hold without respect to the large variations in mean ranges due to visibility differences, and consequently that the observers are indeed responding to some aspect of a basic "subjective" variable, such as that measured by the frequency of seeing curve.

According to these figures, the mean 100 range is approximately 80%, and the mean PI range is 52% of the Glimpse range for a given target.

(b) Mean ranges, by sets (7x50x7° HH Binocular only):

Table B-7 gives the mean ranges for 5 discriminations, the ratios of 100% and "PI" to "G", and pertinent intercorrelations, from the mean ranges of all sets in which data were complete.

The estimates of proportionality obtained by this quite different method are in excellent agreement with those obtained by the first method.

The high intercorrelations of mean ranges based on group averages of various

TABLE B-7

MEAN 7x50x7° HH ABSOLUTE RANGES, BY SETS

Target		Discrimination	N	Mean Range (in Hundreds of Yards)	SD	Ration of Mean Range to G, Same Target
A.	3	G	53	38.3	14.0	1.00
B.	3	100	56	29.2	7.9	0.76
C.	3	PI	56	18.9	4.8	0.49
D.	4	G	44	30.2	9.0	1.00
E.	4	100	43	23.8	6.8	0.79

r_{AB} = 0.81 r_{BC} = 0.86

r_{AD} = 0.82 r_{BE} = 0.85

TABLE B-8

MEAN 7x50x7° HH LOG RANGES BY RUNS
(TARGET 3 ONLY)

		Signal Bridge			Gun Deck		
	Discrimination	No.	Mean	SD	No.	Mean	SD
A.	3-G	171	3.55	0.18	124	3.50	0.19
B.	3-100	171	3.44	0.18	124	3.36	0.15
C.	3-PI	167	3.31	0.20	118	3.23	0.17

Signal Bridge: $r_{AB} = 0.88$, $r_{BC} = 0.33$

Gun Deck: $r_{AB} = 0.82$, $r_{BC} = 0.41$

Difference	Log	Ratio	Log	Ratio
A - B	0.11	0.775	0.14	0.725
A - C	0.24	0.575	0.27	0.537

discriminations, when considered together with the low intercorrelations of ratios reported in the preceding section, indicate the high reliability of observations and the independence of the ratios from the influence of visibility conditions.

(c) Mean log ranges, by runs:

A final analysis investigated the relationships between G, 100, and PI on target 3. Table B-8 gives the results, for the signal bridge and gun deck respectively, on the log ranges on individual runs at which the three discriminations were made.

The ratios obtained, again, are close to those obtained by other methods.

However, the correlations are of more interest. It should be noted that the intercorrelation of G range with 100 range is very high, and is of the same order of magnitude as that obtained when mean ranges of all runs of a set are intercorrelated. The correlation between 100 and PI ranges, on the other hand, are relatively low (.30 - .40). These values permit certain conclusions to be drawn. (1) Different individuals maintain uniform criteria for "first glimpse" and "100% frequency", and (2) different individuals vary in their criterion of "positive identification", so that, although on the average PI ranges are some 50-55% of G ranges, they are relatively more variable. This is in good agreement with previous findings on PI ratios where individual differences were obscured by the use of group means.

This greater variability in criteria for PI among observers reflects real differences in standards for reporting. These were investigated directly by a questionnaire. In late October, 11 men were given a questionnaire which included, among

others, questions asking each man to state the basis on which he "positively identified" Targets 1, 3, 4 and 6. The results, giving the number of men who used each standard, were as follows:

(A) Target 1 (Fort):

- When vertical edges could be made out . 5
- When parapets were distinguishable . . 3
- When beach could be seen at edges . . . 3

(B) Target 3 (Radar Screen):

- Large and not as dark as other targets. 1
- When outline was definite 5
- Position on fort 3
- When internal structure (support beams) distinguishable 2

(C) Target 4:

- Largest black target 4
- Position with respect to radar screen when seen clearly 7
- Clear square shape 5

(D) Target 6:

- Size, smaller than 4 4
- Position 8
- Clear square shape 5

The answers on Targets 4 and 6 were typically complex and usually named two or more characteristics.

(d) Search Results:

No extensive analysis has been performed on the proportionalities existing among G, 100, and PI ranges for the search targets, which are presented in Table B-9. The results on the two targets, it should be noted, are very similar to one another, which indicates that the judgments involved are stable. On the other hand, the values of the ratios are considerably greater than those for the other targets, a phenomenon

TABLE B-9

FILL-IN RATIOS, SEARCH DATA
DETERMINED BY MEAN VALUES OF ALL SIGHTINGS

	G G	100 G	PI G
Sub	1.00	0.875	0.735
SC	1.00	0.878	0.700
Fill-in values	1.00	0.875	0.700

which may be related to the differences in the task, or, in the case of PI, possibly to the anxiety of the observers for the run to be completed--especially on nights when the weather was poor.

Discussion: It is clear from the results given above that the observers were able to set up and to maintain consistent criteria of seeing, that these have a fixed proportionality to each other, and were proportionately affected by visibility change, and that two of them, G and 100,

TABLE B-10

RELATIVE RANGES FOR VARIOUS PROBABILITIES OF SEEING, DETERMINED IN THE LABORATORY, AND FOR THE CRITERIA OF SEEING USED IN THE PRESENT EXPERIMENT

Source of Data	Relative Range 1% Correct	Relative Range 50% Correct	Relative Range 99% Correct
Brown University	1.00	0.725	0.525
Dartmouth University	1.00	0.437	0.282
	"Glimpse"	"100%"	"P.I."
New London	1.00	0.800	0.500

were remarkably uniform from observer to observer, but that individuals differed in the criteria of positive identification employed.

The proportionalities of ranges for the three criteria seem established at approximately 100, .80 and .50 for G, 100 and PI, respectively. It is interesting to compare these relative values with comparable values obtained at Brown and Dartmouth (Table B-10)

The orders of magnitude would suggest that Glimpse corresponds to something over 1% frequency of seeing, and 100% frequency to something less than 99%. In any event, the variations in range over which the reports spread are of the same order of magnitude as those found at Brown, and less than at Dartmouth, which suggests that these data are basically similar to carefully obtained laboratory results.

VARIABILITY OF THE STANDARD INSTRUMENT

Certain assumptions enter into the basic comparison of each instrument with a standard. The first, and most important, is that each test instrument is fully representative of its type, and that the individual peculiarities of an instrument do not invalidate the results obtained by comparing it with the 7x50x7° binocular. If this assumption cannot be made, obviously the number of sets must be greatly increased, so that, for example, several different 20x120x3° binoculars may be compared with a similar sample of 7x50x7° binoculars.

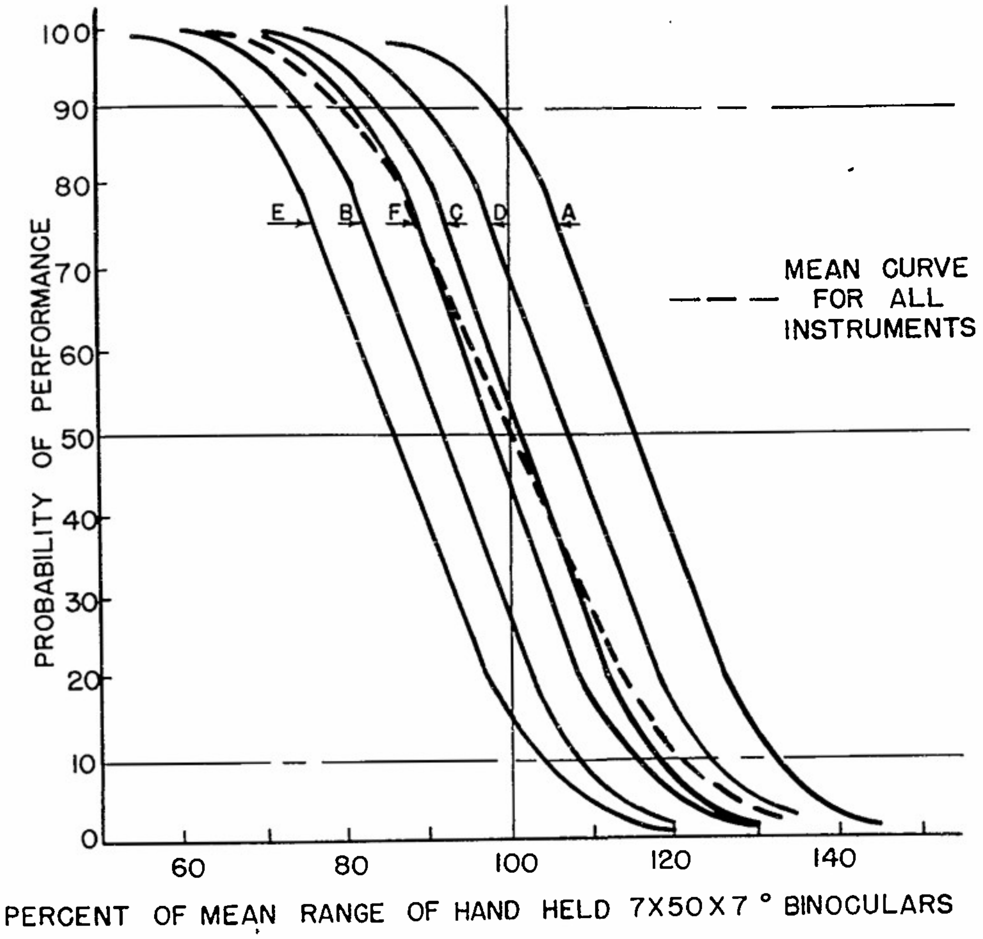
The Sampling Problem: This assumption that the test instrument is representative must be tested; it is necessary to demonstrate that differences in the RRP curve from set to set are not related to the individual instruments, but only to the particular sample of performance obtained in 6 runs.

In order to establish the magnitude of variability to be expected in a sample, the .50 RRP's of each instrument obtained in each of the sets in which it appeared must be examined. But it is also necessary to perform a separate experiment on the problem. For that reason, two night sets, VD and VE, were run, in which all six observers employed 7x50x7° standard hand-held binoculars. If differences in the performance of each individual instrument appear, and if these can be correlated with optical properties peculiar to them, the data which have been presented must be considered as suspect whenever only one or two individual instruments of a given type could be employed.

Results:

(A) Analysis of Variance: On both VD and VE, data were sufficiently complete to permit a full Latin Square analysis of variance on 10 discriminations. Table B-11 gives the number of significant F values obtained from the three sources of variance. In no case do the instruments appear as a significant source of variance, although significant differences appear among runs and observers.

(B) ϵ^2 Analysis of Discrimination of

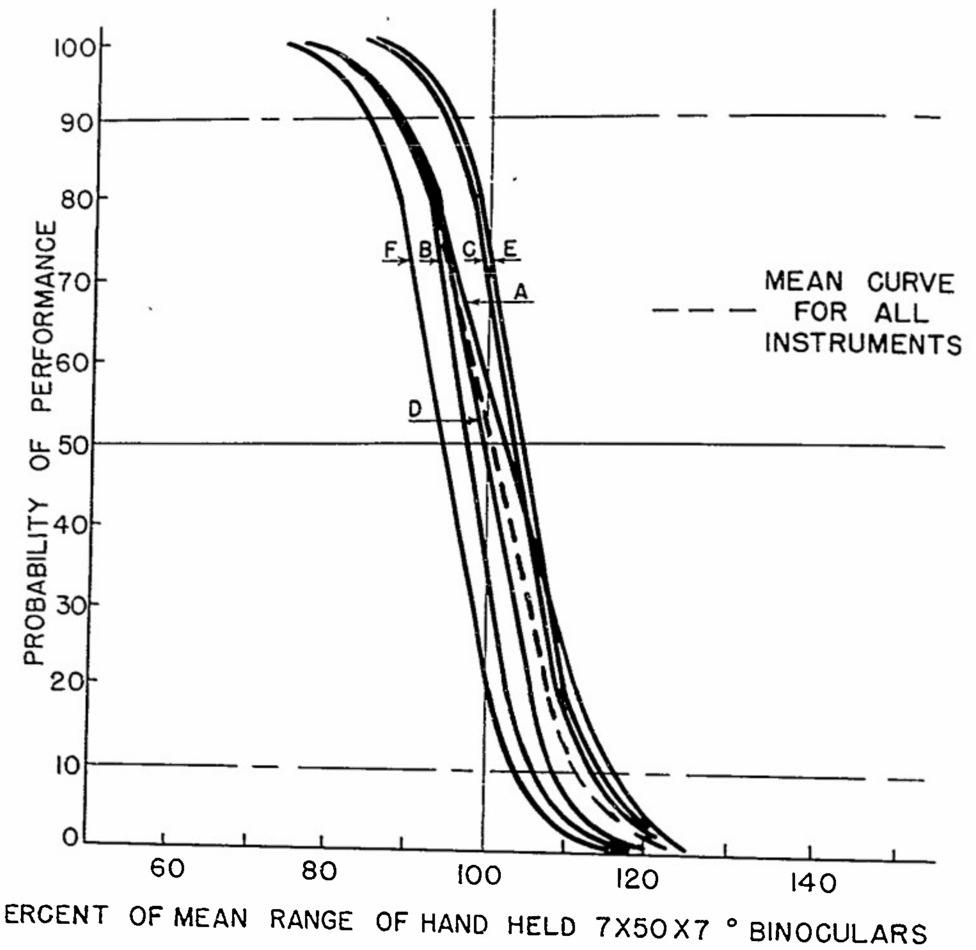


THE RELATIVE RANGE PERFORMANCE OF 6 HAND-HELD 7X50X7° BINOCULARS

BASED ON THE VISIBILITY OF TARGETS AT NIGHT WHEN VIEWED BY OBSERVERS POSTED ON THE SIGNAL BRIDGE OF A DESTROYER ESCORT TRAVELING AT 9 KNOTS

NOTE:
THESE CURVES SHOW THE RESULTS OF SET VD

Figure B-7.



THE RELATIVE RANGE PERFORMANCE
OF 6 HAND-HELD 7X50X7 ° BINOCULARS

BASED ON THE VISIBILITY OF TARGETS AT NIGHT WHEN VIEWED BY OBSERVERS POSTED ON THE SIGNAL BRIDGE OF A DESTROYER ESCORT TRAVELING AT 9 KNOTS

NOTE:

THESE CURVES SHOW THE RESULTS OF SET VE

Figure B-8.

TABLE B-11

SUMMARY OF THE NUMBER OF SIGNIFICANT F VALUES OBTAINED ON SIX 7x50x7° HAND-HELD BINOCULARS

A. Set VD

Source of Variance	Not Significant	Significant at 5% Level	Significant at 1% Level
Runs	8	2	0
Instrument	10	0	0
Observer	10	0	0

B. Set VE

Source of Variance	Not Significant	Significant at 5% Level	Significant at 1% Level
Runs	8	0	2
Instrument	10	0	0
Observer	3	7	0

Target 3-100: As a further check, the data on discrimination 3-100 were subjected to analysis using the ϵ^2 technique.* Not only absolute ranges, but also log ranges were fully treated. The results appear in Table B-12. Only the observers yield significant values of ϵ^2, indicating again that no significant differences occur among the instruments.

(C) Combined RRP Curves: In view of the absence of statistically significant differences among the instruments when tested by either of the previous techniques, it is of interest to examine the combined RRP curves, since these will reveal not only the variability in sampling, but also the magnitude of differences which may be caused by chance alone. Figure B-7 presents the RRP curves for the six instruments from set VD, plotted with the mean curve of the six at 100%. Figure B-8 presents the RRP curves for set VE. Figure B-9 presents the RRP curve of each instrument, combining the results of both sets. The great variability of the results for the six 7x50x7°

TABLE B-12

ϵ^2 ANALYSIS OF DIFFERENCES AMONG INSTRUMENTS, RUNS, AND OBSERVERS, ON TARGET 3 100% FREQUENCY OF SEEING

A. Set VD

	ABSOLUTE RANGE (YARDS)	LOG RANGE (LOG YARDS)
Mean	3558	3.54
Standard Deviation	856	0.11
ϵ^2, Runs	-0.072	-0.078
ϵ^2, Instruments	0.017	-0.043
ϵ^2, Observers	0.074	-0.055

B. Set VE

	ABSOLUTE RANGE (YARDS)	LOG RANGE (LOG YARDS)
Mean	3811	3.57
Standard Deviation	818	0.09
ϵ^2, Runs	0.003	0.033
ϵ^2, Instruments	-0.132	-0.142
ϵ^2, Observers	0.290	0.360*

* This figure was the only ϵ^2 that was significant. It is attributable to one poor observer, and is significant at the 1% level.

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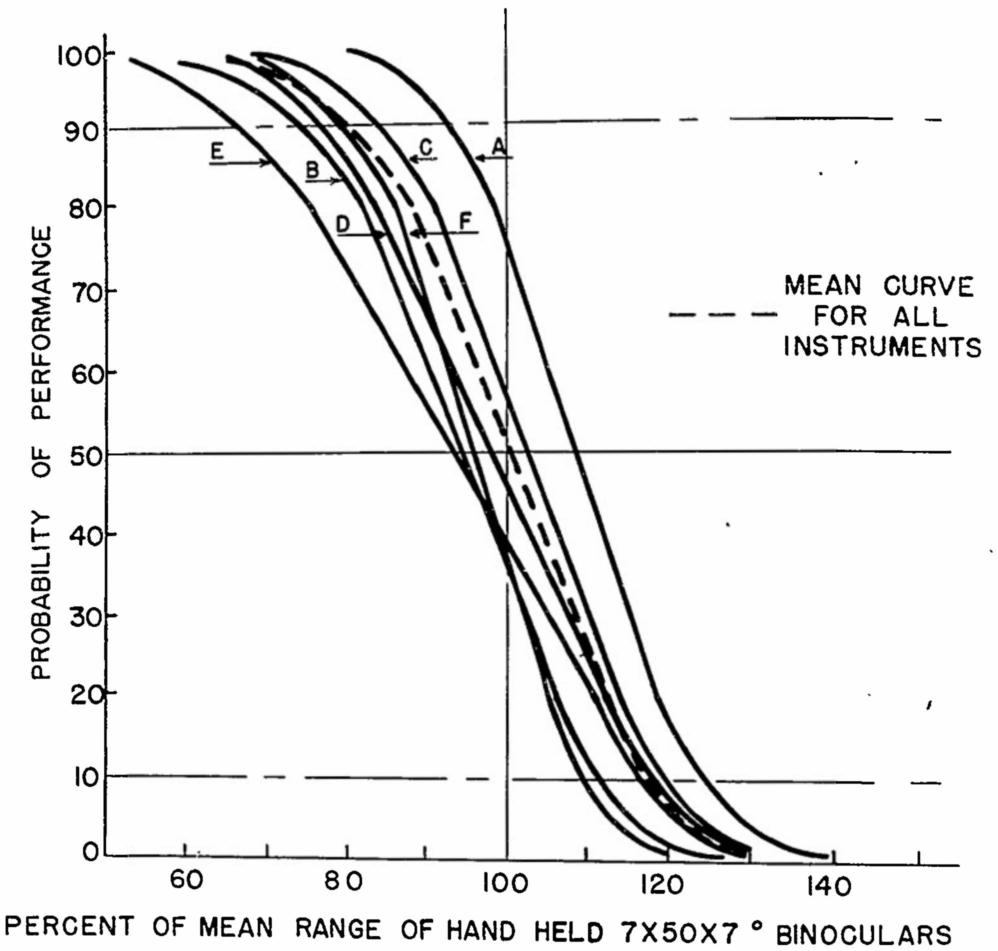
* The use of ϵ^2, the correlation ratio without bias, in demonstrating the significance of differences among classes and in testing the null hypothesis, is presented in full in Statistical Procedures and Their Mathematical Bases, Peters, C. S. and Van Voorhees, W. R. McGraw-Hill, New York, 1940, pp. 4-5 + xiii.



THE RELATIVE RANGE PERFORMANCE
OF 6 HAND-HELD 7X50X7° BINOCULARS

BASED ON THE VISIBILITY OF TARGETS AT NIGHT WHEN VIEWED BY OBSERVERS POSTED ON THE SIGNAL BRIDGE OF A DESTROYER ESCORT TRAVELING AT 9 KNOTS

NOTE:

THESE CURVES SHOW THE COMBINED RESULTS OF SETS VD & VE

Figure B-9.

binoculars in set VD is apparent,* as are the remarkably slight differences found in VE. No differences between the sets to which this may be attributed have been observed. The wide dispersions of the six instruments in VD (Fig. B-7) is greatly reduced when the curve on each binocular for VD is summated with that on the same binocular in set VE (Fig. B-9). This indicates the importance and effectiveness of combining the results for each binocular over the several sets in which it was used.

The apparent differences which appear in Figs. B-7, B-8 and B-9 do not correlate with the optical properties of the instruments as measured at the Optical Inspection Laboratory of Pennsylvania State College shown in Table B-13. The variation of performance, then, among the six instruments is presumably due to the small size of the sample; there is no relationship to the optical constants of the instrument.

A Second Approach to the Variability of Samples:

The treatment just presented clarifies the sampling problem with respect to the RRP obtained on an instrument in any one set. There is another way in which results on sets may differ from one another, besides lateral displacement of RRP curves, and that is in the magnitude of the experimental error within the set, as measured by the remainder variance. This is reflected in the Standard Error of the Difference obtained in the set, which in part determines the slope of the RRP curves of each instrument tested in the set. The steeper the slope, the less is the error of measurement, and the more reliable are the differences found. Since the standard instrument is included in all sets, and reflects

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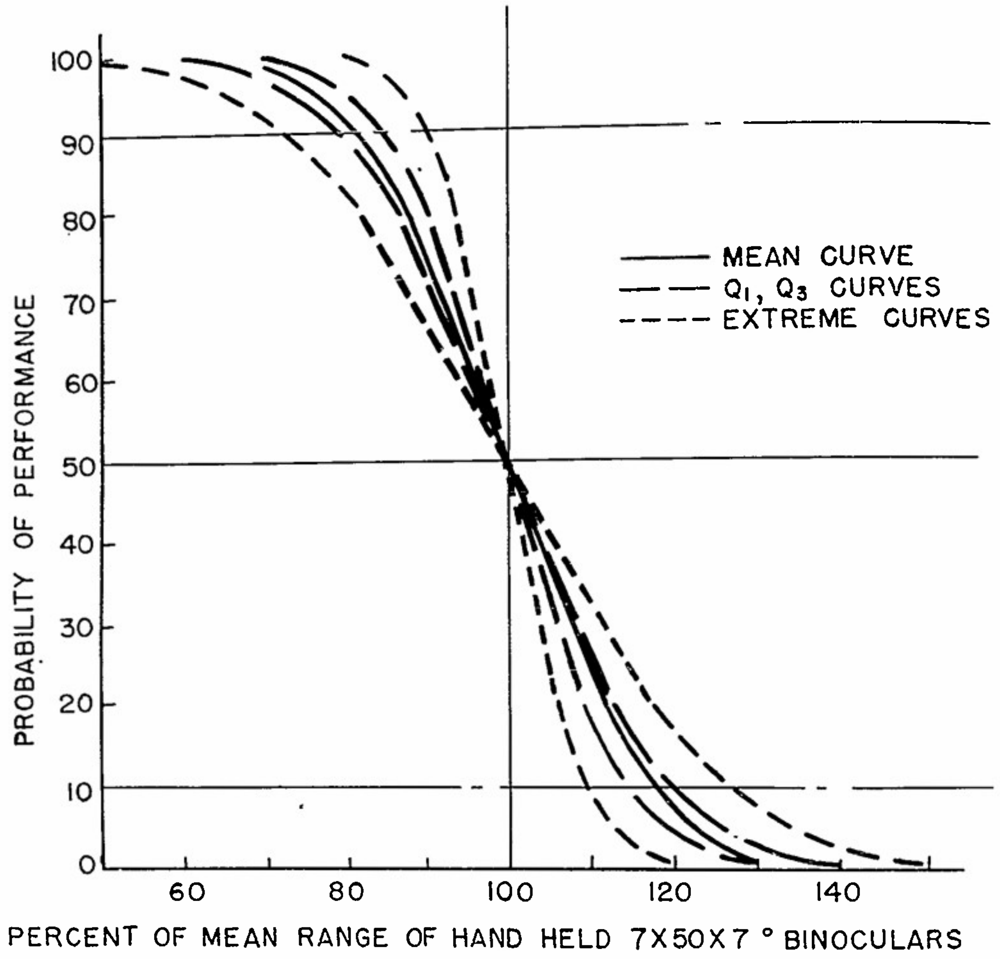
* Note that it is associated with less steep slopes, indicating a large error term in the findings.

TABLE B-13

THE .50 RRP'S OF SIX 7x50x7° BINOCULARS
AS RELATED TO OPTICAL INSPECTION TEST SCORE

Serial No.	Position on Bridge	Set VD	Set VE	Sets VD, VE Comb.	% Contrast Renditions Right Barrel	% Contrast Renditions Left Barrel	KDC Score, Average Center of Field Both Barrels, %
408395 A	1	115.0	101.8	108.0	92	92	70
259904 B	2	91.5	97.0	94.0	93	91	80
408382 C	3	101.0	103.3	102.5	89	92	79
408385 D	4	107.0	99.0	98.0	91	91	69
408389 E	5	85.5	104.0	93.0	91	91	60
259902 F	6	97.5	94.0	95.5	93	93	78



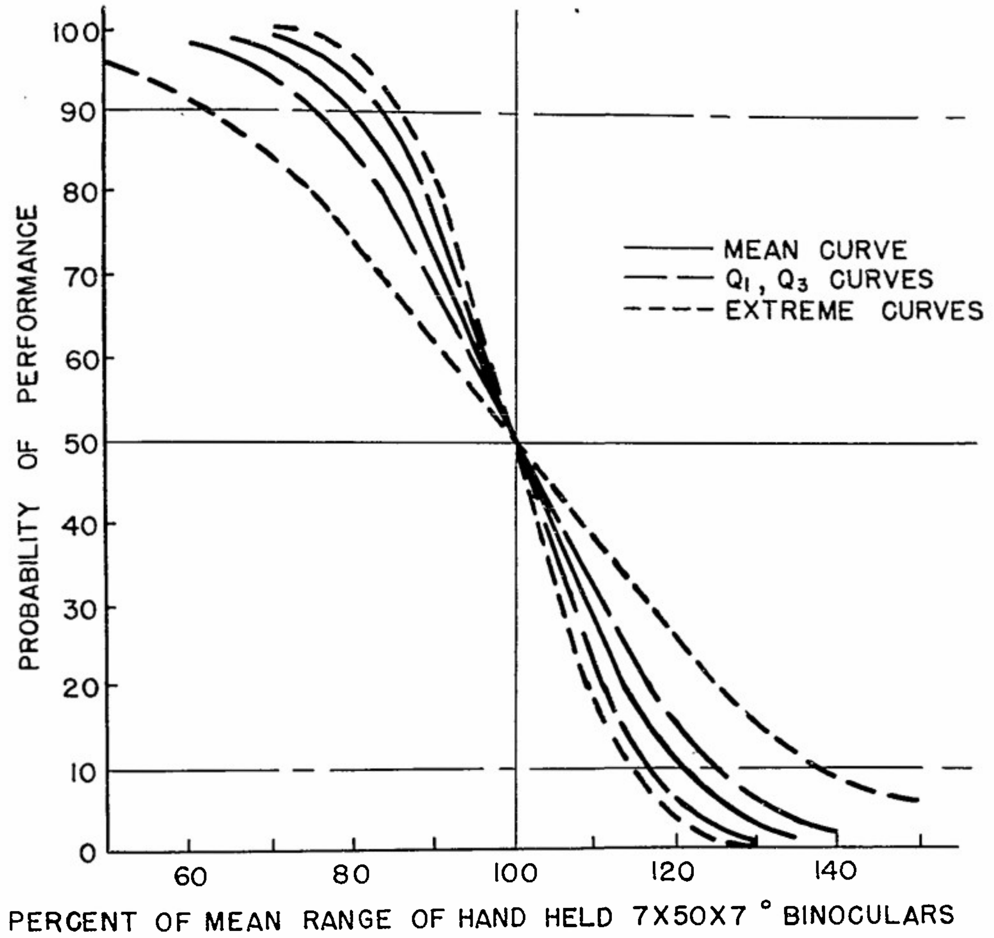
THE RELATIVE RANGE PERFORMANCE OF THE 7X50X7 ° H.H. BINOCULAR

BASED ON THE VISIBILITY OF TARGETS AT NIGHT WHEN VIEWED BY OBSERVERS POSTED ON THE SIGNAL BRIDGE OF A DESTROYER ESCORT TRAVELING AT 9 KNOTS

NOTE:

THE CURVES SHOW THE VARIABILITY OF PERFORMANCE OF THE 7X50X7 ° H.H. BINOCULAR FROM SET TO SET

Figure B-10.



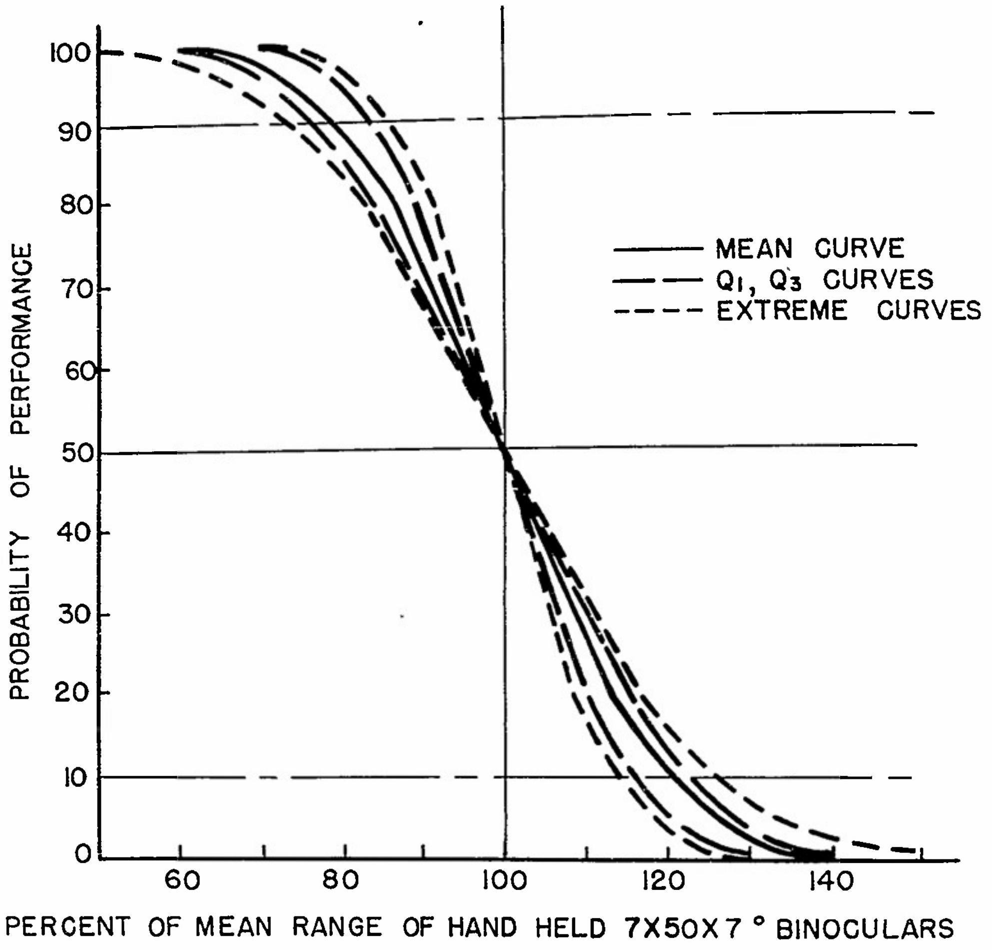
THE RELATIVE RANGE PERFORMANCE OF THE 7X50X7 ° H.H. BINOCULAR

BASED ON THE VISIBILITY OF TARGETS AT NIGHT WHEN VIEWED BY OBSERVERS POSTED ON THE GUN DECK OF A DESTROYER ESCORT TRAVELING AT 9 KNOTS

NOTE:

THE CURVES SHOW THE VARIABILITY OF PERFORMANCE OF THE 7X50X7 ° H.H. BINOCULAR FROM SET TO SET

Figure B-11.



THE RELATIVE RANGE PERFORMANCE
OF THE 7X50X7 ° H.H. BINOCULAR

BASED ON THE VISIBILITY OF TARGETS IN DAYLIGHT WHEN VIEWED BY OBSERVERS POSTED ON A DESTROYER ESCORT TRAVELING AT 12 KNOTS

NOTE:

THE CURVES SHOW THE VARIABILITY OF PERFORMANCE OF THE 7X50X7 ° H.H. BINOCULAR FROM SET TO SET

Figure B-12.

most directly the error of measurement, it may be used to give comparative data on this variability. Figs. B-10, B-11, and B-12 present the mean, the steepest, the shallowest, and the first and third quartile RRP curves obtained with the 7x50x7° binocular during the night observations (signal bridge), night observations (gun deck), and day observations (all decks) respectively. It is apparent from these curves that, in some sets, only slight differences in .50 RRP values may be significant, and that in others, great differences may be without significance because of a large error term. The magnitude of the error term in each set may be examined in Appendix A, where the 90, 50 and 10 intercepts for the 7x50x7° binocular in each set are presented.

It is, again, clearly necessary to establish RRP's by combining results from as many sets as possible.

General Discussion:

The methods of analysis which have been employed in the present study have not been sufficiently developed theoretically for it to be possible to evaluate the error of measurement of the .50 RRP of each of our final curves. There can be no doubt that steps should be taken to determine it Here, as before, the results and the interpretation of them, have been seriously handicapped by the lack of time and personnel to carry the treatment of the data far enough.

The reader is advised to take into consideration both aspects of the sampling factor when evaluating a particular binocular. This may be relatively readily achieved by examination of the graphs of Appendix A. Considerations stemming from this problem have played a large part in the actual planning of the experiment; the policy was set, and every effort was made, to increase the number of sets for an instrument where small differences were found, or where great variability was encountered. This could only be done at the expense of other comparisons where large differences, or differences associated with low variability, were obtained. Because of this policy the precision of the .50 RRP is not the same for all instruments, and some instruments appear in many more sets than others.

OBSERVATION POSITION

The position on the vessel from which observations were made may be a possible source of error, or of misleading results. These may relate to height of eye of the observer or to the position on any given deck in which the instrument is used.

Height of Eye: As reported later in greater detail, during the night runs a consistent difference of the order of magnitude of .10 log units appeared between the mean log range of Target 3-100 as obtained on the signal bridge, and as obtained on the gun deck. The heights of eye are, respectively, 32' and 25'. This difference did not relate itself to any systematic difference in the performance of optical instruments, except in the case of the 10x50x7° HH binocular, which yielded an RRP of 117.0 in the lower position, and of [illegible] in the higher. For this reason, results obtained on the gun deck are presented separately from those obtained on the signal bridge. Analysis of the possible causes of this phenomenon must await a fuller evaluation of all the experimental results.

The data obtained during the day runs from both of these levels, as well as from the lower deck (height of eye: 20') show, for mean log ranges of 3 different discriminations, no systematic differences whatever, so that results from all three levels could be combined in the final RRP curves presented.

Position on Each Deck: Besides height of eye, the effect of the position of each of the six observation posts of the signal bridge, and of each the three on the gun deck must also be analyzed. It is possible that a systematic factor may operate in one position to enhance or diminish the performance of the instrument employed in that position.* One possible systematic factor, the effect of communication between observers, with consequent false reporting or similar effect, should reveal itself in such an analysis. If the reports of one observer affect those of another, consistent differences should appear between the performance of observers in the isolated positions 1 and 6 on the signal bridge, and those of the observers in the relatively close positions 2, 3, 4 and 5. Consistently longer ranges would be expected from positions 2, 3, 4 and 5, if the observer first reporting affected the others, since his report would stimulate the other observers to report earlier than otherwise. Greater variability in observations from positions 1 and 6 would also be expected, since these observers presumably would be unaffected by the "levelling" effect which such interstimulation would produce.

Results - Night Runs:

(A) Table B-14 gives the mean corrected* 7x50x7° HH by ranges (sets VD and VE are not included) on discrimination 3-100, for each of the nine positions of the night observations together with standard deviations, and ϵ^2 for the six positions on the signal bridge.

Discussion: From Table B-14, it would appear that there is a slight tendency for position 1** to give shorter ranges than positions 2, 3, 4 and 5, and a strong tendency, statistically significant at the 1% level, for position 6 to do so. No systematic phenomena relating to variability appear. Analysis of the 12 cases entering into the data in position 6 show that they are by no means a random sample of performance at that position--8 of the 12 were obtained in the September series of tests, when visibility was generally poor.

TABLE B-14

ϵ^2 ANALYSIS OF MEAN RANGES OBTAINED
AT EACH OF NINE POSITIONS (NIGHT OBSERVATIONS)

Position	N	Mean	SD		
1 SB	35	3.53	0.12		ϵ^2_c = 0.048 Just significant at 5% level
2 SB	23	3.57	0.16		
3 SB	38	3.57	0.13		
4 SB	30	3.57	0.14		
5 SB	26	3.58	0.12	T = 3.2 p < 0.001	
6 SB	12	3.39	0.17		
7 GD	43	3.57	0.13	ϵ^2 not calculated	
8 GD	45	3.55	0.13		
9 GD	37	3.56	0.13		
All	289	3.55	0.14		

A further check on the validity of the inference that instruments perform more poorly in position 6 is needed, and is made possible by data from sets VD and VE (Table B-15). In an earlier section of this report, data are adduced which show that the binocular in position 6 obtained RRP's of 97.5, 94 and 95.5 in set VD, set VE, and in the combined sets respectively. The relative standing of the binoculars used in position 6 was 4th, 6th, and 4th from the group of six for the three. If now we consider not only these data, but also those in Table B-14, it is evident that there is only a slight tendency for position 6 to yield consistently poorer performance. If it is a genuine effect, it is a small one, of the order of .03 log yards, and without statistical significance, and even this may be more due to distractions at position 6, mentioned earlier, than to interstimulation of observers.

TABLE B-15

ϵ^2 ANALYSIS OF POSITION EFFECT
ON SETS VD AND VE
(NIGHT OBSERVATIONS)

Position	Set VD		Set VE	
	MEAN LOG RANGE (YARDS)	SD	MEAN LOG RANGE (YARDS)	SD
1	3.59	0.11	3.58	0.14
2	3.49	0.07	3.56	0.08
3	3.55	0.12	3.59	0.06
4	3.56	0.10	3.56	0.09
5	3.50	0.10	3.58	0.08
6	3.53	0.11	3.55	0.08
	ϵ^2 = 0.04; not significant		ϵ^2 =-0.14; not significant	

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* In the night observations made in September, it was possible to rotate the hand-held binoculars tested among the six positions on the signal bridge so that the effect of any systematic factor could be annulled. With the requirement of mounting instruments, however, it was impossible to continue this rotation. The September results had indicated that such rotation was not necessary.

* The corrections employed are based primarily on visibility, and are presented in detail in a later section.

** Inferior ranges from position 1 may be partly because this position was the most difficult to supervise, so that these results might occasionally be on "hand-held-rested" binoculars rather than "hand-held", i.e., it was possible for the men in this position to rest their elbows. It is not believed, however, that this happened except in the case of very bad weather.

TABLE B-16

MEAN LOG RANGES FOR THREE DISCRIMINATIONS FOR FOUR OBSERVATIONS POSTS, WITH ϵ^2 ANALYSIS OF SIGNIFICANCE OF DIFFERENCES IN POSITION

		Discrimination 7-G		Discrimination 8-100		Discrimination D-PI	
	No.	Mean	SD	Mean	SD	Mean	SD
Port, Signal Bridge	12	4.11	0.13	4.13	0.11	3.52	0.20
Starboard, Signal Bridge	12	4.14	0.13	4.06	0.17	3.45	0.13
Gun Deck	12	4.14	0.10	4.05	0.21	3.52	0.14
Lower Deck	12	4.10	0.12	4.08	0.07	3.46	0.20
All observations	48	4.12	0.12	4.08	0.16	3.49	0.17
ϵ^2_c		-0.07		-0.04		-0.02	

No value of ϵ^2_c obtained here is statistically significant.

Day Runs:

There were not sufficient day runs to permit analysis of results on each of the 12 positions employed. During these runs, the practice followed in the later night series, of maintaining the position of an instrument constant through a set, was continued.

Table B-16 gives the results of an ϵ^2 analysis of the day observation posts, grouped as port signal bridge, standard signal bridge, gun deck and lower deck. This analysis suggests that no difference in these positions may be expected.

Comment:

It is concluded that the effect of position on the bridge and of inter-stimulation among observers, is a small one, and that the data do not lose reliability.

Further evaluation is clearly required, however, before the results may be considered as unequivocal, and this must include analysis with respect to the effects of wind, which consistently affected certain posts more than others.

INTERACTION

It is possible that all individuals will not give equivalent performance with the same type of binocular. For some, the 7x50x7° will give optimum efficiency and maximum ranges, and for others, another, such as the 10x50x7°. Comments of observers clearly indicate differences among individuals with respect to the instrument preferred, and it is well known that, on the basis of rough observations.

several experienced individuals will disagree as to which is the best of several types of binoculars. An effect of this sort, which produces different results from different observers, is termed interaction. If such interaction occurs between observers and instruments, and to an important extent (in terms of the relative ranges obtained), it must be taken into account in the interpretation of our results.

Similarly, it is possible that some binoculars are better suited for use under certain conditions of visibility than are others. Such run-instrument interaction is not without interest, although less critical to the results.

It is impossible, in using the Latin Square design, to determine whether either type of interaction appears, since, in this design, each instrument is used only once by each observer and only once on each run, and hence no estimate can be made of the variance of a given instrument for the same runs, or for the same observers, against which the variance attributable to observe-instrument and run-instrument interaction can be evaluated. Since the major concern was the measurement of the differences among instruments, which are most precisely estimated in the Latin Square design, interaction had to be investigated separately.

Because of the limited time available, only one type of interaction was studied. The interaction between instruments and observers was selected, not only because it is more critical to interpretation of our data, but also because the probability seemed slight of getting operationally significant variations in run conditions (from which to obtain instrument-run interaction) within the short time alloted. Unfortunately, under the conditions of this experiment, both types of interactions cannot be evaluated simultaneously.

Statistical Design and Procedure: The design employed to measure the instrument-observer interaction employed 12 observers (Sections A and F), using three instruments over twelve runs. Each observer used a given instrument twice, on alternate runs. The standard 7x50x7° HH, the 7x50x10° HH, and the 10x50x7° HH were the instruments studied since they are similar in over-all performance and mode of use, and they vary from one another in a manner which offered the possibility of yielding correlations with observer-variables. The random assignment of observers to instruments was essentially the same as described for the basic procedure.

TABLE B-17

SOURCES OF VARIANCE AND ASSOCIATED DEGREES OF FREEDOM IN INTERACTION EXPERIMENT

Source of Variance	Number	Degrees of Freedom
Between cells	36	(35)
Instruments	3	2
Observers	12	11
I x O	-	22
Within cells	-	36
Total	72	71

Table B-17 indicates the sources of variance and degrees of freedom associated with and involved in this experiment. The total variance is divisible into two sources, that between cells and that within cells, a cell including the two range values obtained by a given subject on one instrument. There are a total of 36 cells (12 men x 3 instruments), yielding 35 degrees of freedom between two cells. This between-cell variance is itself divisible into three sources: variance attributable to instruments (2 degrees of freedom), variance attributable to observers (11 degrees of freedom), and variance attributable to interaction between instruments and observers (22 degrees of freedom $H = \left[35 - (2 + 11)\right]$).

The remainder of the total variance is attributable to the variance within cells, with 36 degrees of freedom. This includes the variance due to experimental error as well as the run variance which cannot be separated from the error variance. It serves as the basis for estimating the significance of the variance attributable to interaction.*

As in the basic statistical procedures, these analyses for interaction were performed separately on each discrimination.

The computations involved were essentially similar to the basic procedures and will not be detailed here. However, in this case, the critical F-value is obtained by dividing the I x O variance by the within-cells variance. The variance due to consistent differences among instruments and observers is removed from the total variance among cells, and there remains the variance attributable to interaction. The significance of this variance is tested against that due to experimental error, and differences among runs (the within-cells variance) This analysis could be performed on only two targets, 1 and 3, (to all criteria of seeing) owing to poor visibility.

Results:

All six F-values were significant at the 1% level; showing that there exists a significant tendency for an individual observer to perform relatively better with one instrument than with others, and that the best instrument is not the same for all observers. This statistical conclusion is borne out by inspection of the results on each discrimination. Ten of the 12 observers did best with some one instrument on all six discriminations; three men performed best with the standard 7x50x7° HH. four with the 7x50x10° HH, and five with the 10x50x7° HH.

Individual results are given in Table B-18 in terms of the percentage of the mean range on all discriminations for all observers and instruments (3,380 yards).

TABLE B-18

PERCENTAGES OF MEAN RANGE ON ALL DISCRIMINATIONS OBTAINED BY EACH OBSERVER WITH EACH INSTRUMENT IN INTERACTION EXPERIMENT

Subject	Section	Percentage of Mean Range			Overall Average
		7x50x7°	7x50x10°	10x50x7°	
Ca	A	128	76	67	
Tu	F	117	75	109	
Na	F	175	84	82	
	Average	140	78	86	101.3
Co	A	79	140	74	
La	F	83	155	78	
An	A	92	139	71	
Mi	F	77	181	71	
	Average	83	154	73	106.7
At	A	90	65	102	
Cu	F	105	64	124	
Ba	A	104	74	111	
Fi	F	63	70	166	
Br	A	84	73	158	
	Average	89	69	132	97.0
Average		99.7	99.4	101.0	
% 7x50x7° Range		100.0	99.7	101.3	100.0
Section A:	Average	96.1	94.5	97.1	
(Experienced Observers)	Percentage	100.0	98.3	101.1	
Section F: (Less Experienced Observers)	Average	103.3	104.8	105.0	
	Percentage	100.0	101.4	101.6	

No correlation between the preferred instrument and any other variable on which data are available is evident, although it is suggestive that, of the five men who performed better on the 10x50x7°, four had pupil diameters in excess of 7.5 mm. This may indicate that clipping is a factor in decreasing performance, in that it could hardly occur in the case of these men on this instrument. Only one man who had a pupil diameter of this magnitude preferred another instrument. There is some indication that the men who did best on the 10x50x7° did poorest as a group. This does not correlate with training and experience.

No relationship was evident between the observers' comment sheet ratings and their instruments of best performance;

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* It will be noted that in this design the possible effects of run differences are confounded both with the interaction and the error effects. To the extent that real run differences are present, the only consistent influence they seem capable of producing on the value of F is to diminish it. This confounding, then, appears to make the statements of the significance of the interaction effect err in the direction of being conservative. Since the visibility was relatively uniform at the time the runs on interaction were made, the error introduced is believed to be small.

their subjective evaluation did not match their performance.

Interpretation:

These results show that interaction occurs; some men perform better on some instruments than on others. Moreover, it may be, in some cases, a large effect. Relatively great differences in the ranges obtained by individuals on different binoculars are apparent.

It is probable that such differences in performance relate to the tendency of individuals to rate some instruments higher than others, even though, in this small group of twelve men, subjective evaluation data did not seem to bear much relationship to performance on the three binoculars.

The presence of interaction requires that the relative performance of binoculars must be established on a large group of men. If only small samples of men are employed, the results may be misleading. In the present experiment, although it was not anticipated that such large systematic differences among men would appear, it is believed that a sufficiently large and representative population used each instrument to permit its proper evaluation. The data give some support to this belief; the mean percentage values obtained by the men in Section F and Section A in this special experiment compare roughly with the findings in the regular sets on which the same sections observed (Appendices A and C). It must be emphasized that the .50 RRF is calculated differently than the mean percentage ranges in Table B-18. It should also be noted that for both sections in this experiment, the 10x50x7° does not show the superiority usually found.

The most important aspect of interaction between instrument and observer is the implication it carries for instrument design, the selection of personnel, and for visual theory. If the best instrument for the average observer is selected, then it should follow that all personnel who will use it ought to be selected in some manner so that only those for whom it is the most effective will employ it. If all personnel must be employed, then it follows that several types of instruments should be available, so that each man will use that which gives him best results. In either case, more information on the phenomenon should be obtained and the finding verified. A definitive attempt should be made to ascertain the physiological or psychological variables which determine instrument preference so that it will be possible to set up a series of appropriate visual measurements to classify the individual with respect to his performance on various instruments.

The type of individual difference which may serve as the basis of such interaction will probably be found in the absolute values of the constants of the mathematical expressions of the various visual functional relationships. There is some experimental evidence which indicates that there is not necessarily a high correlation among the values for these constants for the same observer.*

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* Tice, F. G., Individual Differences in Fusion Frequency Correlated with Other Visual Processes. Unpublished Doctor's dissertation, University of Virginia, 1939.

Interaction also requires other types of research; the extent to which the advantage of a particular instrument may be off set by the interaction factor should be determined.

As yet, in the absence of further research, and with a lack of understanding of the factors involved, the positive evidence of interaction has no immediate practical application. Further research is essential.

RESULTS, PART II. INSTRUMENTS

In Results Part I the general reliability of the experimental methods developed was discussed. Part II presents the actual results attained by the various instruments tested. It also describes and discusses the relative importance of such factors as mounts, head rests, magnification, and exit pupil.

BINOCULAR VS NAKED EYE

The effectiveness of any optical instrument is the advantage over naked-eye observations which it will yield to the observer. Although it is a basic reference point, the naked eye could not be employed throughout the experiment because of its low efficiency. Consequently, the advantage of the standard 7x50x7° binocular over the naked eye was first established, and evaluations of other instruments were made in terms of its performance. The naked eye was used as an "instrument" in four 6-run sets of the hand-held series run at night in September, and in two of the 3-run day blocks.

Binocular Advantage at Night:

In none of the four sets were sufficient data obtained on the naked eye to permit calculation of RRP curves. This in itself is an index of its poor showing. However, a rough analysis permits calculation of the approximate "binocular advantage" obtained, which is defined as the ratio of range obtained using the standard 7x50x7° binocular to range obtained with the naked eye.

(a) From a total of 9 discriminations in the four sets, mean naked-eye observations were obtained, which could be compared with the mean 7x50x7° HH ranges on the same run. The average binocular advantage Mean Range for Binocular / Mean Range for Naked Eye for these 9 discriminations was 2.50.

(b) On a total of 18 other discriminations, on which mean ranges on the 7x50x7° HH could be determined, it was possible to set a lower limit below which the binocular advantage cannot fall, by dividing the mean range obtained with the standard by the maximum range which the naked eye could not have exceeded, which is the range at which the DE turned from its approach course. The average "minimum" value proved to be 2.44.

These data would seem to indicate that the naked eye range is approximately 40%, certainly no greater, of the 7x50x7° range, and that the binocular advantage is close to 2.50. This figure may be compared with the findings in Comdr. D. R. E. Brown's report to BuShips, A Study of Visibility and Concealment Computed from 708 Sightings of U. S. Submarines:

> "On clear starlight nights, the average range of 236 sightings through 7x50 binoculars was 1560 yards. The farthest sighting range was 3600 yards. When binoculars were not used, but all other conditions remained the same, the average sighting range was not less than 625 yards, the farthest sighting by the unaided eye occurring at 1800 yards "

This yields a binocular advantage of 2.60, close to the present figure.

The agreement between these two field results would seem to indicate the laboratory findings on the 7x50x7° HH, under approximately the same conditions of illumination, yield somewhat greater advantages than can be expected in practice At Brown University, the advantage was determined as 4.0 (OSRD Report 6128). At Dartmouth University, the extremely high value of 6.0 was obtained (OSRD Report 4433).

Binocular Advantage in Daytime:

Data were complete on sufficient discriminations during the day runs to permit determinations of the RRP of the naked eye. The .50 RRP obtained was 90. Figure B-13. presents the RRP graph. The reciprocal of this 90 RRP yields an estimate of the binocular advantage---1.11, which is less than half of that obtained at night. The surprisingly small increase in range yielded by the 7x50x7° binocular by day may in part be attributable to the mediocre visibility encountered, and to the poor observing conditions, although these should handicap the naked-eye observations as well. The result is not unexpected, however, from the computations of visibility and binocular advantage performed by the Tiffany Foundation*, which indicates that optical instruments should not yield great advantage under daylight conditions.

<u>Discussion</u>:

Lest a tendency to underestimate the usefulness of binoculars be reinforced by these findings of 2.50 by night and 1.11 by day, it should, perhaps, be emphasized that the probability of detection of targets is a function of the square of the absolute ranges, so that the binocular advantages for detection of targets in an area are 6.75 and 1.3, for night and day respectively. These values more closely represent the actual operational advantage to be obtained from 7x50x7° HH binoculars than do the range values.

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* Hardy, A. C. The Effects of the Atmosphere on the Performance of Optical Instruments. Minutes and Proceedings of the Army-Navy-NRC Vision Committee, 15th Meeting, 12-13 February, 1946, pp 30-31.

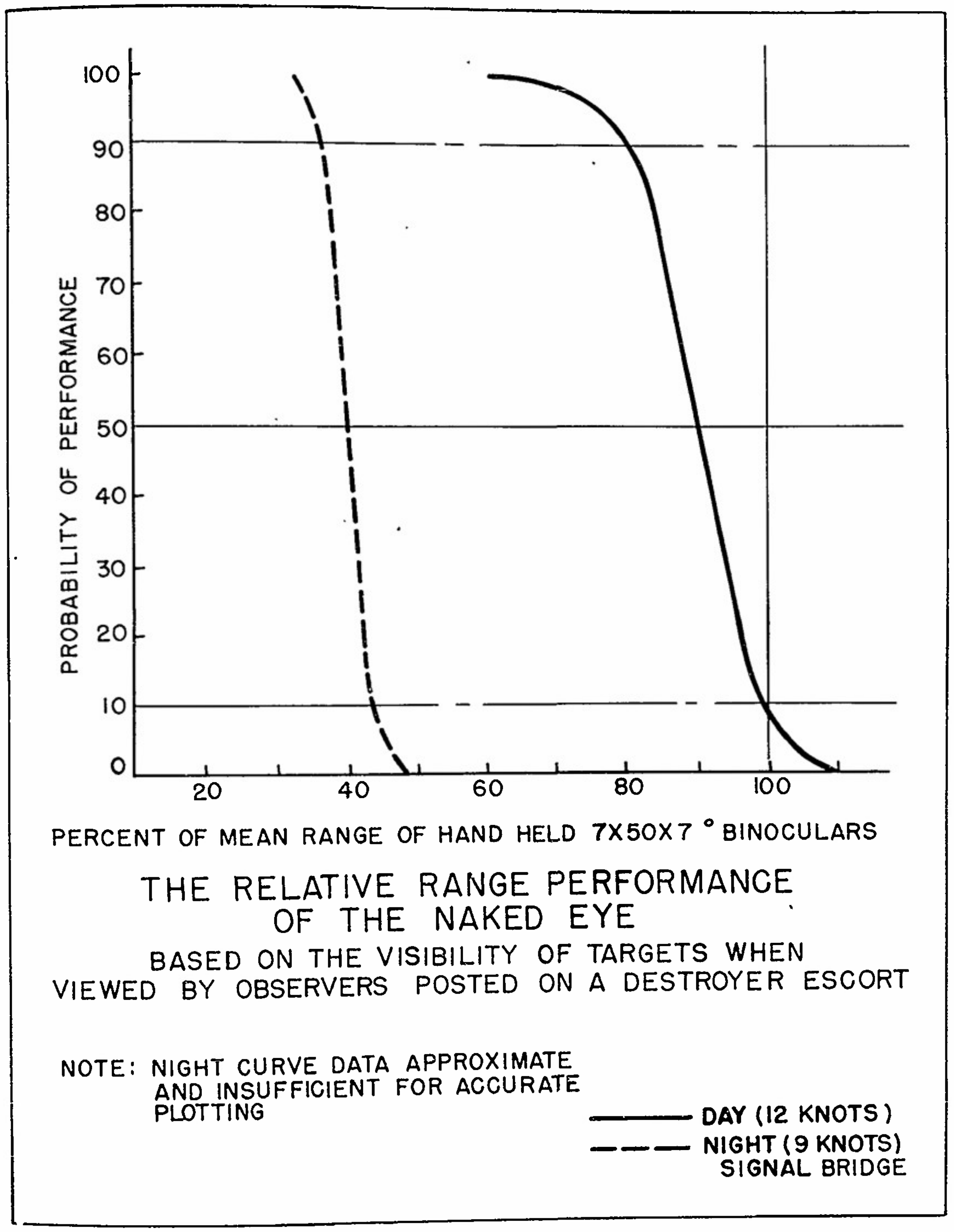
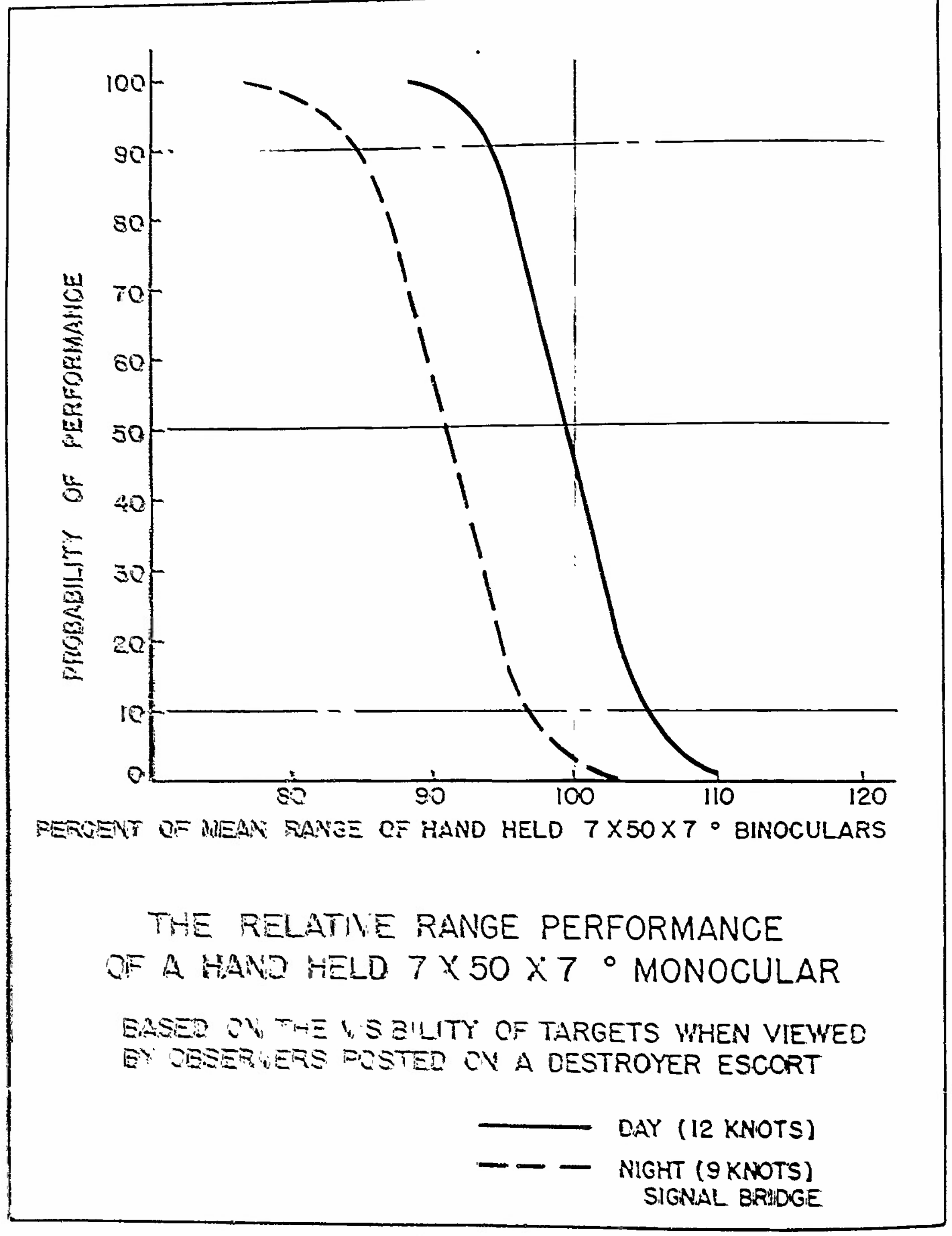


Figure B-13.



THE RELATIVE RANGE PERFORMANCE OF A HAND HELD 7 X 50 X 7 ° MONOCULAR

BASED ON THE VISIBILITY OF TARGETS WHEN VIEWED BY OBSERVERS POSTED ON A DESTROYER ESCORT

Fig. B-14

THE MONOCULAR VS THE BINOCULAR

The $7x50x7^{\circ}$ HH binocular was used both as a monocular and binocular in six 6-run sets by night, and four 3-run sets in the day series.

Night Results: The .50 RRP (Fig. B-14) of the monocular was 91 based on the few discriminations which could be calculated on a relatively inefficient instrument. The use of a binocular rather than a monocular, then, extends the range by 10% at night. This finding in the field compares closely with the 10-25% increase predicted from theoretical data by the Subcommittee on Binoculars of the Army-Navy-NRC Vision Committee.*

At Brown University (OSRD Report 6128) the $7x50x7^{\circ}$ HH binocular increase in range at higher brightness (7.1 log uul, as compared with the present 5.0) was determined as 20%. The Brown report noted that only 10% increase would be predicted at this level of illumination if the two eyes acted as "independent observers" and attributed their greater range to binocular interaction of a not yet understood nature.

Day Results: The $7x50x7^{\circ}$ monocular was used on both the gun deck and the lower deck of the DE during the daylight observations, and the combined estimate of its .50 RRP (Fig. B-14) obtained under these conditions was 99.1. That the advantage of binoculars by day is insignificant may be expected; if it exists at all it might disappear entirely had observers skilled in the use of monoculars (such as signalmen) been used. The smaller advantage is expected for theoretical reasons at daylight brightnesses.

Discussion:

It is extremely difficult to compare these findings with those of Hyde, Cobb, Johnson and Weniger* on the 6x30. In their field experiment, procedures and methods of measurement differed greatly from those of the present study, so that it can only be noted that they report but slight gain from binoculars over monoculars during daylight, and a greater one at night, a finding in conformity with the above. Insofar as it is possible to translate their night results into increase in range, the binocular seemed to give 4% greater ranges.

The present results will be of use in providing an answer to a problem which has faced those engaged in optical design for many years: where limitations are placed upon the size and weight of an instrument, should a binocular be preferred to a monocular, even though the latter may be designed with higher magnification, larger exit pupil, and greater field size? Given the size and weight specifications which

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* Page 24 of Minutes and Proceedings of the Army-Navy-OSRD Vision Committee, 12th Meeting, June 1945.

* Hyde, E. P., Cobb, P. W., Johnson, H. M. and Weniger, W. The Relative Merits of Monocular and Binocular Field-Glasses. Proceedings of the Franklin Institute, Vol. 189 No. 1130-14, February 1920.

must be met, and the optical specifications of the monoculars and binoculars which will meet them, prediction can be made of the ranges which may be obtained with each from the present 10% binocular advantage, and from data presented later in this report on range as a function of magnification and exit pupil. Considerations of cost and maintenance must be held of secondary importance.

However, even though the predicted performance of a monocular and a binocular may be equal, there still remains a substantial, although less tangible, advantage for the binocular. As Hyde and his associates reported, and as Hecht has reiterated*, judgments are made more rapidly and with more assurance when the observer is able to use both eyes. No measure of these phenomena was possible in the present experiment. However, in the subjective evaluation of optical instruments, as described later, consistently lower rates are given to monocular instruments, other things being equal.

In periscope design, the Germans have found one solution to this latter problem. By the insertion into the optical system, at the eyepiece, of a beam-splitter, both eyes may be utilized simultaneously, even though the instrument is fundamentally a monocular. This device may be used or taken out of the system according to the wishes of the observer using the instrument. When the beam-splitting device is used, the brightness of the image on either retina is less than half that when the periscope is used as a monocular. Such a decrease should produce a loss of range as great as 18% on dark nights.* However, part of this loss is made up through stimulation of both retinas, so that the net loss of range from the range of the monocular should be only about 10%. The subjective advantage, and assurance of the observer in making reports is retained, as in the binocular, but at the cost of range, for night observations.

If the use of such devices can be combined with satisfactory increases in magnification, exit pupil, and field size, over binoculars of the same size and weight, the instruments embodying them may be useful ones; they are, however, decidedly subject to further research.

Meritorious though they may prove to be, such devices should not lead to the use of a monocular when it is possible to employ a binocular of equal magnification, exit pupil and field. The data are clear-cut: a binocular has a definite and substantial advantage over a monocular for night use, and this advantage should not be sacrificed to expediency.

RESULTS: HAND-HELD BINOCULARS

Figures B-15, B-16 and B-17 present the Relative Range Performance curves for the hand-held binoculars; Table B-19 gives the corresponding .50 Relative Range Per-

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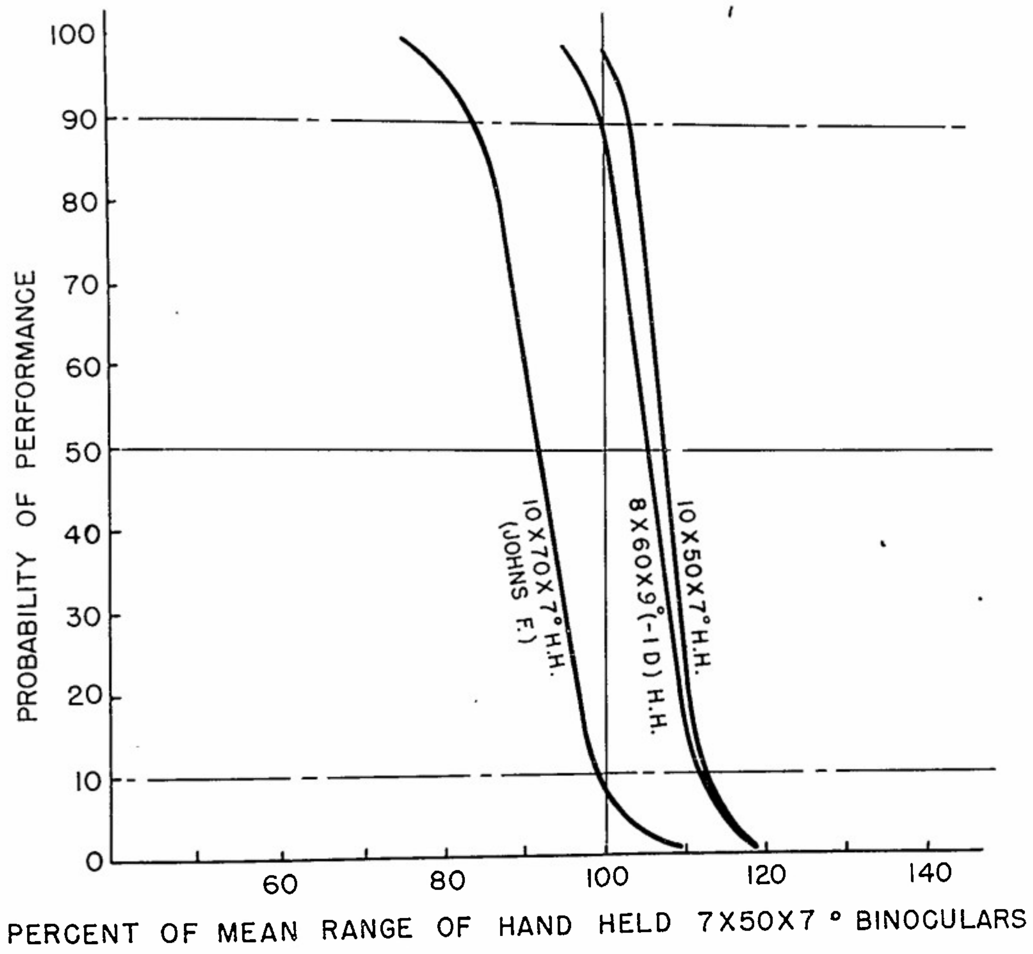
* June 1945 ANOSRDVC minutes.

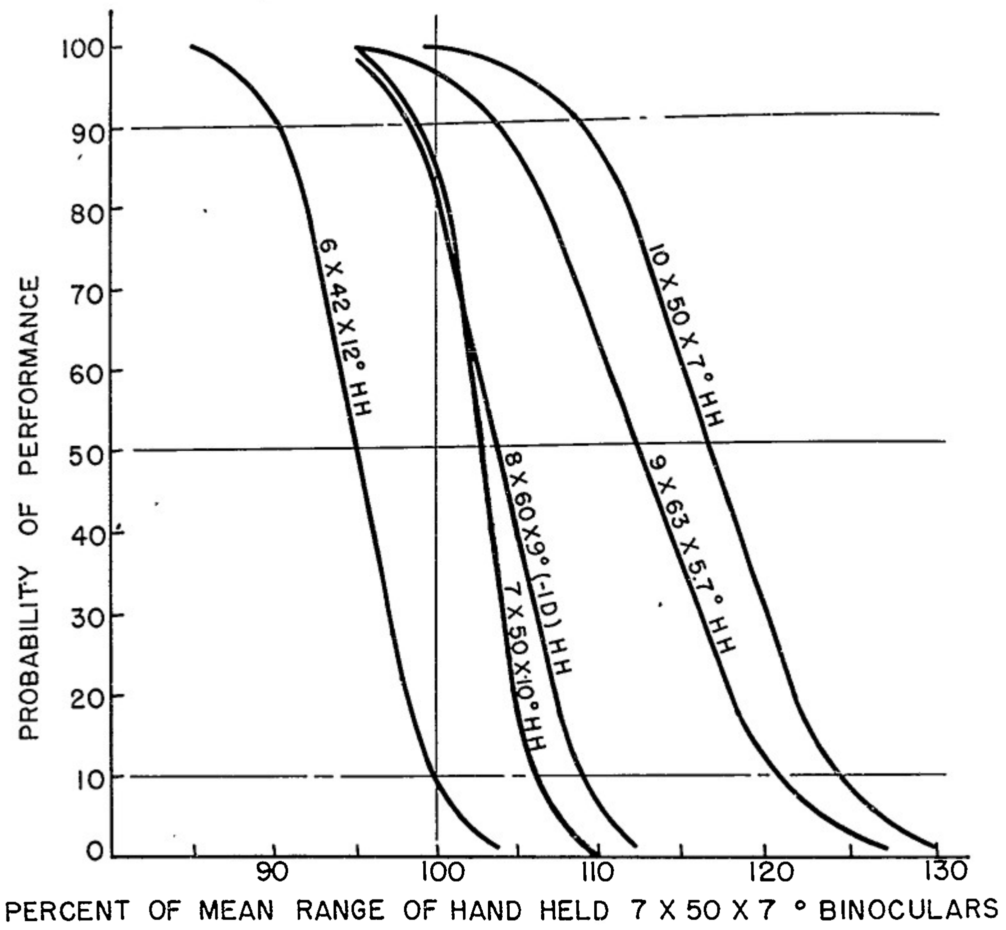
* OSRD 6128



THE RELATIVE RANGE PERFORMANCE OF HAND HELD BINOCULARS

BASED ON THE VISIBILITY OF TARGETS AT NIGHT WHEN VIEWED BY OBSERVERS POSTED ON THE SIGNAL BRIDGE OF A DESTROYER ESCORT TRAVELING AT 9 KNOTS

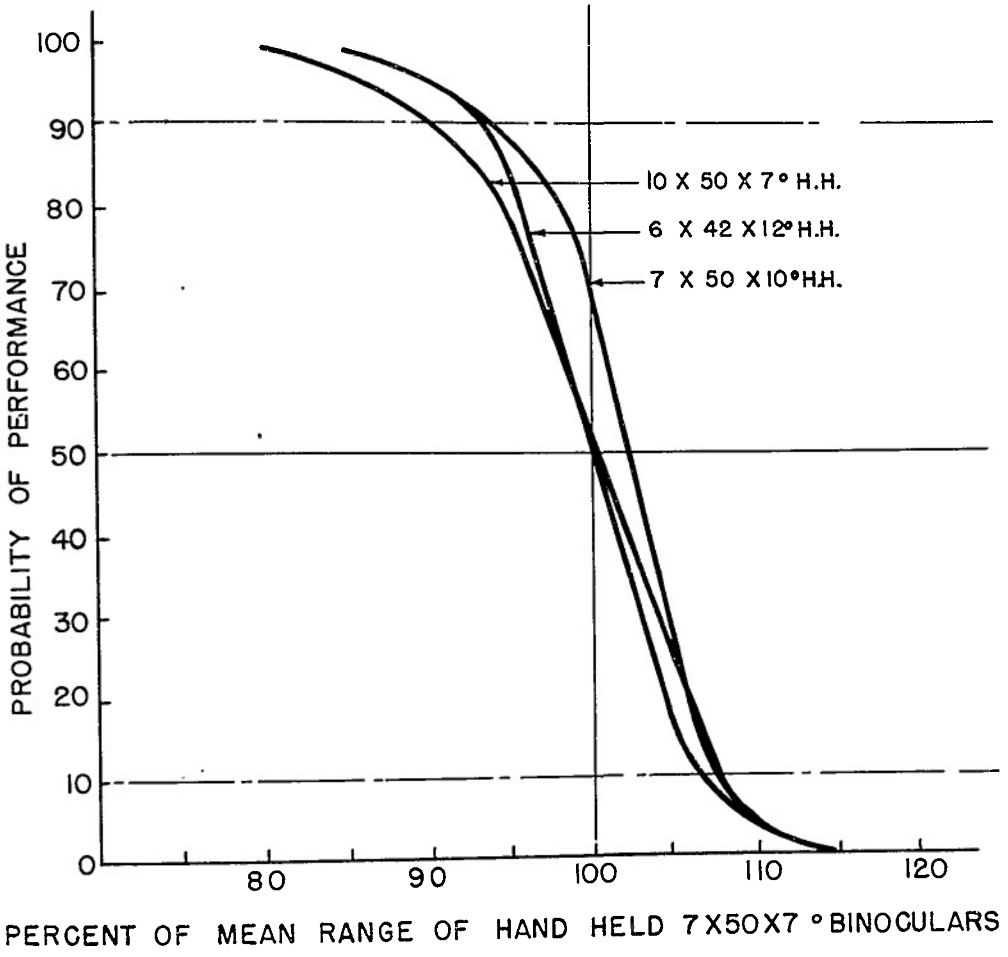
Figure B-15.



THE RELATIVE RANGE PERFORMANCE
OF HAND HELD BINOCULARS

BASED ON THE VISIBILITY OF TARGETS AT NIGHT
WHEN VIEWED BY OBSERVERS POSTED ON THE GUN DECK OF
A DESTROYER ESCORT TRAVELING AT 9 KNOTS

Figure B-16.



THE RELATIVE RANGE PERFORMANCE
OF HAND HELD BINOCULARS

BASED ON THE VISIBILITY OF TARGETS IN DAYLIGHT
WHEN VIEWED BY OBSERVERS POSTED ON A DESTROYER
ESCORT TRAVELING AT 12 KNOTS

Figure B-17.

formance (RRP) values.

TABLE B-19

THE .50 RRP VALUES FOR HAND-HELD BINOCULARS
AS DERIVED FROM
SUMMATED RELATIVE RANGE PERFORMANCE CURVES

	NIGHT OBSERVATIONS		DAY OBSERVATIONS
Instrument	Signal Bridge	Gun Deck	All Decks
6x42x12°	-	95.3	100.0
7x50x7°	100.0	100.0	100.0
7x50x10°	-	103.0	102.5
8x60x9° (-1d)	105.5	103.8	-
9x63x5.7°	-	112.5	-
10x50x7°	106.7	117.0	100.2
10x70x7°(JF)	92.0	-	-

Comments (Night Results):

(1) The 10x70x7° binocular gives anomalous results. This prototype "folded" instrument was constructed at the Johnson Foundation for Medical Physics, and was not sufficiently developed to receive a fair test. Its light transmission was low: .40. Designed to be worn strapped to the head, this instrument was necessarily used as a hand-held instrument. It was difficult to avoid slipping, to keep the eyes at the proper eye-distance, and to avoid getting one or more fingers in front of the objective lens. The poor results obtained should be discounted, and the possibilities of the design should be further explored.

(2) There is no important contribution to range by the provision of a wide field; the 7x50x10° binocular performs very close to the 7x50x7°.

(3) The two samples of the 8x60x9° binocular are in good agreement.

(4) The discrepancy between the results on the 10x50x7° binocular obtained at the two observation levels is not easily accountable. These two values, 106.7 and 117.0 respectively, may be compared with data obtained at Brown University, which show, under precise laboratory conditions and at a brightness close to that of the moonless night sky, that the 7x50x7° binocular gives an average log relative range* of 2.92, and the 10x50x7° one of 2.96. This difference of .04 log units is approximately 10%. The present findings are in agreement with those of the laboratory.

(5) The effectiveness of magnification in increasing range will be discussed later.

Comments (Day Results):

(1) The 6x42x12° appears to perform more satisfactorily by day; it is equal to the standard instrument. Since the 7x50x7° binocular gives only approximately 10% greater range than the naked eye by day, it is not surprising that the 6x42x12° binocular should perform very close to it.

(2) As at night, the 7x50x10° is not distinguishable from the 7x50x7°.

(3) The 10x50x7° shows no advantage over the 7x50x7° for daytime use. This drop-off in efficiency may be attributable to vibration.

(4) No substantial differences appear among any of the hand-held instruments.

Discussion:

The 10x50x7° binocular is clearly the best of this series of binoculars for night use. Although it may perform more poorly than the bulky and heavy 9x63x5.7° binocular, it has a clear advantage over the 7x50x7° binocular which it resembles very closely in size, weight, and convenience of handling. It is decidedly better in these latter respects than the 9x63x5.7° binocular. For day use, the 10x50x7° equals, although it does not excel, the 7x50x7°. This instrument appears to be the most satisfactory for all-purpose use as a hand-held instrument, and it might well replace the 7x50x7° instrument as standard equipment.

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* As defined at Brown University.

RESULTS: MOUNTED BINOCULARS:

Figures B-18, B-19 and B-20 present the Relative Range Performance curves for the mounted binoculars, and Table B-20 gives the .50 RRP values.

Comments (Night Results):

(1) Discussion of the effectiveness of mounts, and of magnification is reserved until a later section.

(2) It is apparent that the 10x70x7° binocular, the NDRC Pilot Model, did not perform as well as would be predicted from its magnification and exit pupil. No optical characteristics, such as uncomfortable eye-distance, or low Contrast Rendition, accounts for a performance roughly 8% below what might be predicted.

Comments (Day Results):

(1) Although curves from only one set are presented in Fig. B-20, the 20x120x3° and the 25x100x3.6° binoculars were used in two sets, and both values are presented in Table B-20. The very large discrepancy between the findings on the two sets has not yet been accounted for, and cannot be attributed to such factors as visibility. The more valid of the two performances cannot be established until, at some later date, observer-binocular interaction can be precisely evaluated. The group of observers yielding the greater .50 RRP values were the better trained and more experienced of the two.

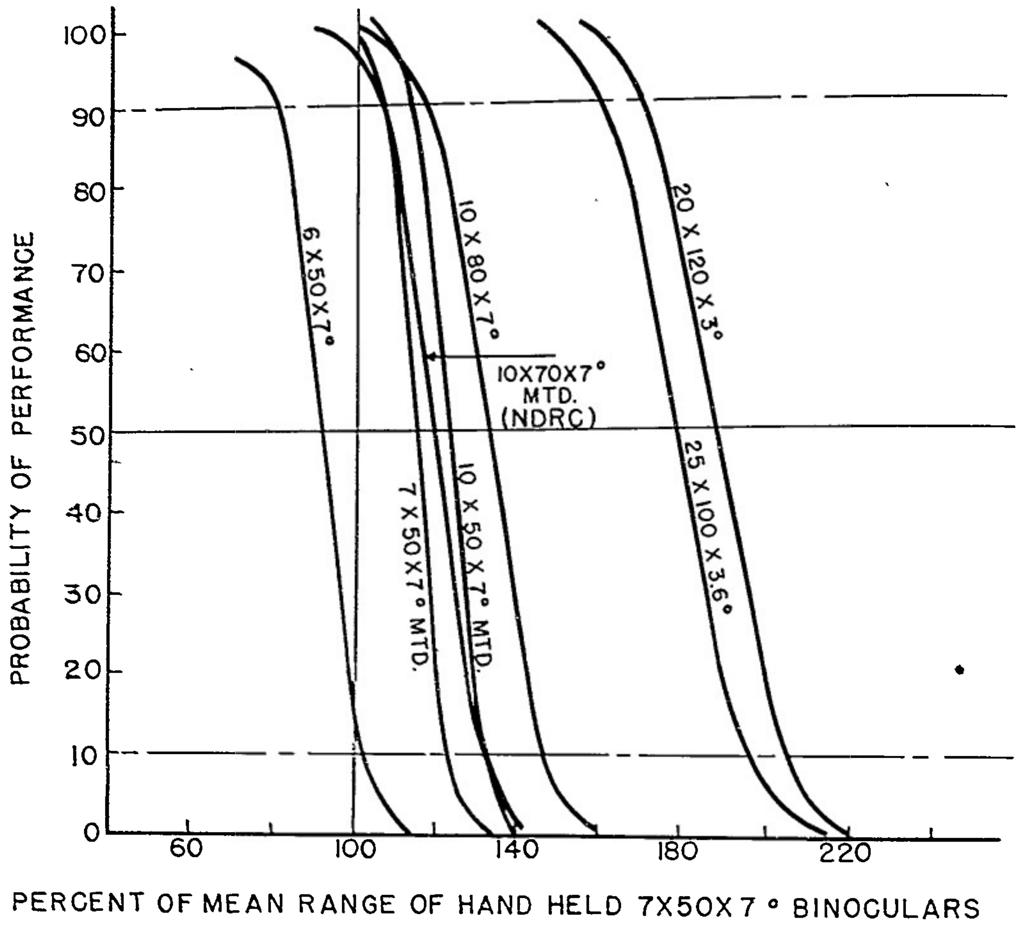
TABLE B-20

THE .50 RRP VALUES FOR MOUNTED BINOCULARS
AS DERIVED FROM
SUMMATED RELATIVE RANGE PERFORMANCE CURVES

	NIGHT OBSERVATIONS		DAY OBSERVATIONS
Instrument	Signal Bridge	Gun Deck	All Decks
6x42x12°	-	**	-
6x50x7°	91.9	-	-
7x50x7°	115.5	-	111.5
7x50x10°	-	105.0	-
9x63x5.7°	-	120.2	-
10x50x7°	122.3	-	117.5
10x70x7°(NDRC)	119.5	-	-
10x80x7°	133.0	-	114.0
20x120x3°	-	-	133.5
25x100x3.6°	-	-	132.5
20x120x3°	188.0	-	193.0*
25x120x3.6°	179.9	-	173.5*

* High figures were obtained with this instrument with more experienced observers.

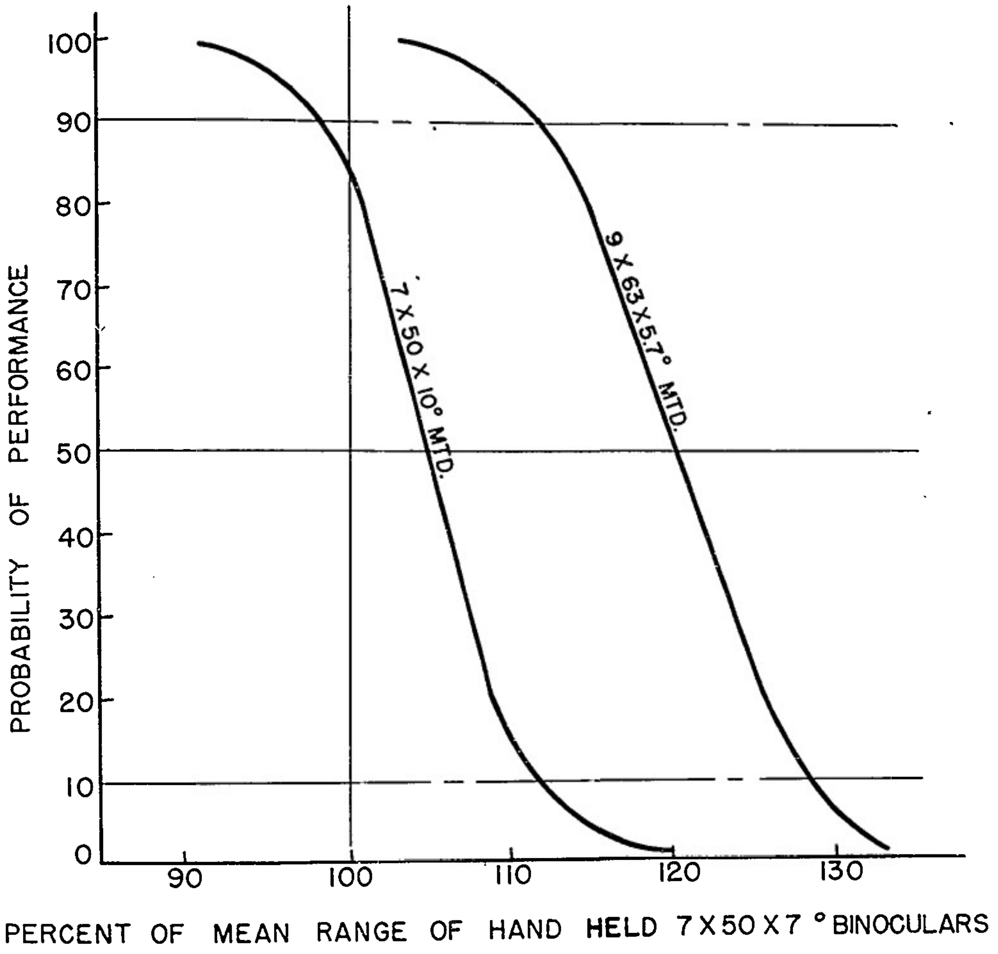
**Data inadequate for plotting.



THE RELATIVE RANGE PERFORMANCE
OF MOUNTED BINOCULARS

BASED ON THE VISIBILITY OF TARGETS AT NIGHT
WHEN VIEWED BY OBSERVERS POSTED ON THE SIGNAL BRIDGE
OF A DESTROYER ESCORT TRAVELING AT 9 KNOTS

Figure B-18.

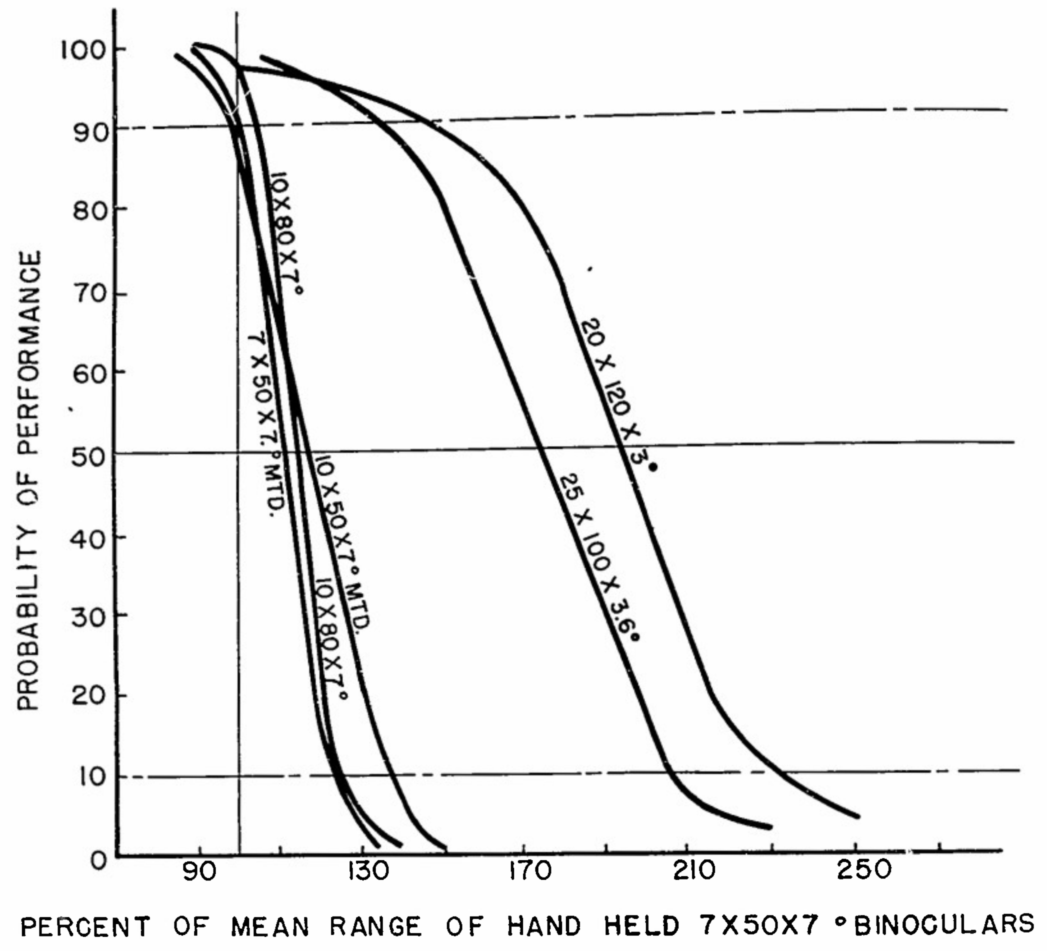


THE RELATIVE RANGE PERFORMANCE
OF MOUNTED BINOCULARS

BASED ON THE VISIBILITY OF TARGETS AT NIGHT
WHEN VIEWED BY OBSERVERS POSTED ON THE GUN DECK
OF A DESTROYER ESCORT TRAVELING AT 9 KNOTS

NOTE :
DATA FOR 6X42X12° INSUFFICIENT FOR PLOTTING

Figure B-19.



THE RELATIVE RANGE PERFORMANCE
OF MOUNTED BINOCULARS

BASED ON THE VISIBILITY OF TARGETS IN DAYLIGHT
WHEN VIEWED BY OBSERVERS POSTED ON A DESTROYER ESCORT
TRAVELING AT 12 KNOTS

Figure B-20.

RESULTS: MOUNTED MONOCULARS

Figures B-21 and B-22 present the Relative Range Performance curves for the mounted monocular instruments, and Table B-21 gives the .50 RRP values.

TABLE B-21

THE .50 RRP VALUES FOR MOUNTED MONOCULARS
AS DERIVED FROM SUMMATED RELATIVE RANGE
PERFORMANCE CURVES

	NIGHT OBSERVATIONS	DAY OBSERVATIONS
Instrument	Signal Bridge	Signal Bridge
4x28x10°	53.0	97.2
6x30x8.5°	53.0	-
6x33x7°	*	94.0
6x33x8°	64.9	100.0
16x96x3.2°	117.0	-
21x76x2.8°	79.8	93.8
24x96x2.2°	126.2	-

* Data inadequate for plotting.

Comment (Night):

(1) The 4x28x10° instrument is employed in a gunsight. The inferior performance to be obtained from a monocular of low power is all too evident; the instrument has little advantage over the naked eye, which gives ranges 40 to 50 percent as great as those of the 7x50x7° standard. The 4x28x10° monocular is of little merit for night use.

(2) The 6x30x8.5° and the 6x33x8° instruments are both prismatic telescopes, employed in fire-control instruments. The 6x33x7° is a modification of the 6x50x7° binocular, and resembles, as closely as possible, the 6x33x8° glass. The modifications were:

(a) obscuration of the left barrel,

(b) fitting of an annulus over the objective lens to reduce its aperture to 33 mm., and

(c) placement of a piece of plate glass over the objective lens in order to reduce the light transmission* to that of the 6x33x8°. It was desired to compare the prismatic telescopes with the more simply designed instrument to determine if the ghost images observable in the former interfered with their performance.

Neither of the prismatic telescopes performs well. Although they give ranges some 50% or better than the naked eye, they are substantially poorer than the standard, and possess even less merit when compared with mounted binoculars of roughly equivalent power. It is unfortunate that during the sets when the 6x33x7° was tested, the visibility was so poor that data quite insufficient for calculation were obtained. This is, of course, a token of their poor performance, since the 6x33x7° binocular gave an RRP of 87.6 on the same runs.

(3) The 16x96x3.2° telescope and the 24x96x2.2° telescope are actually a single instrument of two powers. By comparing the performance of this telescope with that of the two high-powered binoculars, certain interesting inferences with respect to the

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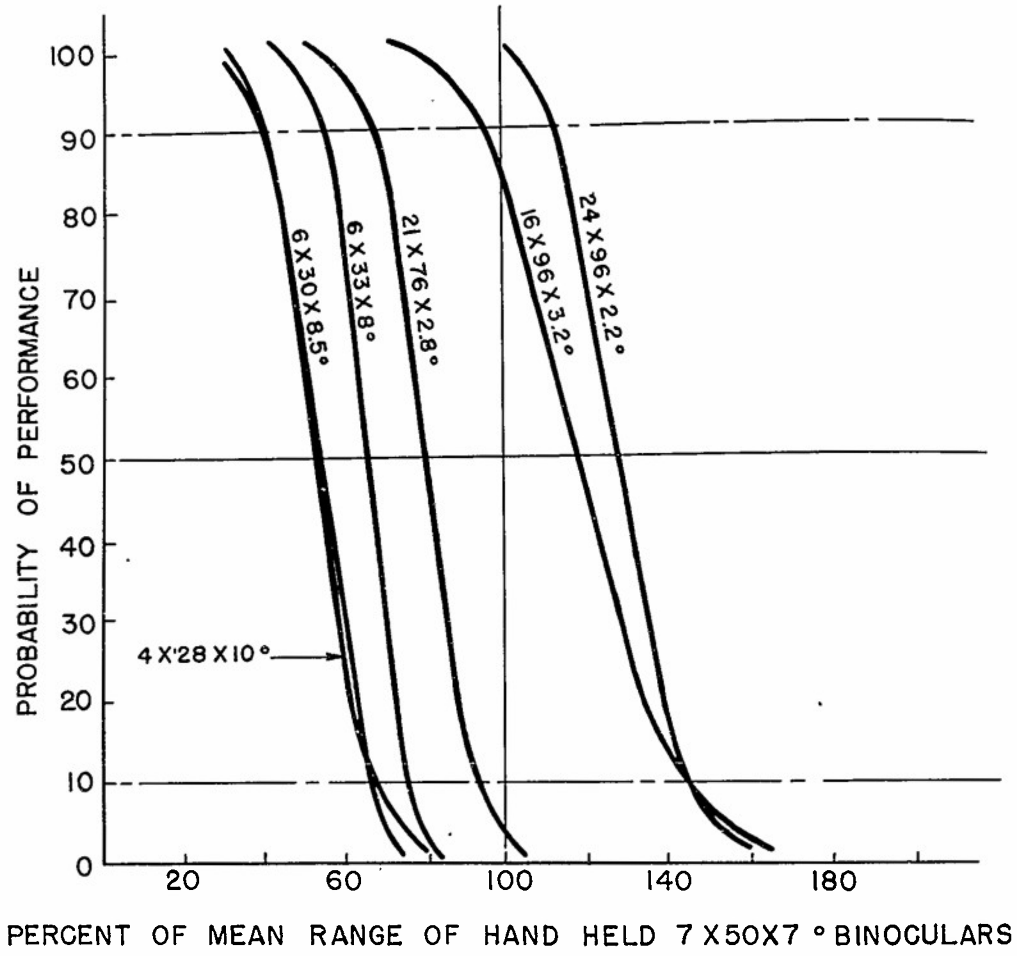
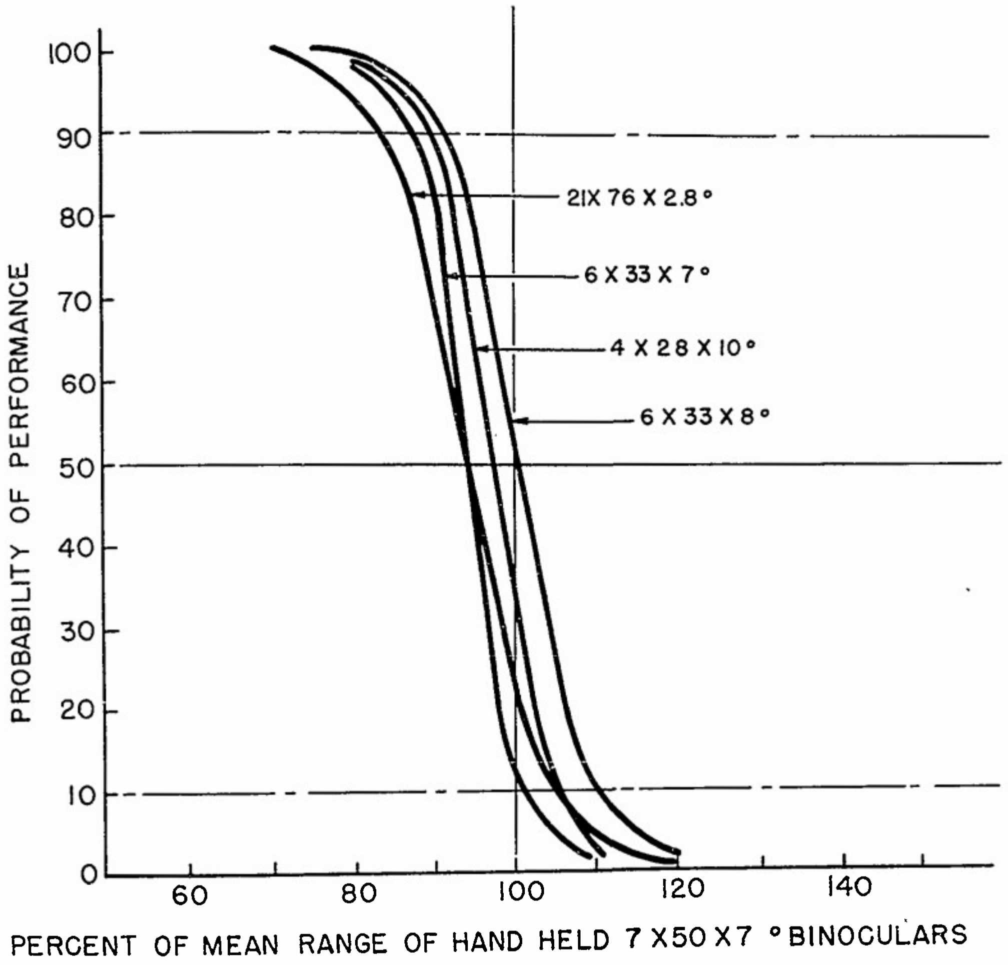
* The data of Appendix A show that this was not entirely effective; the 6x33x7° still had a higher light transmission than the 6x33x8°.



THE RELATIVE RANGE PERFORMANCE OF MOUNTED MONOCULARS

BASED ON THE VISIBILITY OF TARGETS AT NIGHT WHEN VIEWED BY OBSERVERS POSTED ON THE SIGNAL BRIDGE OF A DESTROYER ESCORT TRAVELING AT 9 KNOTS

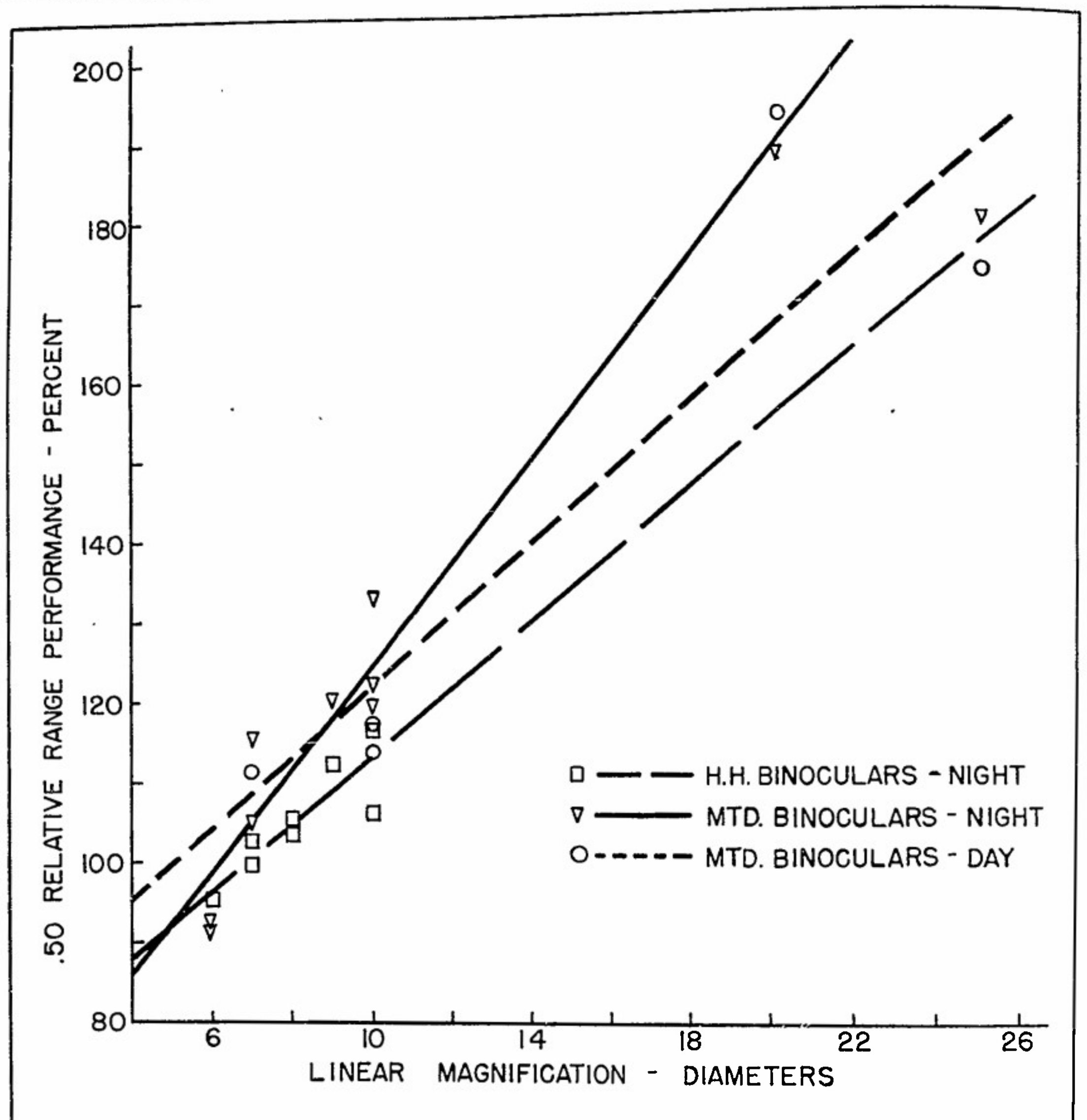
Figure B-21.



THE RELATIVE RANGE PERFORMANCE OF MOUNTED MONOCULARS

BASED ON THE VISIBILITY OF TARGETS IN DAYLIGHT WHEN VIEWED BY OBSERVERS POSTED ON A DESTROYER ESCORT TRAVELING AT 12 KNOTS

Figure B-22.



.50 RELATIVE RANGE PERFORMANCE AS A FUNCTION OF MAGNIFICATION

Figure B-23.

interrelationship of exit pupil and magnification as determinants of range may be drawn, as discussed under "Magnification and Exit Pupil."

(4) The 21x76x2.8° telescope may be taken as a fair sample of a high power nautical instrument. Its performance is poor, and this is not entirely attributable to the small exit pupil. Another factor is its length which, although not so great as the 24x96x2.2°, may serve as a mechanical lever to increase the effect of vibration, which is large in a high-power instrument anyway. The performance of the 21x76x2.8° telescope, like that of the 10x70x7° mounted binocular, must be further analyzed before it is possible to assess its merits.

Comments (Day Observations):

(1) As expected from the small binocular advantage in daylight, the monocular instruments perform relatively better by day than by night.

(2) The 21x76x2.8° performs more poorly than expected by day as well as by night. This is again an anomolous result indicating that this instrument must be more carefully evaluated.

MAGNIFICATION AND EXIT PUPIL

Although not originally selected for the purpose, it was possible to arrange some of the binoculars into a series with nearly constant field size and exit pupil, but of increasing magnification. Such a series provides a basis for the evaluation of the contribution made by magnification to the relative range performance of the instrument.

Figure B-23 presents the .50 RRP plotted against the magnification of these instruments for hand-held, night, and for mounted instruments, day and night use. The great range of exit pupils among the monoculars, and the small range of magnification of the hand-held, day series prevented their inclusion in the figure. Straight lines describe adequately the relationships observed. The equations of the lines on Fig. B-23 were obtained by the method of least squares, and are as follows:

(a) Hand-held binoculars, night use

$.50 \text{ RRP} = 4.3 \text{ M} + 70.4$

(b) Mounted binoculars, night use:

$.50 \text{ RRP} = 6.5 \text{ M} + 59.7$

(c) Mounted binoculars, day use:

$.50 \text{ RRP} = 4.6\text{M} + 76.0$

In these equations, M is the magnification and .50 RRP the most probable relative range performance.

The fit for mounted binoculars, day use, is questionable, in view of the discrepancy in the results obtained from two sections of observers with the high powered instruments. In drawing the figure and deriving the equations, the lower values were not considered.

Discussion:

Although the exit pupils of the binoculars whose .50 RRP's were plotted together varied from 4.0 to 8.5 mms., this variation appears to produce very little deviation from the performance predicted on the basis of magnification alone, except in the case of one instrument with an exit pupil as small as 4 mm.: the 25x100x3.6°. Within the limits of magnification on the illustration, 4 to about 20, Relative Range Performance may be accepted as a linear function of magnification, provided that exit pupil is 5.0 mm. or greater. This is in accord with the results of the Dartmouth experiments on hand-held binoculars of magnifications up to ten (OSRD No. 4433). However, the equation which approximately describes those findings has a slope constant of 14.3, indicating the effect of magnification on range to be more than three times greater than that obtained in the field. The experiments on binoculars at Brown, on the contrary, yielded diminishing returns with binoculars of higher magnification under equivalent levels of brightness.

At night the advantage of increased power is greater for mounted instruments than for hand-held ones. This is a rather meaningless finding, since high-power instruments of sufficiently great exit pupil are necessarily mounted, because of their size and weight. It is, however, in agreement with what might be predicted from the greater effect of vibration during the daytime, and on hand-held instruments.

It may be concluded that high power is decidedly advantageous in an instrument for night, and less so for day use. Magnification may be as high as is consistent with the expected conditions of the instrument s use, with the requirements of maintaining exit pupil diameter at a satisfactory magnitude, and with providing an adequate field. Other things being equal, instruments of higher magnification perform as well or better than instruments of lower magnification, under all circumstances studied.

Exit Pupil

Figure B-24 presents the RRP curves of two series of instruments varying in exit pupil diameter. The .50 RRP values are given in Table B-22. All these data were obtained during the night observations, since the short time available did not permit inclusion of such series in the day observations. By day, large exit pupils should yield either no effect, because of the contraction of the pupils of the observer's eyes, or an adverse one because of the greater amount of light introduced into the instruments, which might be expected to reduce Contrast Rendition.*

TABLE B-22

THE .50 RRP AS A FUNCTION
OF EXIT PUPIL DIAMETERS
OF MOUNTED BINOCULARS

Exit Pupil Diameters in Millimeters	6-Power Binocular	10-Power Binocular
5.0	-	122.3
5.5	88.0	-
7.0	92.5	119.5
8.0	-	133.0
8.3	91.9	-

From Fig. B-24, it is evident that some advantage is gained in performance

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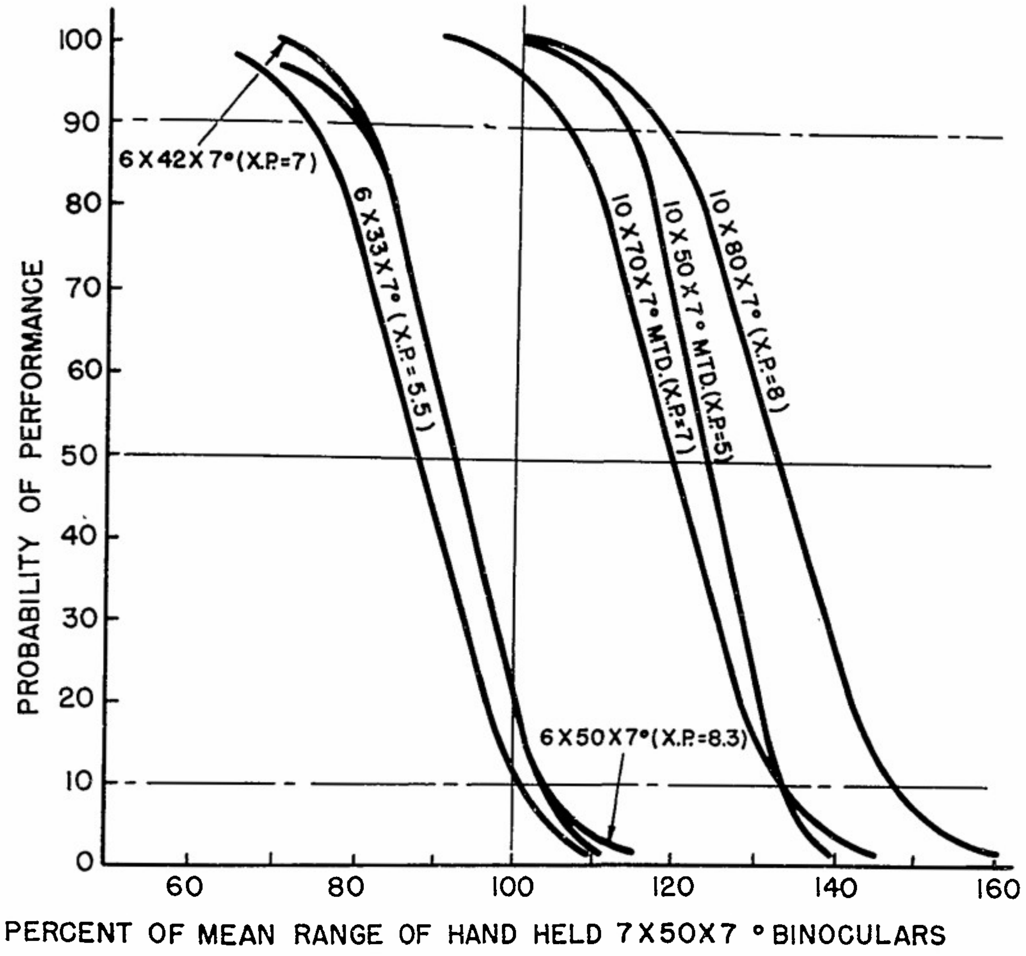
* It is of interest to note that the German 25x100x3.6° and the 10x80x7° instruments were fitted, not only with long sunshades, but also with objective stops which reduced the exit pupil diameter considerably.



THE RELATIVE RANGE PERFORMANCE OF MOUNTED BINOCULARS VARYING IN EXIT PUPIL DIAMETER

BASED ON THE VISIBILITY OF TARGETS AT NIGHT WHEN VIEWED BY OBSERVERS POSTED ON THE SIGNAL BRIDGE OF A DESTROYER ESCORT TRAVELING AT 9 KNOTS

Figure B-24.

744999 O - 47 - 13

with large exit pupils, but these gains are not so great as might have been expected. No conclusion can be made on the effect of increasing exit pupil beyond 7 mm. Further analysis of the present data may lead to more decisive results in this respect.

Relative Contribution of Magnification and Exit Pupil:

Some estimate of the combinations of magnification and exit-pupil diameter which prove best for performance, and of the balance between the two variables which should be maintained, may be obtained from the three comparisons of Table B-23. In each pair of instruments which is compared, an increase in magnification is associated with a decrease in exit-pupil diameter, and with in two cases, increasing, and, in one case, decreasing performance as measured by .50 RRP.

From these comparisons, it may be inferred that, when choosing between two instruments which differ in both magnification and exit-pupil diameter, the instrument of higher magnification is to be preferred provided that it has at least 33% greater linear magnification, and not less than 67% of the exit pupil diameter of the other. Thus, an 8x60 would be preferred to a 10x40, since the latter has only 25% greater magnification, with a 33% loss in exit-pupil; but not to a 12x48 which has, with the same loss in exit pupil, an increase of 50% in magnification. The data on which this rule of the thumb is based are not conclusive, but it seems to hold for instruments with exit pupils falling in the range 4-8 mm.

TABLE B-23

ESTIMATE OF RELATIVE CONTRIBUTION OF EXIT PUPIL AND MAGNIFICATION TO .50 RRP

Instrument Pair	Increase in Power	Decrease in Exit Pupil Diameter	Change in .50 RRP (%)
7x50x7° 10x50x7°	43.%	29%	app. + 10
16x96x3.2° 24x96x3.2°	50%	33%	+ 8
20x120x3° 25x100x3.6°	25%	33%	- 5

General Discussion: The general conclusion from the results presented is that:

(a) other things being equal, increases in magnification are accompanied by proportional increases in range, up to a magnification as least as high as 20x, and (b), other things being equal, gains in range may be obtained by increasing exit pupil up to 8 mm. The best combination of magnification and exit pupil for an instrument must be based on the requirements of size and weight, with the highest values of both as the optimal, and with the rule of thumb reported above as a rough guide.

It is unfortunate that at the time during which the field tests were run, a wider variety of instruments could not be tested. Inclusion of such an instrument as the Japanese two-powered 22½x30x180, with its unique combination of high power and large exit pupil, would have been helpful.

BINOCULAR MOUNTS AND VIBRATION

The problem of vibration of an optical instrument is a complex one. It arises from both the unsteadiness of the platform on which observer and instrument are placed and the tremor of the observer's body. Its effect is increased by the optical leverage entailed through the magnification of the instrument and by the mechanical leverage produced by the length of the barrel of the instrument.

Vibration has often been considered to set a sharp upper limit to the useful magnification of an instrument. The displacement of an image on the retina of the eye by vibration increases in direct proportion to magnification. This displacement increases the effective area of an image, lessens its contrast, and so reduces its visibility.

Presumably, any type of mount which will reduce vibration should effectively increase the RRP of binoculars; even though the mounts transmit vibration of the vessel to the binocular, they will eliminate some body tremor. A mount designed so that mediated vibration of the platform is damped as effectively as possible should still further reduce vibration and improve performance.

Results:

Table B-24 presents the .50 RRP results for night observations for the 7x50x7° binocular, utilizing three types of mounts, and Table B-25 presents the data on the other binoculars which were employed both hand-held and with the standard Mark 51 director mount, or with the Mark V alidade, which give equivalent results.

These tables show that substantial benefit is to be obtained from mounting binoculars, and that greater benefits are obtained by the instruments of higher magnification. The range increase is of the same order of magnitude both by night and by day.

Table B-24 may be compared with the data obtained by NDRC at Brown University. Their findings, presented in Table B-26, were obtained at a higher brightness, but in the absence of a vibrating platform. Field results and laboratory findings are in close conformity.

In the day runs, mounting the 7x50x7° binocular yielded a .50 RRP of 111.5, which may be compared with a relative range of

TABLE B-24

THE .50 RRP OF THE 7x50x7° BINOCULAR
WHEN USED WITH STANDARD MOUNT,
ANTI-VIBRATION-MOUNT (VFA),
HAND-HELD AND HAND-HELD RESTED

Instrument and Mount	Night Observations	Day Observations
	Signal Bridge	All Docks
7x50x7° HH	100.0	100.0
7x50x7° HHR	115.5	-
7x50x7° MTD	115.5	111.5
7x50x7° VFA	114.8	114.6

TABLE B-25

THE .50 RELATIVE RANGE PERFORMANCE VALUES OF HAND-HELD AND MOUNTED INSTRUMENTS

	NIGHT OBSERVATIONS						DAY OBSERVATIONS		
	Signal Bridge			Gun Deck			All Decks		
Instrument	HH	MTD	Ratio MTD/HH	HH	MTD	Ratio MTD/HH	HH	MTD	Ratio MTD/HH
7x50x10°	-	-	-	103.0	105.0	1.02	-	-	-
9x63x5.7°	-	-	-	112.5	120.2	1.07	-	-	-
10x50x7°	106.7	122.3	1.15	-	-	-	100.2	117.5	1.17

121.0, which was obtained in daylight field tests on land early in 1943.*

High Speed Runs:

In order to evaluate mounts more rigorously, two 6 run night sets, during which the Destroyer-Escort traveled at 17 knots, were made. This speed was considered by the officers of the vessel to be that at which vibration was a maximum.** Two instruments and four types of mounts were used in these sets:

7x50x7° HH
7x50x7° HHR
7x50x7° Mounted
7x50x7° Vibration-free alidade
10x50x7° HH
10x50x7° Mounted

The 10x50x7° was chosen as the second instrument because it had seemed superior to the 7x50x7° in previous sets at 9 knots. It was desired to determine whether this superiority would be maintained with greater vibration, since many experimenters* have considered that vibration would render binoculars of magnification greater than 8 or 9 less efficient.

TABLE B-26

RATIO OF RELATIVE RANGES OF ALIDADE-MOUNTED INSTRUMENTS TO HAND-HELD INSTRUMENTS AT BRIGHTNESS OF 7.1 LOG MICRO-MICRO-LAMBERTS WITH 100% CONTRAST (BROWN UNIVERSITY)

Instrument	Ratio
7x50x7°	1.05
10x50x7°	1.13
10x70x7°	1.08

The same set of instruments and mounts were tested in four other sets run at approximately the same time at standard speed (9 knots).

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* A report on sample binocular serial #6268 Mark I, Mod. 2., Medical Research Department. U.S. SubBase, 23 July, 1943.

** It was, unfortunately, not possible to measure quantitatively the vibration obtained; equipment for this purpose was not obtainable.

* See Shober, Herbert (The Best Correlation Between Enlargement and Pupillary-Diameter for Hand-Held Binoculars for Night Use) LP/1-50, n.d., and also Hartline, H. K. Paper forthcoming in the Minutes and Proceedings of the 16th Meeting of the Army-Navy-NRC Vision Committee, June 1946.

TABLE B-27

THE .50 RRP OF TWO BINOCULARS, HAND-HELD AND MOUNTED, AT TWO SPEEDS. ALL DATA COLLECTED ON SIGNAL BRIDGE AT NIGHT.

Instrument	9 Knots	17 Knots
7x50x7° HH	100.0	100.0
7x50x7° HHR	115.5	122.3
7x50x7° MTD	115.5	120.1
7x50x7° VFA	114.8	125.0
10x50x7° HH	106.7	112.8
10x50x7° MTD	122.3	144.7

Results:

Figure B-25 gives the RRP curves of the four sets run at 9 knots, with which have been combined those from other sets where this was possible, and also those at 17 knots. The data are summarized in Table B-27.

The increase in .50 RRP of the 10x50x7° binocular in the presence of greater vibration may be caused by a decrease in the performance of the standard 7x50x7°. To check this, a careful comparison of the absolute ranges obtained on the 9-knot runs was made with those obtained on the 17-knot runs; using the three discriminations on Target 3. After the correction for visibility (described elsewhere) had been applied, it was found that the 10x50x7° yielded the same ranges at both speeds, while the 7x50x7° lost from 10% to 30% in range (depending on the target) at the higher speed. On the reasonable assumption that the 7x50x7° performed relatively more poorly with vibration, and that the 10x50x7° binocular was not affected, Table B-28 was computed from Table B-27 with the 10x50x7° HH binocular used as a standard instead of the usual 7x50x7°*.

When this transmutation has been made, the results become clearer: the hand-held-rested, and the mounted 7x50x7°, and the hand-held 10x50x7° yield approximately the same ranges at high speed as at low. The vibration-free alidade (Eastman's Anti-Vibration Mount), and the mounted 10x50x7° perform better in the presence of greater vibration. This result is at variance with laboratory predictions, and may lead to the suprising conclusion that low-power instruments suffer more from vibration than do high-power instruments.

Magnification and Vibration: A check on

TABLE B-28

THE .50 RRP OF TWO BINOCULARS, HAND-HELD AND MOUNTED, AT TWO SPEEDS. BASIC 100% RANGE, CONVERTED FROM 7x50x7° TO 10x50x7° BINOCULAR

DATA COLLECTED ON SIGNAL BRIDGE AT NIGHT.

Instrument	9 Knots	17 Knots
7x50x7° HH	93.7	88.7
7x50x7° HHR	108.2	108.4
7x50x7° MTD	108.2	106.5
7x50x7° VFA	107.6	110.8
10x50x7° HH	100.0	100.0
10x50x7° MTD	114.6	128.3

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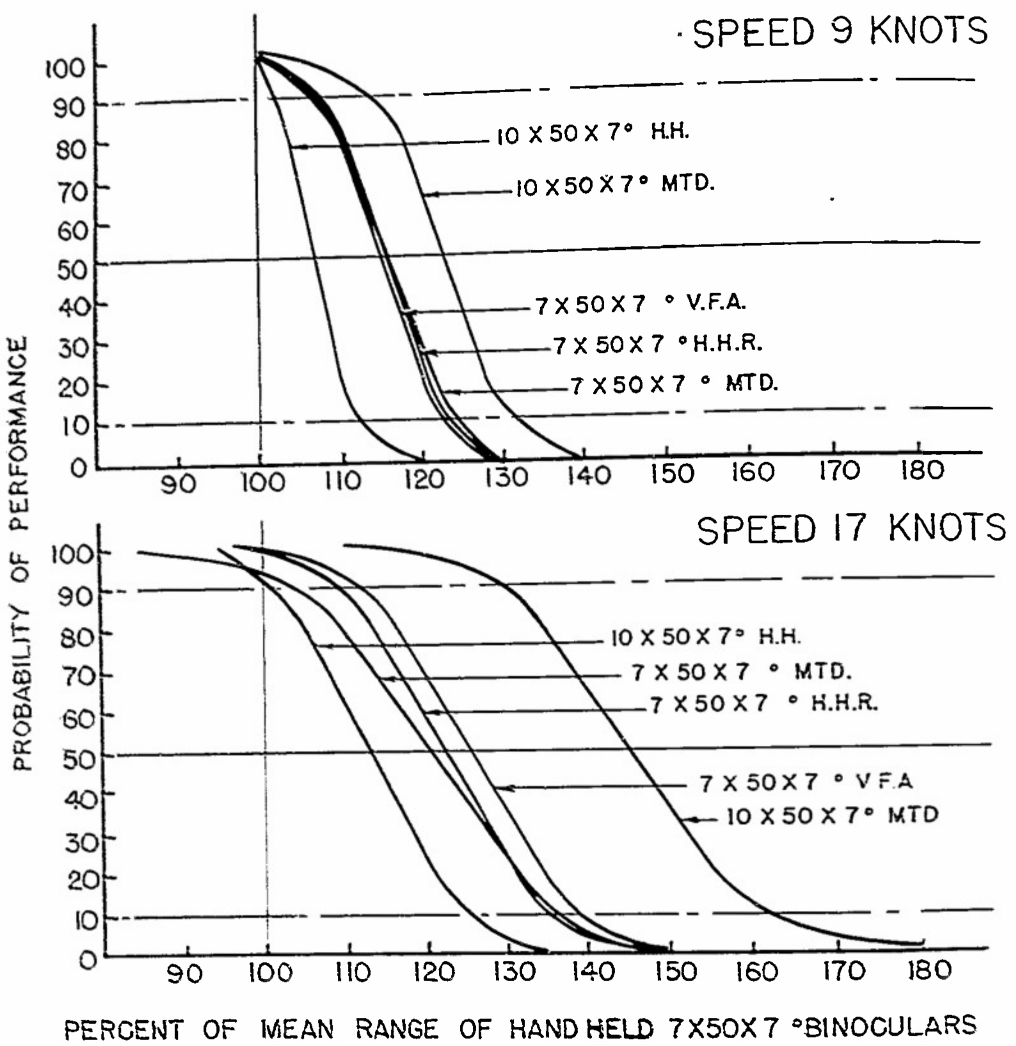
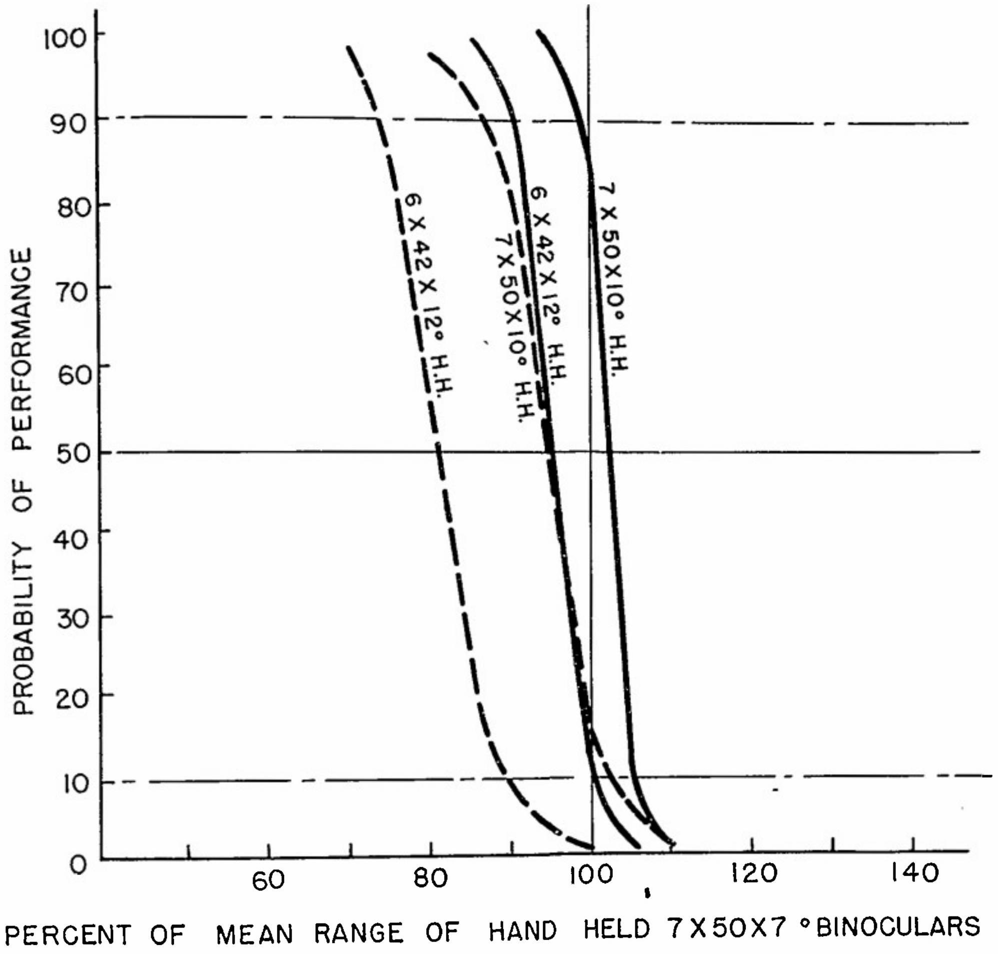
* Such direct transmutations are, strictly speaking, only possible when data on exactly the same discriminations enter into each of the curves combined. In this case, the basic instrument may be shifted at will. Where the discriminations differ, a slight error is introduced if other than the 7x50x7° HH is used as standard. This error is small, and should not produce misleading results. Its presence must, however, be acknowledged.



THE RELATIVE RANGE PERFORMANCE
OF HAND HELD AND MOUNTED BINOCULARS

BASED ON THE VISIBILITY OF TARGETS AT NIGHT
WHEN VIEWED BY OBSERVERS POSTED ON THE SIGNAL
BRIDGE OF A DESTROYER ESCORT

Figure B-25.



THE RELATIVE RANGE PERFORMANCE
OF LOW POWER HAND HELD BINOCULARS

BASED ON THE VISIBILITY OF TARGETS AT NIGHT
WHEN VIEWED BY OBSERVERS POSTED ON THE GUN
DECK OF A DESTROYER ESCORT

Figure B-26.

TABLE B-29

THE .50 RRF OF THREE HAND-HELD BINOCULARS AT TWO SPEEDS

ALL DATA COLLECTED ON GUN DECK AT NIGHT

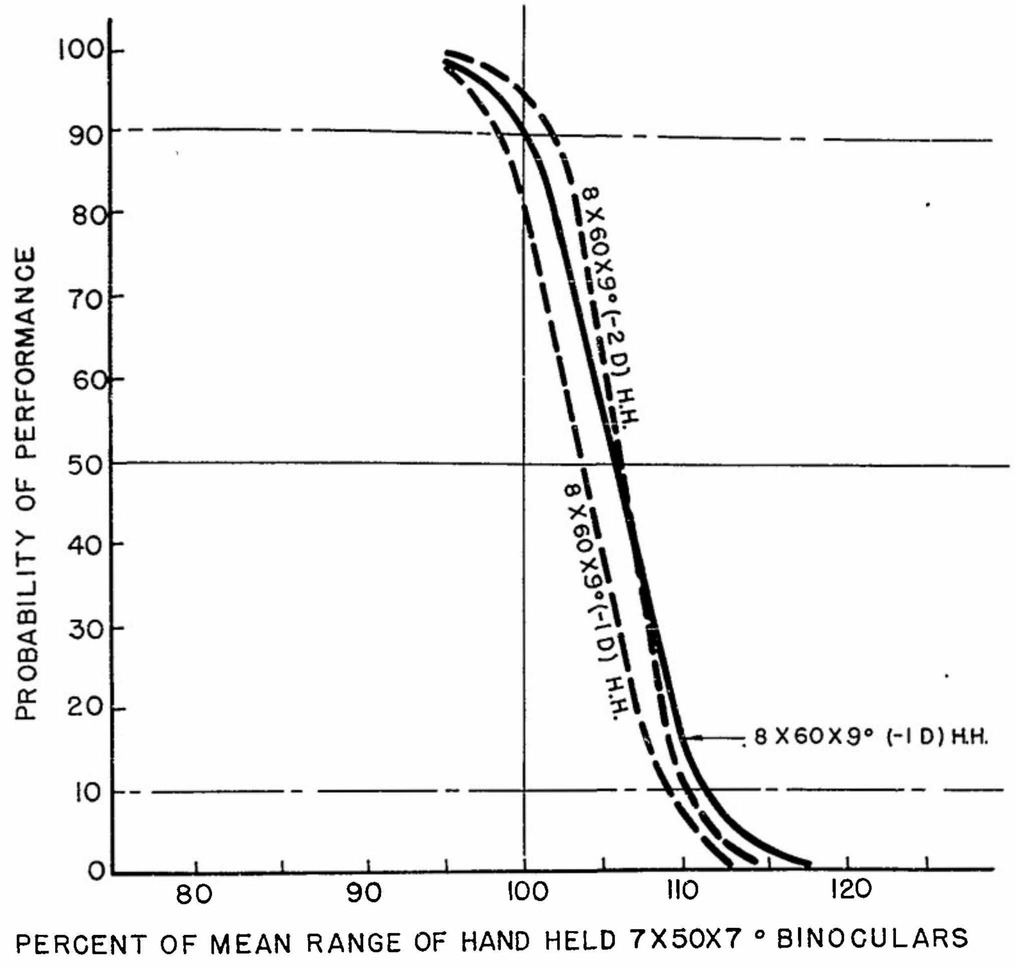
Instrument	9 Knots	17 Knots
7x50x7° HH	100.0	100.0
7x50x10° HH	103.0	94.5
6x42x12° HH	95.3	80.5

this finding is available in the sets run simultaneously on the gun deck, where the 6x42x12° binocular was compared with the 7x50x10° and the 7x50x7°, all hand-held. The results of these sets are shown in Fig B-28, and in Table B-29.

The sample at 17 knots is small. The 7x50x10° appears to perform approximately the same; the 6x42x12 yields poorer performance than at 9 knots. Again the results indicate that low-power instruments are more adversely affected by vibration than high-power instruments.

This result cannot be accounted for by calculations of the reduced contrast of the retinal image produced by vibratory movement of the image on the retina, since this would yield the opposite effect. If it is a genuine effect, as it appears to be, it is most probably due to the behavior of the observers in compensating for the vibration of the vessel. It is the common experience of those familiar with binoculars that vibration becomes increasingly noticeable and bothersome as magnification is increased. Vibration is decidedly more noticeable in a high-power glass than in a low-power glass it may be observed when quite unnoticed in the lower-power binocular. In many psychological experiments it has been observed that subjects required to give a performance under a basal condition, and under an adverse one (e.g., against a background of noise or similar distraction, in extreme fatigue, or other unsatisfactory physical conditions) will very often give a performance equal to or better than that given under the basal condition. This is possible by virtue of greater effort, with full or over-compensation for the distraction. It is suggested that this effect accounts for the findings in the present experiment: the more noticeable the vibration, the more the observers were stimulated to compensate for it. Where vibration was less noticeable, perhaps less effort, or none at all, was made to compensate. Whether the same psychological mechanism will be effective at all times with routine use of these instruments, or whether it will only appear under special circumstances such as those of this test is a question.

Type of Mount and Vibration: Under either condition of vibration, the 7x50x7° binocular performs very much the same whether mounted rigidly or whether it is "hand-held-rested", i.e., the subject is free to compensate as he pleases for the ship motion. The effectiveness of resting binoculars is remarkable. The vibration-free mount becomes superior only in the presence of marked vibration, at which time it exceeds slightly its performance under the standard conditions. This is also true of the 10x50x7° when mounted



THE RELATIVE RANGE PERFORMANCE OF HAND HELD FIXED FOCUS BINOCULARS

BASED ON THE VISIBILITY OF TARGETS AT NIGHT WHEN VIEWED BY OBSERVERS POSTED ON THE SIGNAL BRIDGE AND GUN DECK OF A DESTROYER ESCORT TRAVELING AT 9 KNOTS

—— SIGNAL BRIDGE
– – – GUN DECK

Figure B-27.

Comment: From all these results it may be concluded that substantial benefits are to be gained from the provision of effective mounts for binoculars. Increases in range of the order of 10-20% are possible if a suitable mount is provided, and the gain is greater for higher-powered instruments. Still further benefits should be gained from further development of special vibration-suppressing mounts, such as the Eastman Kodak Anti-Vibration Mount used here.

This vibration-free alidade* was the only one available, but it is deficient in certain respects. It is installed within a housing behind a glass window, so that the light transmission of the system is less than it might be. The mechanical suspension is complex, and the instrument, in its present form, probably is not sufficiently substantial to stand up under conditions of operational use. Development of a more practical vibration-free mount is in order.

There remain certain phenomena with respect to the performance of low-power instruments in our high-speed data which should be further investigated.

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* Chandler, J. S. Binocular Anti-Vibration Mount, Eastman Kodak NDRC Contract OEMsr-392, August 27, 1945, 15 pp.

FIXED FOCUS

The use of the fixed focus for binoculars has been extensively studied throughout the late war, not only in the United States, but also in allied and enemy countries. May binoculars be built with a fixed focus, and if so, at what focus should they be fixed for day, and at what for night use?

The consensus of expert opinion is in favor of a focus of −3/4 or −1 diopter for both night and day use. This is based upon acceptance of 0 diopter as average setting for the emmetropic eye under high levels of illumination, and of −1 diopter for night.

The German 8x60x9° binocular which was employed in this experiment was fitted with a water-tight locking screw which provided for adjustment and locking of an internal focus. There is no scale setting for focus This made it impossible to allow each subject to adjust the instrument to his own best focus, and consequently, it was decided to fix the adjustment at −1 diopter at the Submarine Base Optical Shop, and to use the instrument with a fixed focus. Through the trials in September, the 8x60x9° was used in this manner.

The acquisition of a second 8x60x9° binocular made possible control tests for the effect of this fixed focus, so that the 8x60x9° might be evaluated independently of the fixed focus, and so that results might be obtained permitting the evaluation of the 6x33x8°, 6x42x8°, and 6x50x8°, and the 4x27x12° monocular, which were also fixed-focus instruments (−3/4 diopter).

Four three-man sets were run twice each at night on a comparison of the 8x60x9° with fixed focus at −1 and at −2 diopters* with the standard 7x50x7°. Observations were made from the gun deck.

Results:

The .50 RRP results of these sets (Fig. B-27) were 103.8 for the 8x60x9° (−1d) and 105.9 for the 8x60x9° (−2d), the ratio of the latter to the former being 1.02.

Only a slight difference appears between the two fixed focuses; this difference may be attributed to sampling.

Further Analysis: Since it was desired to investigate the relationship of fixed focus to the individual's own focus, a further analysis was made. The ranges of all discriminations of each observer for the 8x60x9 (−1d) and for the 8x60x9 (−2d) were averaged separately, and the mean difference and the reliability of the difference computed. In order to obtain the latter measure, it was necessary to calculate the correlation between the range for each discrimination obtained with one binocular with that obtained with the other binocular on both sets of runs. This yielded, as a by-product, a measure of the reliability of observations made by each observer since the data for each observer were obtained under comparable conditions of visibility.

The results of this analysis for each of 13 observers (1 man substituted for another in one section for one complete set) are presented in Table B-30, together with each man's average night focus for several different binoculars.

The first finding is that the average results embodied in the .50 RRP obscure the actual performance of each observer with the two fixed focuses. These observers differed radically among themselves in their relative performances with the two glasses. Although, on the average (as calculated this way), the mean range within the -2 diopter fixed focus was greater by only 3½%, different individuals gained as much as 33% with the -2 diopter setting, or lost as much as 12½%. All differences in mean individual range as great as 5% are highly reliable.

The findings on fixed focus thus depend on selection of the individuals in the group tested. In this case, the group seems to contribute a fairly representative sample of the population. Slight relationship, if any, exists between the focuses chosen by the individuals themselves, and the fixed focus at which they perform better. If anything, the evidence indicates that those performing better in the -2d setting prefer on the average a less negative setting (-1.1 diopter) than do those performing better with the -1d (who prefer -1.3 diopters). The sample is too small, however, to permit final conclusions to be drawn.

Reliability of Observations: From the coefficients of correlation between observations, it is evident that these observers, under comparable conditions, reproduce ranges remarkably closely. Examination of the raw data shows that the high reliability coefficients are not artefactual in nature, but indicate that one can predict with some accuracy from one performance another made under comparable conditions. This is true

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* -2 diopters were used as the second fixed focus rather than 0 diopter in view of the negative focuses generally obtained by the observers, who rarely set a day focus at 0.

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TABLE B-30

THE PERFORMANCE OF 13 OBSERVERS ON HAND-HELD 8x60x9° BINOCULAR
WITH FOCUSES FIXED AT -1 AND -2 DIOPTERS

Observer*	No. Discriminations	Mean Night Focus (Diopters). Both Eyes, All Binoculars	Mean Range, All Discriminations, Both Runs. Focus Fixed at: -1 Diopter	-2 Diopters	Diff.	%	r **	t	p ***
Zi	21	-1.0	4509	5670	1161	125	.93	76.90	<.00..01
Br	18	-1.0	3139	4186	1047	133	.89	35.90	<.00..01
Fa	11	-1.0	1754	2286	532	130	.63	19.10	<.00..01
Co	11	-1.4	2154	2455	301	114	.98	43.00	<.00..01
St	14	-1.3	2712	2846	134	105	.85	5.30	<.001
Ve	14	-1.3	2436	2421	−15	99.5	.68	0.10	>.10
Vd	22	-1.9	2755	2621	− 134	95	.93	11.00	<.00..01
Sa	14	-1.0	2776	2635	− 141	95	.92	8.80	<.00..01
La	21	-1.7	5524	5356	—168	97	.88	8.90	<.00..01
Sg	22	-1.4	2445	2231	− 214	91	.84	13.40	<.00..01
Bz	18	-1.3	4007	3499	− 508	86	.95	24.90	<.00..01
Ha	18	-1.0	5209	4623	− 586	89	.90	27.00	<.00..01
Ph	21	-1.3	4870	4253	− 617	87.5	.90	29.50	<.00..01
Average						103.5			

* Ranges of individuals may not be directly compared because of differences in visibility.

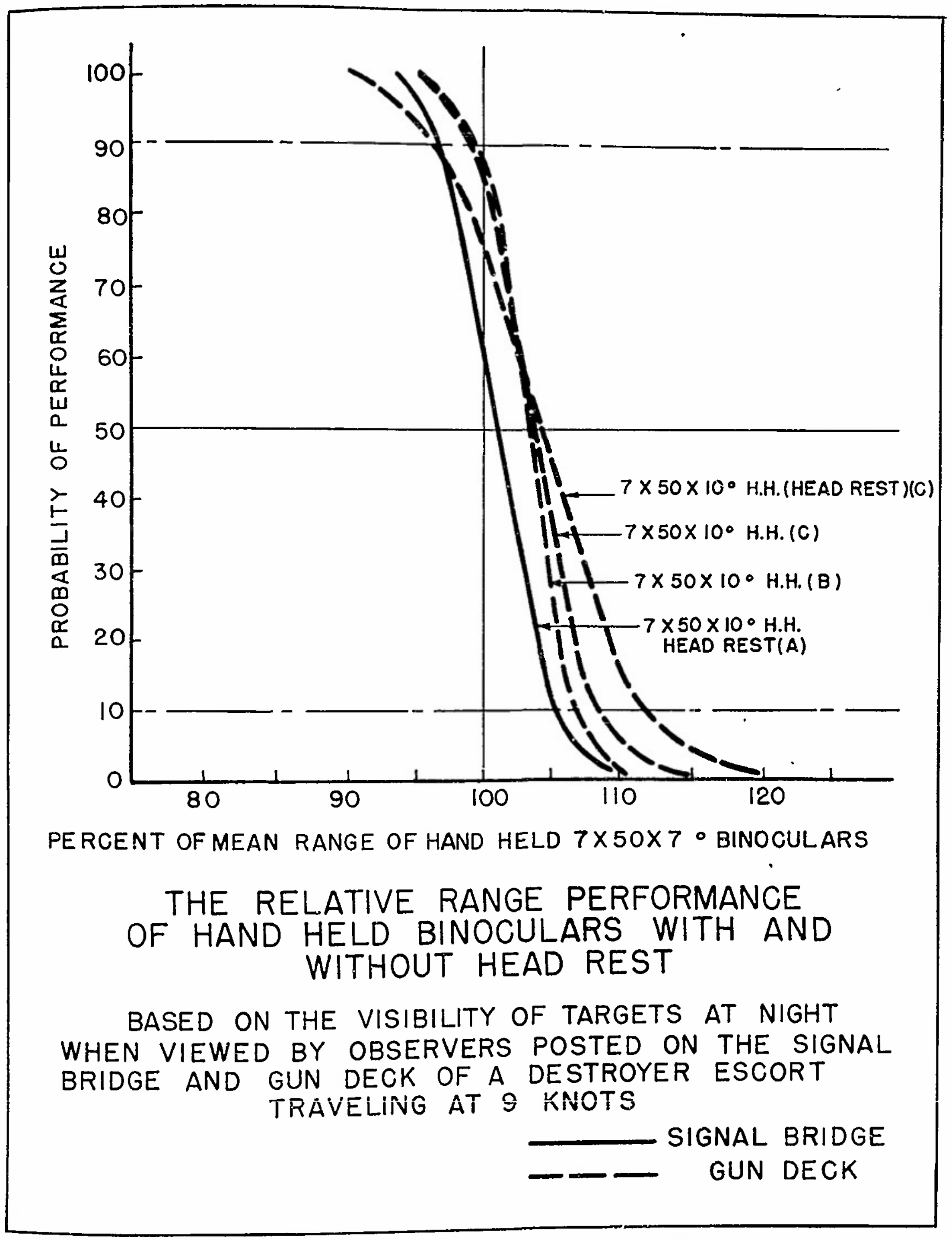
** The range obtained with -1d fixed focus is correlated with that obtained with -2d in the same set.

*** "p" is the probability that the difference found would occur by chance.

despite the occasionally large differences between the binoculars, which are evidently systematic ones. These data are, unfortunately, the only data which offer so neat an opportunity to measure the reliability of observations directly.

HEAD RESTS

Many binoculars, such as the 7x50x10° instrument, incorporate head rests. These have two functions: the first to maintain the eye at the proper eye-distance (although this is equally well effected by the use of narrow cylinders affixed to the eyepiece which extend the tube of the binoculars the proper distance); the second to provide pro-



THE RELATIVE RANGE PERFORMANCE OF HAND HELD BINOCULARS WITH AND WITHOUT HEAD REST

BASED ON THE VISIBILITY OF TARGETS AT NIGHT WHEN VIEWED BY OBSERVERS POSTED ON THE SIGNAL BRIDGE AND GUN DECK OF A DESTROYER ESCORT TRAVELING AT 9 KNOTS

Figure B-28.

tection against wind and glare from the side. For several reasons, it was judged advisable to run comparative series with and without head rests. (1) The Bureau of Ordnance considered the usefulness of head rests sufficiently promising to include them in its statement of problems. (2) The 7x50x10° binocular, which is equipped with a head rest owing to the critical eye relief of this instrument, was delivered late, and consequently had to be used unaltered in the September night series. Since other hand-held binoculars were not so fitted, it was deemed necessary for a fair comparison to obtain results on the 7x50x10° without head rest but with simple cylindrical adaptors fitted to eyepiece to maintain the proper eye-relief. (3) Finally, critical eye-distances, and the general structures of some of the monoculars, and of such high-powered binoculars as the 10x80x7°, the 25x100x3.6°, and the 20x120x3° required that they be fitted and used with eyecups or head rests*, and a measure of the efficiency of head rests was necessary if the instruments were to be compared as instruments, irrespective of such fundamentally irrelevant fittings.

Because of these considerations, a direct study of the effects of head rests was made. Eight 3-run sets of night runs were performed on the gun deck, comparing the 7x50x10° fitted with a head rest, the 7x50x10° fitted with the adaptors, and the 7x50x7° binoculars.

TABLE B-31

THE .50 RRP OF THE 7x50x10° HAND-HELD BINOCULAR USED WITH AND WITHOUT HEAD REST

Observation Position and Group	With Head Rest	Without Head Rest	Ratio
Gun Deck (same observers)	103.9	103.5	1.004
Gun Deck (all observers)	-	103.0	0.986
Signal Bridge (all observers)	101.5		

The resulting RRP curves, together with that of the 7x50x10° HH (head rest) from its September trials on the signal bridge, are given in Fig. B-28. The values are summarized in Table B-31.

The differences between the instruments are minute and not statistically significant; they may very probably be attributable to sampling error. Certainly this is true if the differences in the 7x50x10° HH (head rest) .50 RRP's obtained on the gun deck and signal bridge.

It is interesting to compare the subjective evaluation scores of the 7x50x10° binocular used with and without head rest (see page 209): On the whole, the men prefer the binocular with the head rest. This was not by any means true for all the men; some definitely preferred the 7x50x10° without the extra equipment. It has not been possible to analyze the data of each individual in order to determine whether substantial differences among individuals exist in the performance obtained, as was found with fixed-focus instruments. Such differences might well be found to correspond with differences in general head-structure which affect the fit of the head rest to the individual. Of the 13 observers, the fit was good for seven of them.

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* These head rests differed, but not substantially, among themselves. All were comfortable, and all provided for ventilation so that fogging of the eye-piece lens would not occur.

TABLE B-32

RATIO OF RELATIVE RANGE OBTAINED WITH HEAD REST TO RELATIVE RANGE OBTAINED WITHOUT HEAD REST (BROWN UNIVERSITY DATA)

Instruments	Brightness Level (in Log Micro-Micro Lamberts)	Contrast %	Ratio
7x50x7°	6.6	40	0.844
9x63x5.6°	5.6	100	0.985
9x63x5.6°	6.6	40	0.973
10x70x7°	5.6	100	1.000
10x70x7°	5.6	40	1.039
10x70x7°	6.6	40	0.997

These results on head rests are not dissimilar to those obtained by NDRC at Brown University (OSRD Report No. 6128). Those data (Table B-32) yield, at higher brightnesses, ratios closely comparable with the present 100.4 obtained at starlight levels.

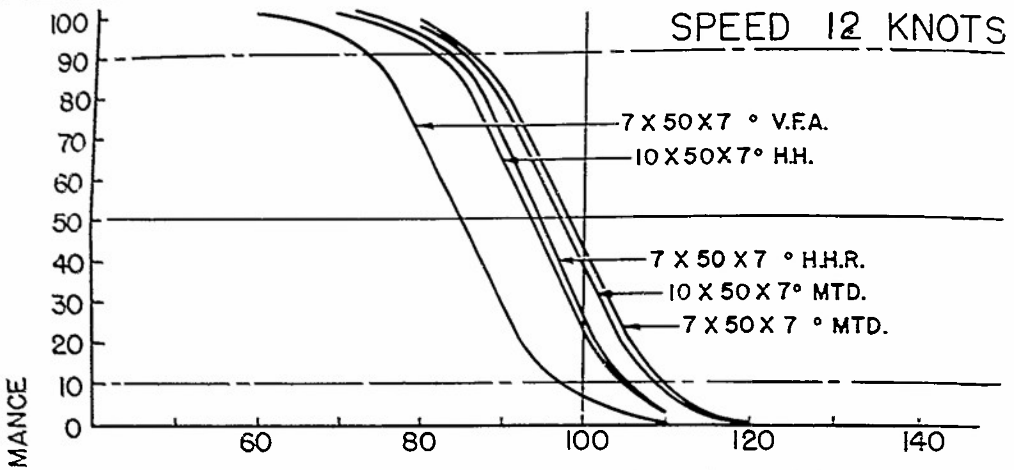
Since the 7x50x7° data in Table B-32 are considered dubious (page 56, OSRD Report No. 6128), the two studies are in good agreement.

Head rests, then, are of extremely limited advantage, so that data on binoculars so equipped may be compared directly with those not so equipped. The head rest, although apparently helpful, may be dispensed with, except where it is necessary to maintain proper eye-distances.

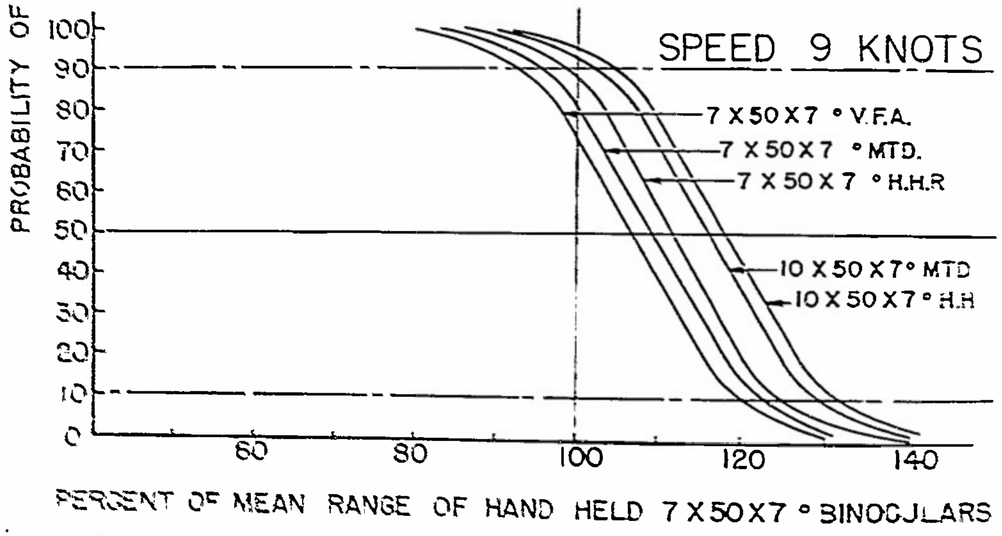
SEARCH

The results on search for the submarine and the SC are not so complete as those on the examination of the other targets. This is the consequence of the fact that on a few nights it was not possible to station target vessels when, owing to the complexities of scheduling, several sets of runs might be being made As a result, the number of sets on which search data are complete is very restricted indeed.

It had been anticipated that the data on sighting the fort to the first two criteria of seeing would serve as supplementary search data, since the observers could not be certain of the location in which either the fort, or the target vessels would first appear, except that it would be within a few degrees of the bow. This expectation seemed to be verified by the RRP curves on discriminations 1-G and 1-100, which resembled the search curves closely. However, further examination of these same data showed that in every set, on one or more runs, one or more observers made these discriminations so soon after the beginning of the run as to make it probable that they were not made at maximum range. Therefore, these discriminations have not been studied. The data on search are thus restricted in number, and are definitive only in the case of the binoculars of high magnification on which they are practically as com-



BASED ON SEARCH AT NIGHT FOR A SUBMARINE
BY OBSERVERS POSTED ON THE SIGNAL BRIDGE OF A
DESTROYER ESCORT TRAVELING AT 12 KNOTS



BASED ON THE VISIBILITY OF TARGETS AT NIGHT
WHEN VIEWED BY OBSERVERS POSTED ON THE SIGNAL
BRIDGE OF A DESTROYER ESCORT TRAVELING AT 9 KNOTS

THE RELATIVE RANGE PERFORMANCE
OF MOUNTED AND HAND HELD BINOCULARS

NOTE OBSERVERS AND RUNS ARE SAME FOR BOTH SETS OF DATA

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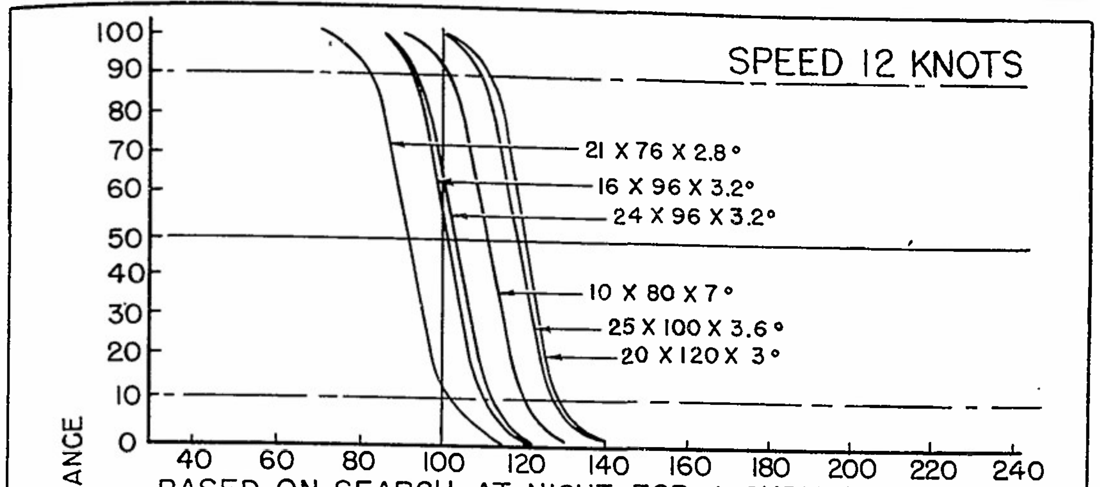
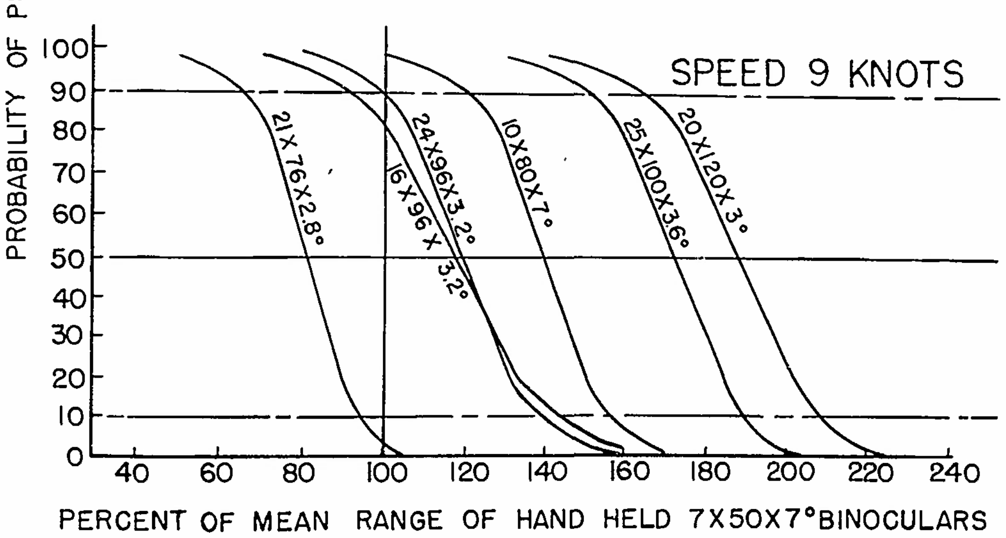


BASED ON SEARCH AT NIGHT FOR A SUBMARINE CHASER
BY OBSERVERS POSTED ON THE SIGNAL BRIDGE OF A
DESTROYER ESCORT TRAVELING AT 12 KNOTS



BASED ON THE VISIBILITY OF TARGETS AT NIGHT
WHEN VIEWED BY OBSERVERS POSTED ON THE SIGNAL
BRIDGE OF A DESTROYER ESCORT TRAVELING AT 9
KNOTS

THE RELATIVE RANGE PERFORMANCE
OF MOUNTED OPTICAL INSTRUMENTS

NOTE: OBSERVERS AND RUNS ARE SAME FOR BOTH SETS OF DATA

Figure B-30.

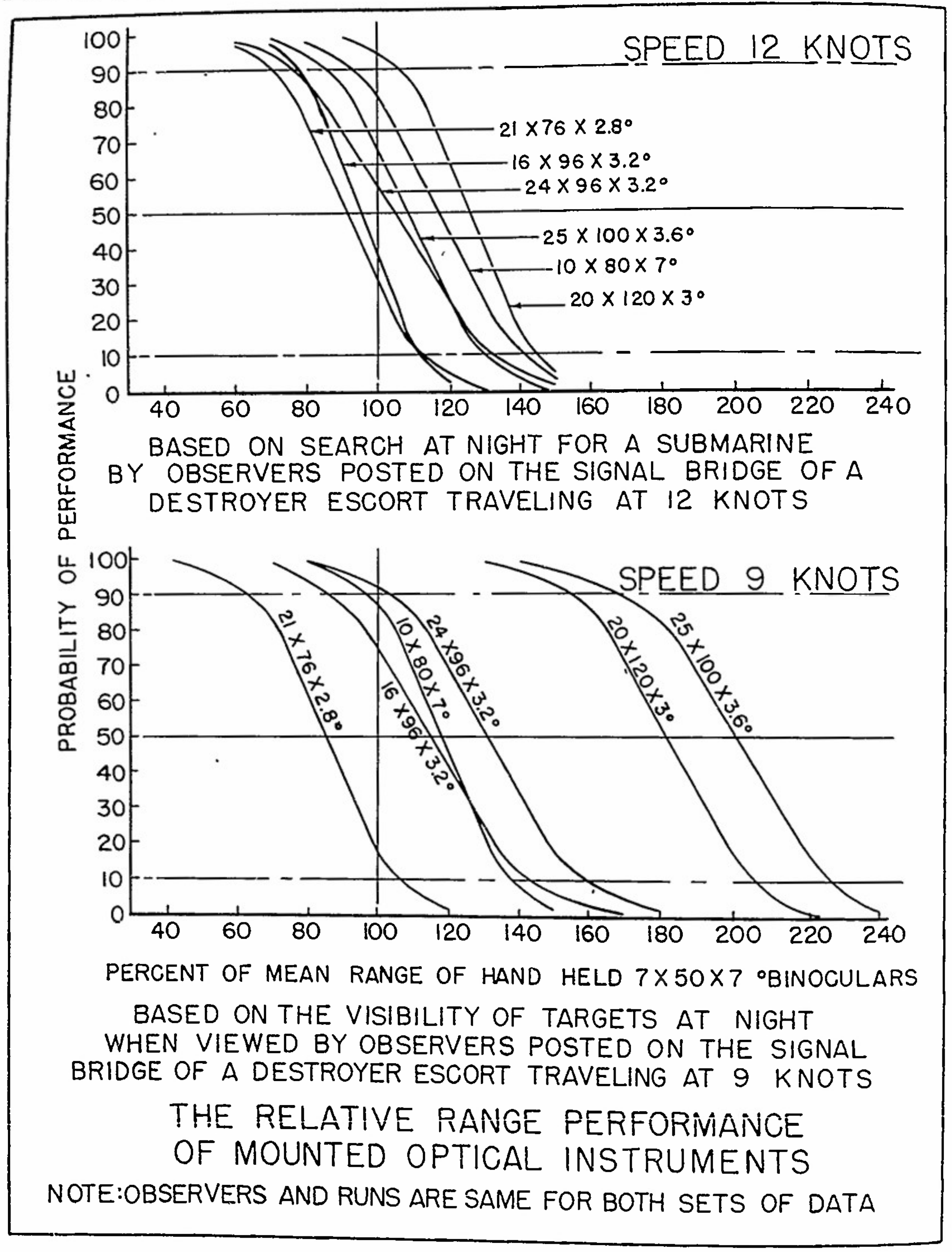


Figure B-31.

plete as the standard results. The data are limited in their application, too, because the necessities of ship handling controlled the size of the region in which the target vessels first could appear, so that only a small sector some 20° in width needed to be searched. Consequently, it is possible that wide-field instruments did not show to full advantage.

TABLE B-33

.50 RRP RESULTS ON SEARCH PROBLEM AND FOR EXAMINATION OF OTHER TARGETS ON THE SAME RUNS BY THE SAME OBSERVERS

Instrument	Sub-marine Search	All-Targets-Same Runs and Ob-servers	SC Search	All Targets--Same Runs and Ob-servers
Hand-Held Binoculars				
7x50x7°	100.0	100.0		
10x50x7°	93.2	118.3		
Mounted Binoculars				
7x50x7° HHR	94.2	111.8		
7x50x7°	98.0	109.2		
7x50x7° VFA	84.8	106.7		
10x50x7°	96.8	116.0		
10x80x7°	116.8	117.8	110.7	139.5
20x120x3°	126.0	182.0	119.3	187.5
25x100x3.6°	108.1	201.0	117.8	171.6
Mounted Monoculars				
16x96x3.2°	95.0	115.0	100.7	116.7
21x76x2.8°	91.4	85.3	91.3	80.8
24x96x2.2°	104.2	131.4	102.3	119.0

$$RRP_s = .239\ RRP + 72.9$$

Results: .50 RRP:

Table B-33 gives the .50 RRP's for hand-held binoculars, mounted binoculars, and mounted monoculars respectively, for search, and for the standard targets on the same observers and same runs. Figures B-29, B-30 and B-31 give the corresponding RRP curves.

These data show a very great reduction of the differences among instruments. With a possible exception, all tend to yield the same ranges and previously striking differences among instruments shrink. Since the higher powered instruments had smaller fields, this may indicate that the usual advantage of a higher powered instrument is lost because of its small field. The one exception, the 10x80x7° had the largest field, which reinforces this suggestion.

However, the instruments still differentiate themselves with respect to power, and their performance on search is, in general, proportional to their performance on the other targets. This is shown in Fig. B-32, in which RRP (search) is presented as a function of RRP. The equation of the rectilinear fit (method of least squares) is

$$.50\ RRP_{search} = .239 \times (.50\ RRP) + 72.9$$

Results: Mean Ranges:

Table B-34 gives the mean ranges obtained with the standard instrument for sightings of the submarine and the subchaser. The mean "100%" range on the submarine, 3085 yards, may be compared with a mean of 86 sure sightings of a fleet-type submarine which was reported by Comdr. D. R. E. Brown to be 2610 yards. The discrepancy is not great, and it is suggested that the criterion of "sure sighting" employed by Comdr. Brown's small group of

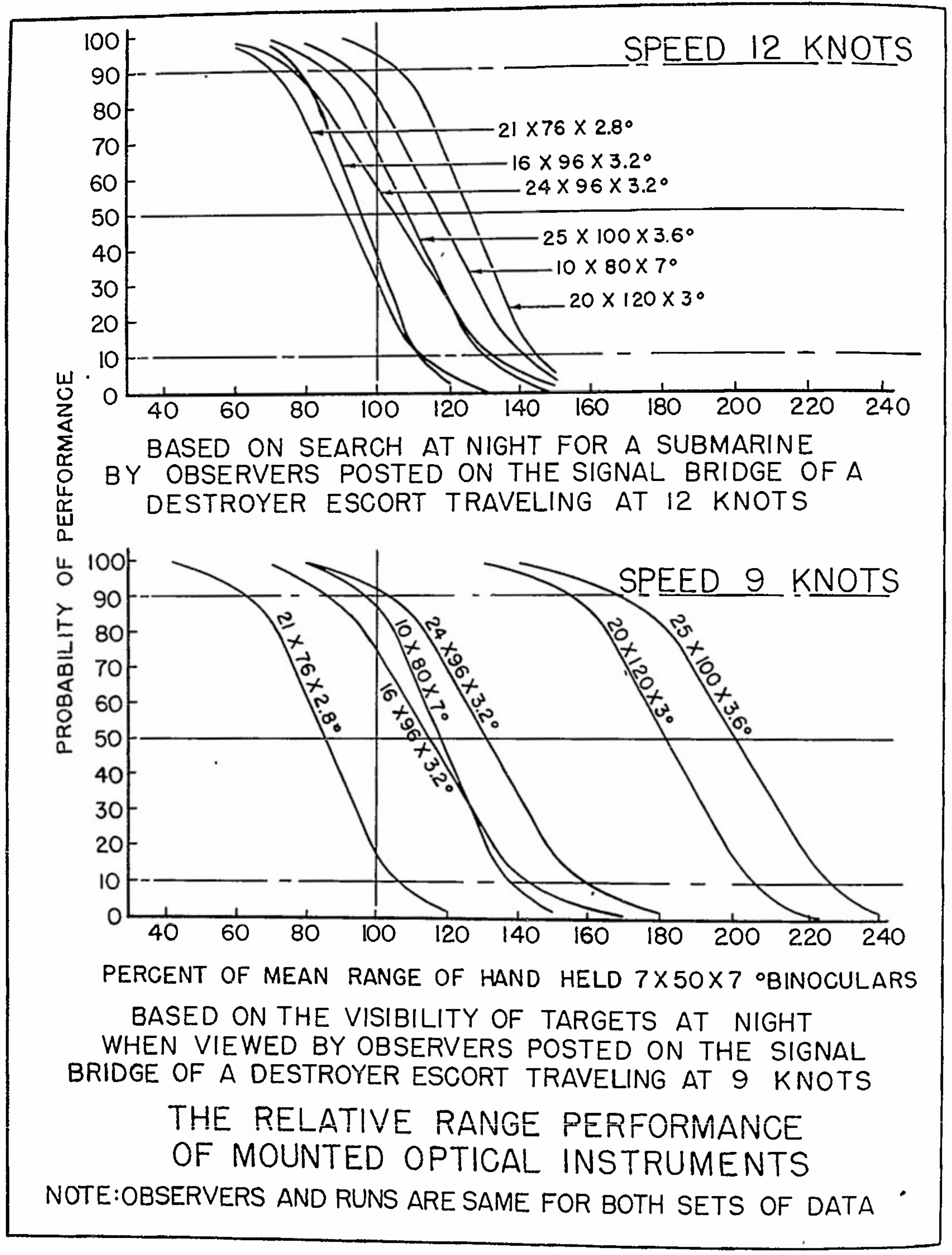


Figure B-31.

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Instrument	Sub-marine Search	All-Targets-Same Runs and Ob-servers	SC Search	All Targets--Same Runs and Ob-servers
Hand-Held Binoculars				
7x50x7°	100.0	100.0		
10x50x7°	93.2	118.3		
Mounted Binoculars				
7x50x7° HHR	94.2	111.8		
7x50x7°	98.0	109.2		
7x50x7° VFA	84.8	106.7		
10x50x7°	96.8	116.0		
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20x120x3°	126.0	182.0	119.3	187.5
25x100x3.6°	108.1	201.0	117.8	171.6
Mounted Monoculars				
16x96x3.2°	95.0	115.0	100.7	116.7
21x76x2.8°	91.4	85.3	91.3	80.8
24x96x2.2°	104.2	131.4	102.3	119.0

$$RRP_s = .239\ RRP + 72.9$$

Results: .50 RRP:

Table B-33 gives the .50 RRP's for hand-held binoculars, mounted binoculars, and mounted monoculars respectively, [illegible] search, and for the standard [illegible] same observers and same [illegible] B-30 and B-31 give the [illegible]

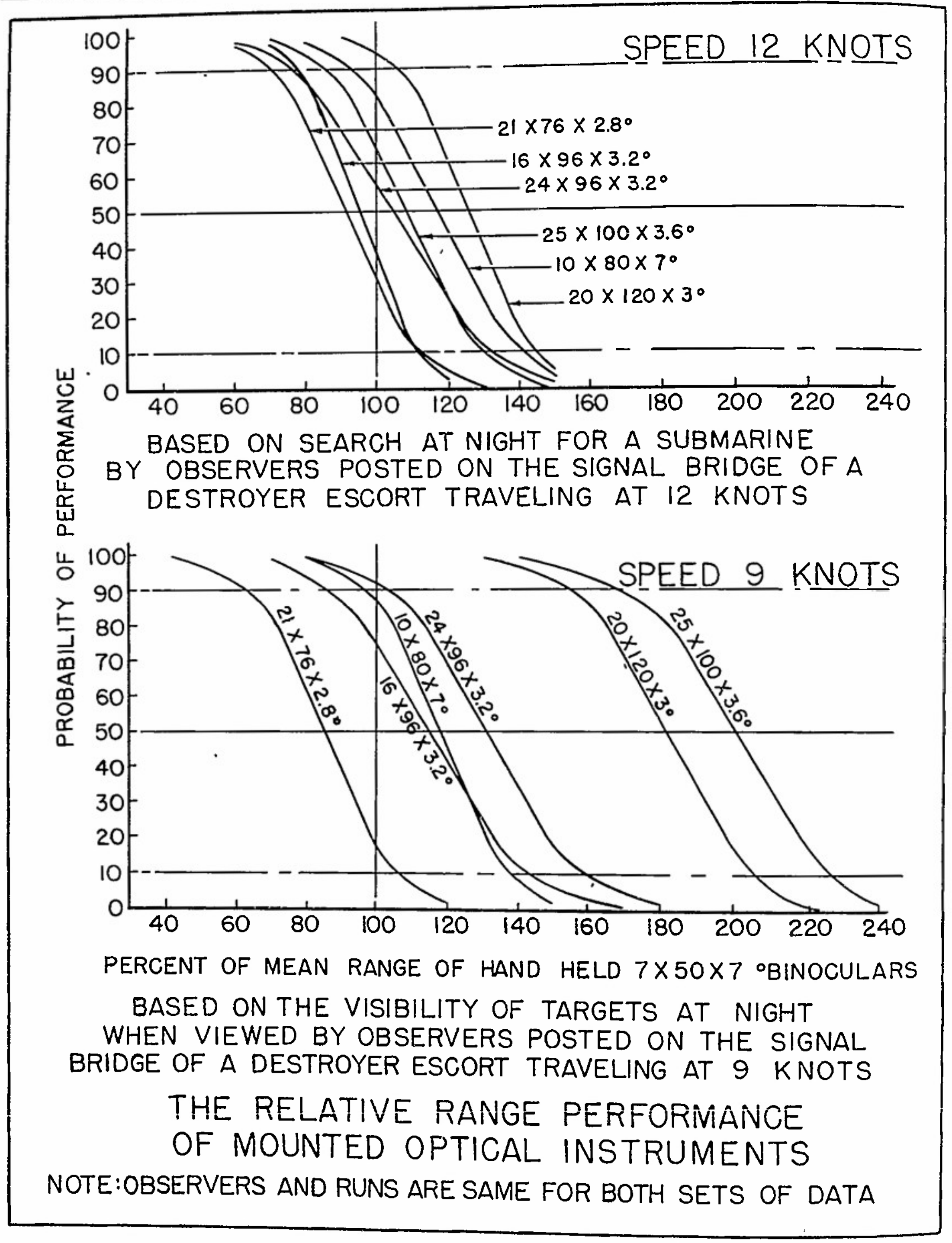
These data show a very [illegible] of the differences among inst[illegible] a possible exception, all tend [illegible] same ranges and previously striking [illegible] ences among instruments shrink. Since higher powered instruments had smaller fields, this may indicate that the usual advantage of a higher powered instrument is lost because of its small field. The one exception, the 10x80x7° had the largest field, which reinforces this suggestion.

However, the instruments still differentiate themselves with respect to power, and their performance on search is, in general, proportional to their performance on the other targets. This is shown in Fig. B-32, in which RRP (search) is presented as a function of RRP. The equation of the rectilinear fit (method of least squares) is

$$.50\ RRP_{search} = .239 \times (.50\ RRP) + 72.9$$

Results: Mean Ranges:

Table B-34 gives the mean ranges obtained with the standard instrument for sightings of the submarine and the subchaser. The mean "100%" range on the submarine, 3085 yards, may be compared with a mean of 86 sure sightings of a fleet-type submarine which was reported by Comdr. D. R. E. Brown to be 2610 yards. The discrepancy is not great, and it is suggested that the criterion of "sure sighting" employed by Comdr. Brown's small group of



BASED ON SEARCH AT NIGHT FOR A SUBMARINE BY OBSERVERS POSTED ON THE SIGNAL BRIDGE OF A DESTROYER ESCORT TRAVELING AT 12 KNOTS

BASED ON THE VISIBILITY OF TARGETS AT NIGHT WHEN VIEWED BY OBSERVERS POSTED ON THE SIGNAL BRIDGE OF A DESTROYER ESCORT TRAVELING AT 9 KNOTS

THE RELATIVE RANGE PERFORMANCE OF MOUNTED OPTICAL INSTRUMENTS

NOTE: OBSERVERS AND RUNS ARE SAME FOR BOTH SETS OF DATA

Figure B-31.

plete as the standard results. The data are limited in their application, too, because the necessities of ship handling controlled the size of the region in which the target vessels first could appear, so that only a small sector some 20° in width needed to be searched. Consequently, it is possible that wide-field instruments did not show to full advantage.

TABLE B-33

.50 RRP RESULTS ON SEARCH PROBLEM AND FOR EXAMINATION OF OTHER TARGETS ON THE SAME RUNS BY THE SAME OBSERVERS

Instrument	Submarine Search	All-Targets-Same Runs and Observers	SC Search	All Targets--Same Runs and Observers
Hand-Held Binoculars				
$7x50x7^{\circ}$	100.0	100.0		
$10x50x7^{\circ}$	93.2	118.3		
Mounted Binoculars				
$7x50x7^{\circ}$ HHR	94.2	111.8		
$7x50x7^{\circ}$	98.0	109.2		
$7x50x7^{\circ}$ VFA	84.8	106.7		
$10x50x7^{\circ}$	96.8	116.0		
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Mounted Monoculars				
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$$RRP_s = .239\ RRP + 72.9$$

Results: .50 RRP:

Table B-33 gives the .50 RRP's for hand-held binoculars, mounted binoculars, and mounted monoculars respectively, for search, and for the standard targets on the same observers and same runs. Figures B-29, B-30 and B-31 give the corresponding RRP curves.

These data show a very great reduction of the differences among instruments. With a possible exception, all tend to yield the same ranges and previously striking differences among instruments shrink. Since the higher powered instruments had smaller fields, this may indicate that the usual advantage of a higher powered instrument is lost because of its small field. The one exception, the 10x80x7° had the largest field, which reinforces this suggestion.

However, the instruments still differentiate themselves with respect to power, and their performance on search is, in general, proportional to their performance on the other targets. This is shown in Fig. B-32, in which RRP (search) is presented as a function of RRP. The equation of the rectilinear fit (method of least squares) is

$$.50\ RRP_{search} = .239 \times (.50\ RRP) + 72.9$$

Results: Mean Ranges:

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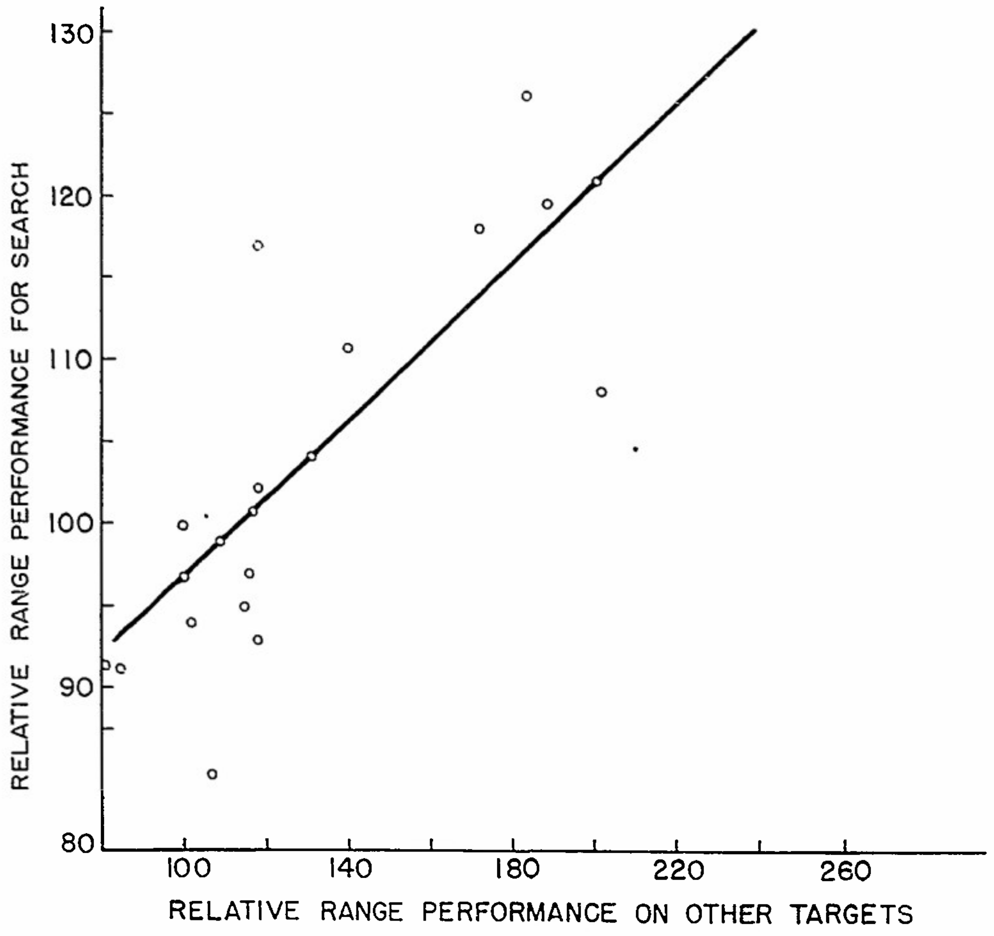

THE RELATIVE RANGE PERFORMANCE OF OPTICAL INSTRUMENTS FOR SEARCH AS PREDICTED BY THE RELATIVE RANGE PERFORMANCE ON OTHER TARGETS

R.R.P. (SEARCH) = .239 R.R.P + 72.9

Figure B-32.

TABLE B-34

MEAN $7x50x7^{\circ}$ HAND-HELD RANGES OBTAINED ON SEARCH

Target	Observer Location	N	Glimpse Mean (yards)	SD	N	100 Mean (yards)	SD	N	PI Mean (yards)	SD
Sub	Signal Bridge	35	3635	1018	32	3085	1021	30	2495	895
	Gun Deck	37	3474	976	35	3212	504	33	2278	732
SC	Signal Bridge	49	3975	1504	52	3401	1548	47	2968	1375
	Gun Deck	43	3990	1639	46	3151	1246	38	2042	977
			G/G			100/G			PI/G	
Sub:	Ratio of Mean Range		1.000			0.875			0.735	
SC:	Ratio of Mean Range		1.000			0.878			0.700	

lookouts may fall intermediate between 100% and P.I.

In general, the ranges at which the SC was sighted are greater than those for the submarine. This reflects the larger area presented by the hull and superstructure of the former, as compared with the small conning tower, and greatly elongated and narrow hull of the latter. Since each run was concluded and the observers were able to go below, as soon as PI had been reported on the search targets, there is some reason to discount the ranges at which Positive Identification was reported. Cold weather, or unpleasant wind may account for the range obtained as well as visual factors. This does not, of course, affect reports of First Glimpse.

Discussion:

It is strongly recommended that more extensive data on search be obtained. Although the present results are reliable on the small group of instruments tested, other instruments with rather different properties--e.g., great differences in the size of the true field--should be compared. Again, it may be desirable to perform a field test in which the plan is rather different, requiring search of a larger sector than is required when approaching a submarine or an SC lying dead in the water.

Analysis of the search data makes it clear that the reduced .50 RRP's found in the search problem are a consequence of the nature of the task, since the mean range at which the submarine and SC are spotted is closely comparable to those at which Target 3, the radar screen, is correspondingly sighted.

THE SUBJECTIVE EVALUATION OF OPTICAL INSTRUMENTS

The procedure of the experiment required each observer, at the termination of each run, to fill in a comment sheet on which the instrument just used was evaluated on a four-point rating scale with respect to several variables. Figure B-4 presented such a filled-in comment sheet.

The purpose of these sheets was to determine the validity of subjective evaluations of optical instruments, as well as to obtain a measure of the acceptability of various instruments.

A second approach to the problem of subjective evaluation was also made. About one week after the termination of the October series of observations, each of the men who had served as observers was given a set of cards on each of which was printed the name of a single instrument. He was then asked to arrange the cards in order of the general excellence of the instruments.

Treatment of Results (Ratings): Analysis of comment sheets was performed only for the night observations. Day comment sheets were collected, but it has not been possible to treat them statistically. Of the various properties with respect to which the instruments were evaluated, several* were dropped from analysis either because they were not understood by the observer or because they were not relevant to night observations. Consequently, discussion is limited to the following factors: "Weight", "Ease of handling", "Steadiness (vibration)", "Ease of locating target", "Fatigue or comfort", "Desirability for constant use (search)", and "Desirability for occasional use (recognition)."

Each instrument, under each condition of use, was given a single score for each factor by use of the following formula:

$$\text{Score} = \frac{100}{N}\ (2E + G - P) + 100$$

where E = Number of ratings as "excellent"

G = Number of ratings as "good"

P = Number of ratings as "poor"

N = Total number of times the instrument was rated.

This formula weights "excellent" ratings, and yields a score which is always positive.

Results (Rating Scores):

Table B-35 gives the score made on subjective evaluations made by the various instruments. As a group, the monoculars are clearly the least acceptable.

Results (Ranking): Only ten of the observers were sufficiently familiar with each of the instruments used to supply complete data. The mean rank accorded each instrument by the ten men was accordingly calculated. These mean ranks are present in Table B-36.

Inter-correlations:

a. With ratings: Since "Desirability for constant use (Search)" was considered the index most likely to be correlated to the general acceptability of an instrument, Pearson "r"'s were calculated between this and each of the scores on other criteria. Rank order rhos were also computed between the scores made by and the mean rank given to the 16 instruments which were ranked. The results are presented in Table B-37.

The high correlations suggest that there is a great "halo" effect, i.e., that each judgment is based largely upon a general subjective evaluation, rather than on a specific basis for each judgment.

b. Validation of the Subjective Evaluations: Fortunately, it is not necessary to limit the analysis to guesswork on the significance of these findings. There is, in the .50 RRP of each instrument, a criterion of actual performance to which may be related the subjective evaluations made. Table B-38 gives the Pearson coefficients of correlation of this objective index of performance with scores on each of the bases on which the instruments

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* These were: "clarity at edge of field", "chromatic aberration", and "uniformity of field brightness".

TABLE B-35

RATING SCORES OF OPTICAL INSTRUMENTS ON EACH OF SEVEN VARIABLES

Instrument	Number of Ratings	Weight	Ease of Handling	Steadiness	Ease of Locating Target	Fatigue or Comfort	Desire. (Search)	Desire. (Recog.)
Hand-Held Binoculars								
6x42x12°	50	180	188	177	171	168	141	147
7x50x7°	400	211	208	175	196	191	194	193
7x50x10°	40	178	170	153	158	135	103	136
7x50x10° (HR)	132	171	160	165	173	147	135	166
8x60x9° (-1d)	55	15	58	139	193	43	63	148
8x60x9° (-2d)	29	4	56	172	203	84	100	165
9x63x5.7°	12	158	167	158	167	83	92	158
10x50x7°	118	200	211	168	192	167	176	205
10x70x7° (J.F.)	11	50	30	109	82	27	18	73
Monoculars								
4x28x10°	26	106	100	117	39	19	15	22
6x30x8.5°	22	78	119	143	38	35	1	168
6x33x8°	47	99	122	124	50	127	31	145
6x33x7° *	25	94	100	108	75	74	56	64
7x50x7° (HH)	42	174	191	157	66	127	53	124
16x96x3.2°	12	83	90	100	75	67	58	83
24x96x2.2°	11	175	138	178	137	91	91	118
21x76x2.8°	25	55	78	86	28	27	15	36
Mounted Binoculars								
6x33x7°	16	157	138	118	69	100	113	87
6x42x7° *	16	133	156	113	59	113	81	94
6x42x12°	12	173	192	150	117	127	142	118
6x50x7°	17	153	133	123	51	88	82	80
7x50x7° (HHR)	32	212	215	161	202	190	197	181
7x50x7°	67	207	202	214	197	185	188	188
7x50x7° (VFA)	27	235	215	254	203	182	186	165
7x50x10°	10	175	170	155	173	267	145	164
9x63x5.7°	12	225	189	125	175	142	125	150
10x50x7°	45	217	186	200	205	191	191	204
10x70x7° (NDRC)	29	174	184	188	229	165	163	220
10x80x7°	27	210	186	178	152	167	141	173
20x120x3°	38	220	172	223	229	179	189	234
25x100x3.6°	25	236	181	208	117	192	200	220

*No RRP was available on these instruments, so they are not included in later correlations.

TABLE B-36

MEAN RANKS OF OPTICAL INSTRUMENTS

Instrument	Mean Rank
20x120x3°	2.3
10x50x7° MTD	3.9
10x70x7° MTD	4.2
7x50x7° HH	5.8
7x50x7° MTD	5.9
10x50x7° HH	6.0
7x50x7° VFA	6.6
7x50x10° HH	6.8
7x50x10° HH (Head Rest)	7.4
6x42x12° HH	7.9
9x63x5.7° HH	7.9
8x60x7° HH	9.8
7x50x7° (MON)	13.0
6x33x8° (MON)	14.2
6x30x8.5° (MON)	14.2
4x28x10°	14.3
Naked Eye	16.4

were rated on the comment sheets, and also, for 16 of them, the rank-difference rho between the mean ranks already reported and the rank of the instruments in performance.

As had been anticipated, "desirability for search" correlates most highly with the criterion, actual field performance, and the suggestion is strong that the high correlations found between this and the other basis of rating are owing to "halo effect," and that relatively complex interrelationships exist among the ratings employed.

It was possible to obtain some measure of these interrelationships by using the technique of partial correlation. Taking the correlations of the criterion (.50 RRP) score and of the desirability for search score with each of the other ratings and the intercorrelations of these with each other, the effect of one upon the other may be partialled out and the correlations between each rating with the RRP score, or with the desirability for search score, without the

TABLE B-37

CORRELATION OF SCORE ON DESIRABILITY FOR CONSTANT USE (SEARCH) WITH SCORES ON OTHER BASES OF RATING AND WITH MEAN RANK

Basis of Rating	Pearson "r" (29 Instruments)	PEr	Level of Significance	ρ with Mean Rank (16 Instruments)
Weight	0.80	0.05	1%	0.81
Ease of Handling	0.86	0.03	1%	0.58
Steadiness (Vibration)	0.78	0.05	1%	0.84
Ease of Locating Target	0.79	0.05	1%	0.89
Fatigue or Comfort	0.87	0.03	1%	0.82
Desirability - Constant Use (Search)	1.00	0.00	-	0.89
Desirability - Occasional Use (Recognition)	0.76	0.05	1%	0.77

TABLE B-38

CORRELATION BETWEEN .50 RELATIVE RANGE PERFORMANCE OF EACH INSTRUMENT AND RATING SCORES

Basis of Rating	r	PEr	Level of Significance (%)
Weight	0.53	0.10	1
Ease of Handling	0.39	0.11	1
Steadiness (Vibration)	0.62	0.08	1
Ease of Locating Target	0.58	0.09	1
Fatigue or Comfort	0.52	0.10	1
Desirability - Constant use (Search)	0.70	0.07	1
Desirability - Occasional use (Recognition)	0.62	0.08	1

Rank difference rho between mean subjective ranking and rank in .50 RRP = .86

TABLE B-39

PARTIAL CORRELATION OF RATING SCORES ON EACH BASIS WITH .50 RRP, AND WITH DESIRABILITY FOR CONSTANT USE (SEARCH), THE EFFECT OF THE OTHER BEING PARTIALED OUT.

Basis of Rating	Correlation with RRP	PEr	Correlation with RRP "Suitability for Constant Use (Search)" Held Constant r	Correlation with "Suitability for Constant Use(Search)" Score r	PEr	Correlation with "Suitability for Constant Use(Search)" Score; RRP Held Constant r	Correlation Between RRP and "Suitability for Constant Use (Search)" With Each Held Constant r
Weight	0.53	± 0.10	-0.05	0.79	± 0.05	0.69	0.54
Ease of Handling	0.39	± 0.11	-0.18	0.69	± 0.07	0.63	0.65
Steadiness (Vibration)	0.62	± 0.08	0.18	0.77	± 0.05	0.60	0.44
Ease of Locating Target	0.58	± 0.09	0.06	0 79	± 0.05	0.66	0.48
"Fatigue" or "Comfort"	0.52	± 0.10	-0.23	0.86	± 0.03	0.81	0.58
Desirability - Constant Use (Search)	0.70	± 0.07		1.00		1.00	
Desirability - Occasional Use (Recognition)	0.62	± 0.08	0.18	0.77	± 0.05	0.60	0.44

contaminating effect of the other, may be derived. The results of this analysis are presented in Table B-39.

In these results, "desirability for constant use - (search)" correlates most highly with actual performance and, if only one such mode of rating is all that can be used as an index of an instrument's utility, it gives results which are not misleading. Some factor other than the visual efficiency of the binocular appears to enter into this rating, a factor closely related to "ease of handling" and "fatigue or comfort."

"Desirability for constant use - (search)", then, seems to yield an over-all estimate of the subjective satisfactoriness of an instrument, but it leads to a misevaluation of the instrument on the other bases by the "halo effect." Thus a spuriously high correlation is reached between each of the others and the .50 RRP score. Judgments of "steadiness" and "suitability for occasional use - (recognition)" are also slightly positively related to performances.

It was not possible to extend analysis of these data further, and to determine the nature of the bases other than efficiency, as measured by .50 RRP, on which a binocular is evaluated. It is strongly suggested by the data that the most important basis on which this is done is "comfort" in handling, and that this factor must be taken into account in evaluating the general utility and acceptability of an instrument.

Rating by Civilians:

It was originally planned to employ a large number of civilian and technical observers, as well as enlisted men, since, it was anticipated, these men might, by superior qualifications, give better results as observers, and might better be able to judge the instruments objectively.

A comparison of the scores given five instruments by the civilian group and by a comparable group of enlisted men who used them at the same time, and for approximately the same number of runs is presented in Table B-40.

TABLE B-40

COMPARISON OF RATING SCORES GIVEN FIVE INSTRUMENTS BY THE CIVILIAN GROUP AND BY A GROUP OF ENLISTED MEN HAVING THE SAME EXPERIENCE WITH THE INSTRUMENTS

Instrument	Weight		Ease of Handling		Steadiness and Vibration		Ease of Locating Target		Fatigue or Comfort		Desirability (Search)		Desirability (Recognition)	
	E	C	E	C	E	C	E	C	E	C	E	C	E	C
7x50x10° HH	134	150	133	167	176	223	200	216	128	170	124	200	168	109
10x50x7° HH	165	207	170	207	165	113	180	153	130	154	125	164	210	207
7x50x7° HH (MON)	201	207	203	179	169	172	68	93	105	173	35	34	90	50
8x60x9° HH (-1d.)	0	6	32	54	111	93	179	200	21	64	26	38	94	243
7x50x7° HH	202	213	202	223	174	188	195	150	169	213	155	194	201	181
Mean	140	157	148	166	159	158	164	162	111	155	93	126	153	158

It appears that the enlisted men judge the instruments more rigorously than the civilian group. There is good agreement between the two groups in relative ratings.

Discussion:

These results show that observers who have necessarily familiarized themselves with a number of instruments by using them to a considerable extent are able, as a group, to evaluate them satisfactorily in terms of their actual utility in the field.

The large "halo effect" found indicates that the more closely related to the specific job for which the instrument is to be used are the terms in which it is evaluated, the better, i.e., the more valid, the evaluation.

These evaluations were all made on the basis of comparison of the instrument with the verbal standards which the observers have set up; they do not require immediate and direct comparisons between two instruments.

Warning: These results should not lead anyone into the belief that persons familiar with the use of optical instruments are able to make off-hand judgments as to the probable performance of a binocular or monocular unfamiliar to him. It must be emphasized that all the raters and rankers from whom data were obtained had had thorough experience with an instrument, on a fixed and familiar set of targets, before they evaluated it; no off-hand judgments were obtained. Such judgments, if made on non-comparable targets, may be seriously misleading. As an instance of this, several submarine commanding officers and OD's stated, on the basis of a few weeks casual use, that the inferior 6x42x12° binocular was a better instrument than the 7x50x7°. It must be assumed that such misevaluations are derived from the "comfort" or "convenience" factor.

CONCLUSIONS

On the basis of the results which have been reported, certain conclusions may be drawn which apply to the problems of optical design:

(1) An instrument which is selected for its superiority at night will perform satisfactorily by day. It is neither necessary nor advisable to provide separate instruments for use under each condition. Although certain instruments perform relatively better by day than by night (e.g. lower-power instruments and instruments with small exit pupils), no inversions have been found.

(2) A binocular instrument is to be preferred to a monocular. Although the advantage is slight by day, it is sufficiently great by night to warrant the increased cost, weight, and complexity of design. The advantage stems not only from increased ranges, but

from the relatively greater comfort, acceptability, and ease of use noted in subjective evaluations.

(3) A mounted instrument is to be preferred in all instances to a hand-held instrument, and mounts or rests should be provided for all optical instruments. It is, for example, suggested that provision be made on the navigation bridge of vessels for convenient mounts or rests on which OD's may place their glasses when using them. Similarly, all lookouts should be provided with mounts or rests. It must be emphasized that those in use at present are not entirely satisfactory. The superior performance obtained with the Eastman Kodak Anti-Vibration Mount which is not, in its present form, entirely satisfactory, indicates that research directed at the design of a simple and efficient vibration-reducing mount would lead to greatly improved performance, especially for high-powered instruments.

(4) Fixed focuses are acceptable. Although any focus arbitrarily selected will handicap the performance of some observers, if taken at the average of the population, it should simplify the observer's problem, and consequently enhance group performance.

(5) Head rests are acceptable, if properly designed. They will lead to little or no changes in performance.

(6) A hand-held binocular must be light, easy to handle, and of the highest power and largest field feasible. The 10x50x7° binocular fits these specifications in a manner entirely satisfactory. It is urged that it replace the 7x50x7° as the standard instrument-- a recommendation well founded in the substantially superior performance shown by it under most circumstances.

(7) Instruments which are designed to be used only as mounted instruments should be of the highest power possible consistent with a large exit pupil and large field. On the basis of the data, which did not reach diminishing returns in magnification, the ideal instrument would seem to be a 20x120x4.5° binocular, if such can be produced. A still higher power might have been recommended had there been the opportunity to test higher magnifications, for example, the Japanese 30x180x2.2° instrument. It is believed, however, that the field size sets a practical limitation on the magnification that can be utilized.

(8) Any instrument used exclusively for search should have a field at least 7° in width. Larger fields might have an advantage in search for aircraft. On this point, we have no data, although it was desired to obtain them.

(9) In most instances where the field tests cover problems also studied in the laboratory, the laboratory results have been verified. It should be noted that, in the field differences between instruments are generally not so great as those found in the laboratory. Those instances where field results fail to verify laboratory results, e.g., in the case of the effect of vibration on instruments of high magnification, show that laboratory results must always be tested in the field.

RESULTS, PART III. SECONDARY ANALYSES

General:

The field experiments which have been reported upon were designed to yield statistically sound results on the differences in performance of binoculars and telescopes; these results have been reported upon in Part II. However, the experiment provided the opportunity to obtain data on many other problems as well, and the results on such subordinate problems are presented in Part III.

Such incidental analyses provide the opportunity to obtain new data of interest on such problems as the selection and variability of lookouts, the effects of training, and on the effects of wind and similar variables upon performance. Laboratory data on such problems as the visibility of targets, meteorological visibility, etc., can be re-evaluated.

In general, the secondary problems fall into two classes:

(a) Those relating to visibility and allied problems.

(b) Those relating to individual differences among subjects.

Data are available in both classifications but in no case are they as complete or have they been as completely analyzed as one would wish. Time and personnel have not been available to carry the treatment as far as it could have been; statistical treatment of the data obtained on them has awaited completion of the basic calculations.

Difficulties: There are many inherent, and some extraneous, difficulties in making such analyses. The experiment was designed for one purpose: to evaluate optical instruments. As a consequence, the data treated in subordinate analyses are, in some cases, scanty and incomplete with respect to many variables. For some purposes, they are not amenable to analysis directly, but require considerable preliminary work. Many analyses have had to be performed concurrently, with the not infrequent outcome that the results of one analysis show that another has been inadequate, and must be reperformed. Several analyses have proven abortive for this reason and have been discarded; others are by no means complete.

The extraneous difficulties have arisen from the shortness of time, and the scarcity of skilled and permanently assigned personnel. The work performed has required time-consuming copying, recopying, checking and rechecking, and it has been interrupted several times for retraining of statistical personnel.

Therefore, the results of the secondary analyses must be considered, in large part, preliminary and only suggestive of what a final analysis of these same data would yield.

Methods: In view of the many difficulties, certain policies were established with respect to treatment of the data in order to get maximum results in the shortest time.

1. In almost all subordinate results, analysis is restricted to the data on only one discrimination: the report of 100% frequency of Seeing, on Target 3 (the radar screen) for the night observations, and the report of 100% frequency of Seeing on Target 8 (the flagpole) for the day observations. The selection of these discriminations was predicated on the supposition that they were representative of data on all targets. This supposition is justified by the results presented under Criteria of Seeing. Treatment is further restricted to the data obtained with the standard 7x50x7° binocular. These restrictions reduce the amount of work to a small fraction of that which is actually necessary, but at the expense of statistical reliability and completeness, in many cases. A thorough analysis, utilizing data on all targets and all instruments, was out of the question because of shortage of time and personnel.

2. Both absolute and log range values were used in subordinate analyses, with the greater stress being placed on the logarithmic values. Treatment of logarithmic values was preferred not only since they better represent the data obtained under all conditions of visibility, but also since they are more easily handled mathematically and provide for simple methods of applying corrections. The choice of using logarithmic or arithmetic values has, in some cases, been based on convenience, or on the sequence in which the work was performed.

3. The statistical treatment, however, is limited not only with respect to the number of items accorded a uniform treatment, but also in the variety of treatments which have been applied. In planning the statistical work, the procedures best suited to the particular set of data under consideration were followed, often to the exclusion of performing uniform operations on several somewhat dissimilar sets. The course yielding the most meaningful results most rapidly was selected.

4. Where it has been deemed necessary, corrections have been applied to the data. Thus, in order to make possible, for certain purposes, combinations of data obtained on the gun deck at night with data obtained on the signal bridge, a constant log value derived from the data has been added to all log ranges obtained on the gun deck. Similar corrections have been, for some analyses, applied for visibility. Such corrections have been indicated wherever they have been applied.

Because of the limited scope of the present analyses, there remains a body of data well suited to provide definitive answers to many problems of visibility and the use of optical equipment. It is not impossible that, at some future data, further analysis of them will be made; the results of the analyses herein presented, which are essentially a series of first approximations, indicate that such further work is desirable.

VISIBILITY AND RANGE

The most important secondary analysis which can be made of the data obtained in this experiment relates to the visibility of fixed targets. A substantial body of data has existed for some time from which theoretical average ranges at which targets may be detected may be computed. Only recently, an ambitious experimental program was completed which was designed to establish the relationships existing between visibility and target size, target contrast, and background brightness, which are without question the most important of the variables determining the range at which a target may be detected. On the basis of this program, which was performed at the Tiffany Foundation by NDRC Section 16.3, a set of nomographs has been published which purports to predict the range at which targets of given characteristics may be detected under various conditions of visibility and sky brightness. These nomographs have not yet been tested under service conditions with respect to their validity.

The data which have been obtained in the present experiment are well-suited to the validation of such nomographs. Targets varying in contrast and size have been sighted under wide variations in visibility, and the ranges recorded. Data on the relevant variables entering into the laboratory results are either directly available or may be easily computed. A target-by-target, night-by-night, and day-by-day analysis should lead to the production of results which should unequivocally verify or fail to verify many of the predictions based upon laboratory data.

In this report, data on a single discrimination under night observation conditions, and on three discriminations under day conditions, are treated. The discrimination selected for analysis of night observations was 3-100, for this was representative, and the data on it were most complete. Distriminations 7-G, 8-100, and D-PI were those selected for day treatment. All results considered in the present treatment were obtained with the 7x50x7° binocular.

Night Results:

Target and Course Differences: Target 3 is the radar screen, a wire screening, painted orange, and affixed to a complex wooden frame constructed of 2x4's of over-all dimensions 16' x 16'. This target acted as a filter as well as a reflecting surface in that it not only reduced the brightness of the sky seen through it but also acted as a reflecting surface, so that it was necessary to measure its "transmission-reflectance" rather than its reflectance alone. Course 210 T was normal to the face of this target, so that a square was presented to the observers, and a minimum of its structural framework could be seen. Its "transmission-reflectance," measured with a Macbeth Illuminometer on a bright overcast day, was .595. Since it was painted orange this value should be somewhat lower at night, owing to the Purkinje shift. It was not possible to obtain any measurements at night.

From course 065 T, the approach is not normal to the plane of the 16' x 16' square, and a rectangle of the proportion 16 x 13 is presented to the observer. At the same time, the structure of the target--its cross-braces and angular planes--is revealed, so that the "transmission-reflectance" of the target is decreased, and its contrast enhanced. The net effect of these two shifts, which act to counterbalance each other, may be close to zero, so that the ranges obtained from one course may be expected to average close to those obtained on the other.

Fundamentally, there was little difference between courses 055 T and 065 T; the shift between the two was made because of the appearance of a distracting light on the former course. There did exist, however, one previously mentioned difference between these two courses and course 210 T. In the former courses, the fort always appeared against a clear sky-sea horizon. On the latter, it appeared against a land background, 5.5 sea miles beyond the fort. Owing to the nature of Target 3-100, this did not affect contrast measurements, and calculations show it should have no effect on ranges obtained.

Table B-41 gives the mean 7x50x7° ranges for 3-100 for all three courses, 210 T, 055 T and 065 T. The difference on observations from the signal bridge between the two courses is close to .01 log units, and, for the present, results from both courses will be treated together.

The difference found between the two courses on the gun deck data is somewhat greater, and it is not yet accounted for, but must be reserved for treatment at a later date.*

TABLE B-41

MEAN LOG RANGES, BY COURSE, NIGHT OBSERVATIONS

September Observations	N	Mean	S. D.
Course 210T	22	3.410	0.10
Course 055T	17	3.420	0.22

Oct., Nov., Dec. Observations		Signal Bridge		Gun Deck	
	N	Mean	S.D.	Mean	S.D.
Course 210T	62	3.446	0.19	3.31	0.14
Course 065T	60	3.459	0.19	3.40	0.16

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* In nearly all secondary analyses, the data obtained at night on the gun deck are not accorded the full treatment given the signal bridge data, nor is a rigorous attempt made to account for the occasionally anomolous results obtained there. The reasons for thus weighting the results for the signal bridge are four:

(1) The most experienced observers were almost always assigned to the signal bridge sections, and new observers to the gun deck, since the most important comparisons among instruments were carried out at the former level.

(2) It is probable that the evident secondary importance of the gun deck comparisons reflected itself in lower motivation of observers there.

(3) The 6-men sections on the signal bridge seldom, if ever, repeated observations with the 7x50x7° binocular on any one night of observations. On the other hand, men of the 3-men sections of the gun deck frequently did so. Consequently, the signal bridge data constitute a better sample of the performance of a large population.

(4) It has not yet been possible to analyze for the effect, if any, of the lower height of eye.

Mean and Median Ranges, 7x50x7° HH Binocular Night Data: Target 3-100:

(1) Total number of observations:

(a) Of the total of 179 runs, 12 were made at 17 knots, rather than at the standard 9, and consequently are not included in the analysis.

(b) On 116 runs, observations were made simultaneously from the signal bridge and the gun deck.

On 102 of these, sightings were made from both levels.

On 4, sightings were made from the signal bridge but not the gun deck.

On 7, sightings were made from the gun deck but not the signal bridge.

On 3, no one sighted the target.

(c) On 46 runs, observations were made from the signal bridge only. Sighting was made on all of these.

(d) On 5 runs, observations were made from the gun deck only. Sighting was made on all of these.

(2) Statistical Treatment

The data obtained on the signal bridge and gun deck are treated separately since the results show a highly significant difference between them.

Both the absolute ranges and log ranges have been investigated, and means, standard deviations, medians, quartile deviations, and Pearson product moment "r"'s between gun deck and signal bridge ranges have been computed. These have been calculated and are presented not only for the population on which sightings are complete, but also on the incomplete sightings, when the minimum range to which the observation vessel approached the targets is used as a fill-in value. This last is a necessary procedure since failure to take such incomplete runs into account discards some of the most significant data--that obtained under the poorest visibility conditions. The minimum range gives an estimate of the missing values, which are necessarily too great, but are adequate for present purposes.

(3) Results:

The results of a run-by-run analysis are presented in Tables B-42 and B-43.

(1) The distributions are logarithmic. This is reflected not only in the close agreement between the medians and means of the logarithmic distribution but also in the coefficients of correlation obtained between the logarithmic values of simultaneously obtained ranges, which are higher than those between absolute ranges.

(2) The variability of performance is great.

(3) There is a substantial difference between the ranges obtained from the signal bridge, and those obtained from the gun deck. Ranges from the gun deck are only 75-80% as great as those obtained under the same conditions from the higher position.

(4) The correlation between ranges obtained on the signal bridge and gun deck offers one measure of the contribution of visibility and other lesser run-variables to the performance, as opposed to the contribution made by individual differences and chance, or other variability. Accepting .595 as the best estimate of this correlation, a coefficient of alienation of .804 and a "percentage of casual factors measured" of 35.4% are obtained. Many factors other than visibility evidently play a part in

to the Purkinje shift. It was not possible to obtain any measurements at night.

From course 065 T, the approach is not normal to the plane of the 16' x 16' square, and a rectangle of the proportion 16 x 13 is presented to the observer. At the same time, the structure of the target--its cross-braces and angular planes--is revealed, so that the "transmission-reflectance" of the target is decreased, and its contrast enhanced. The net effect of these two shifts, which act to counterbalance each other, may be close to zero, so that the ranges obtained from one course may be expected to average close to those obtained on the other.

Fundamentally, there was little difference between courses 055 T and 065 T; the shift between the two was made because of the appearance of a distracting light on the former course. There did exist, however, one previously mentioned difference between these two courses and course 210 T. In the former courses, the fort always appeared against a clear sky-sea horizon. On the latter, it appeared against a land background, 5.5 sea miles beyond the fort. Owing to the nature of Target 3-100, this did not affect contrast measurements, and calculations show it should have no effect on ranges obtained.

Table B-41 gives the mean 7x50x7° ranges for 3-100 for all three courses, 210 T, 055 T and 065 T. The difference on observations from the signal bridge between the two courses is close to .01 log units, and, for the present, results from both courses will be treated together.

The difference found between the two courses on the gun deck data is somewhat greater, and it is not yet accounted for, but must be reserved for treatment at a later date.*

TABLE B-41

MEAN LOG RANGES, BY COURSE, NIGHT OBSERVATIONS

September Observations	N	Mean	S. D.		
Course 210T	22	3.410	0.10		
Course 055T	17	3.420	0.22		
Oct., Nov., Dec. Observations		Signal Bridge		Gun Deck	
	N	Mean	S.D.	Mean	S.D.
Course 210T	62	3.446	0.19	3.31	0.14
Course 065T	60	3.459	0.19	3.40	0.16

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* In nearly all secondary analyses, the data obtained at night on the gun deck are not accorded the full treatment given the signal bridge data, nor is a rigorous attempt made to account for the occasionally anomolous results obtained there. The reasons for thus weighting the results for the signal bridge are four:

(1) The most experienced observers were almost always assigned to the signal bridge sections, and new observers to the gun deck, since the most important comparisons among instruments were carried out at the former level.

(2) It is probable that the evident secondary importance of the gun deck comparisons reflected itself in lower motivation of observers there.

(3) The 6-men sections on the signal bridge seldom, if ever, repeated observations with the 7x50x7° binocular on any one night of observations. On the other hand, men of the 3-men sections of the gun deck frequently did so. Consequently, the signal bridge data constitute a better sample of the performance of a large population.

(4) It has not yet been possible to analyze for the effect, if any, of the lower height of eye.

Mean and Median Ranges, 7x50x7° HH Binocular

Night Data: Target 3-100:

(1) Total number of observations:

(a) Of the total of 179 runs, 12 were made at 17 knots, rather than at the standard 9, and consequently are not included in the analysis.

(b) On 116 runs, observations were made simultaneously from the signal bridge and the gun deck.

On 102 of these, sightings were made from both levels.

On 4, sightings were made from the signal bridge but not the gun deck.

On 7, sightings were made from the gun deck but not the signal bridge.

On 3, no one sighted the target.

(c) On 46 runs, observations were made from the signal bridge only. Sighting was made on all of these.

(d) On 5 runs, observations were made from the gun deck only. Sighting was made on all of these.

(2) Statistical Treatment

The data obtained on the signal bridge and gun deck are treated separately since the results show a highly significant difference between them.

Both the absolute ranges and log ranges have been investigated, and means, standard deviations, medians, quartile deviations, and Pearson product moment "r"'s between gun deck and signal bridge ranges have been computed. These have been calculated and are presented not only for the population on which sightings are complete, but also on the incomplete sightings, when the minimum range to which the observation vessel approached the targets is used as a fill-in value. This last is a necessary procedure since failure to take such incomplete runs into account discards some of the most significant data--that obtained under the poorest visibility conditions. The minimum range gives an estimate of the missing values, which are necessarily too great, but are adequate for present purposes.

(3) Results:

The results of a run-by-run analysis are presented in Tables B-42 and B-43.

(1) The distributions are logarithmic. This is reflected not only in the close agreement between the medians and means of the logarithmic distribution but also in the coefficients of correlation obtained between the logarithmic values of simultaneously obtained ranges, which are higher than those between absolute ranges.

(2) The variability of performance is great.

(3) There is a substantial difference between the ranges obtained from the signal bridge, and those obtained from the gun deck. Ranges from the gun deck are only 75-80% as great as those obtained under the same conditions from the higher position.

(4) The correlation between ranges obtained on the signal bridge and gun deck offers one measure of the contribution of visibility and other lesser run-variables to the performance, as opposed to the contribution made by individual differences and chance, or other variability. Accepting .595 as the best estimate of this correlation, a coefficient of alienation of .804 and a "percentage of casual factors measured" of 35.4% are obtained. Many factors other than visibility evidently play a part in

TABLE B-42

SIMULTANEOUS SIGHTINGS: SIGNAL BRIDGE AND GUN DECK--AVERAGE RANGES IN YARDS

A. Complete (N = 102)

	Signal Bridge		Gun Deck		
	Mean (Yds.)	SD (Yds.)	Mean (Yds.)	SD (Yds.)	
Absolute	3310	1340	2510	923	Absolute range: $r_{SB-GD} = 0.446$
Log	3.49	0.18	3.37	0.15	
	Mdn.	Q*	Mdn.	Q*	
Absolute	3200	1050	2330	600	Log Range: $r_{SB-GD} = 0.501$
Log	3.51	0.15	3.37	0.11	

B. Including interpolated data (N = 116)

	Signal Bridge		Gun Deck		
	Mean (Yds.)	SD (Yds.)	Mean (Yds.)	SD (Yds.)	
Absolute	3110	1390	2400	930	Absolute range: $r_{SB-GD} = 0.520$
Log	3.45	0.19	3.35	0.16	
	Mdn.	Q*	Mdn.	Q*	
Absolute	2730	1050	2200	615	Log Range: $r_{SB-GD} = 0.595$
Log	3.44	0.16	3.34	0.12	

* Q = Quartile deviation

the performance.

General Results: Day Data:

Three discriminations have been selected for analysis. They are: #[illegible] (-x- black'B: #[illegible] (flagpole).[illegible]: and [illegible](4 [illegible] target against fort).[illegible]

On the total of 12 runs, data are complete on 48 sightings 12 from each of the four day observation posts (port side signal bridge, starboard side signal bridge, [illegible]). In these data only log ranges are treated, and the mean log ranges are computed for each target observed from each observation post, and on each target for all four posts taken together. The ϵ^2 technique has been employed to test the significance of differences between observations made at the four stations. The results are presented in Table B-1c.

Comment: 1. The variability is comparable to that of the night data. It appears that

TABLE B-43

ALL SIGHTINGS--SIGNAL BRIDGE AND GUN DECK

A. Signal Bridge Sightings

			Mean	SD	Median	Q
(a)	Complete (N = 152)	Absolute	3120	1270	2770	900
		Log	3.46	0.18	3.45	0.14
(b)	Including Interpolations (N = 162)	Absolute	3020	1290	2770	900
		Log	3.44	0.19	3.45	0.14

B Gun Deck Sightings

			Mean	SD	Median	Q
(a)	Complete (N = 114)	Absolute	2450	920	2200	640
		Log	3.36	0.16	3.34	0.12
(b)	Including Interpolations (N = 121)	Absolute	2390	930	2200	640
		Log	3.35	0.16	3.34	0.12

0.16 log units is a uniform value for the variability of observation under the variety of visibility conditions encountered in both day and night runs. Thus, two-thirds of the observations fall between approximately 69% and 145% of the mean.

2. No reliable differences exist among observations made at the various observation posts In this respect, the data obtained by day differ from those obtained at night.

3. With data on only 12 runs, it is not possible to evaluate the contribution of visibility by means of correlating simultaneous observations.

Visibility Analysis:

Weather contributes to the data obtained and to its variability in four different ways: by meteorological visibility, wind, sky brightness, and by sea condition (including cloud coverage). An extensive analysis of the data with respect to the first was possible, and a less extensive analysis with respect to the second. Sky brightness measurements have received a minimum of treatment and no attempt has yet been made to check data on cloud coverage. On sea condition as a variable, no treatment was undertaken, since the sea was almost never sufficiently rough to produce appreciable roll and pitch.

Meteorological visibility is important in still another way than that which has already been discussed: on the night of 5 October 1945, visibility was unlimited, and a number of lights not previously seen were evident. As a consequence, some of the personnel associated with the project raised the question of whether these lights invalidated our results. A panel of OSRD and staff personnel, familiar with the experiment in all its phases, considered these lights not a serious problem, but emphasized the importance of checking the results according to visibility, since anomolous results on nights of good visibility might be attributed to such lights. Analysis of the sets run on these nights showed no anomolous results with respect to the performance of the binoculars.

In the original outline of the experiment provision was made for accurate and objective measurement of meteorological visibility. However, the plans were dropped following the advice of Dr. F. O. Hulbert, of the Naval Research Laboratory. In his experience, such measurements, especially when made at night, do not yield results sufficiently reliable to warrant the great expenditure of time and effort required to make them.

Original Analysis, Night Observations: Accordingly, it was decided to employ the usual quartermaster's ratings of visibility, and one member of the bridge crew was assigned to record, three times during a night's runs, and on any apparent change in visibility, the range and identity of the most distant light visible. These results, it was anticipated, could be checked against and correlated with quartermasters' entries in the ship's log.

Results of Original Analysis: Much time and effort were expended in an attempt to obtain useful data from these records of visibility. The reliability of observations was extremely low, and the disagreements between the two estimates were discouraging. After careful cross-check, the runs were classified, on the basis of the quartermaster's reports, into three classes: 0-5, 6-9, and 10-plus miles visibility. Table B-44 gives the mean log ranges of 3-100 for these three classes.

TABLE B-44

MEAN LOG RANGES FOR THREE CLASSES OF VISIBILITY AS DETERMINED BY THE QUARTERMASTER'S RECORDS

Visibility Class	Mean	S. D.
0-5 miles	3.48	0.17
6-9 miles	3.42	0.18
10 miles or more	3.49	0.18

This analysis indicates that the quartermaster's efforts were misleading, and entirely inadequate to provide a basis for analysis.

A second analysis was made on the basis of the starting range of each run. The ship's officers had been instructed to start at greater ranges on clear nights than on average and hazy ones. In general, this instruction was carried out. However, analysis based on these was fruitless for the reason that two other important variables, the skill and mood of the OD, and the power* of the instruments being tested, also determined them.

A third abortive analysis was based upon mean absolute ranges from the various sets,

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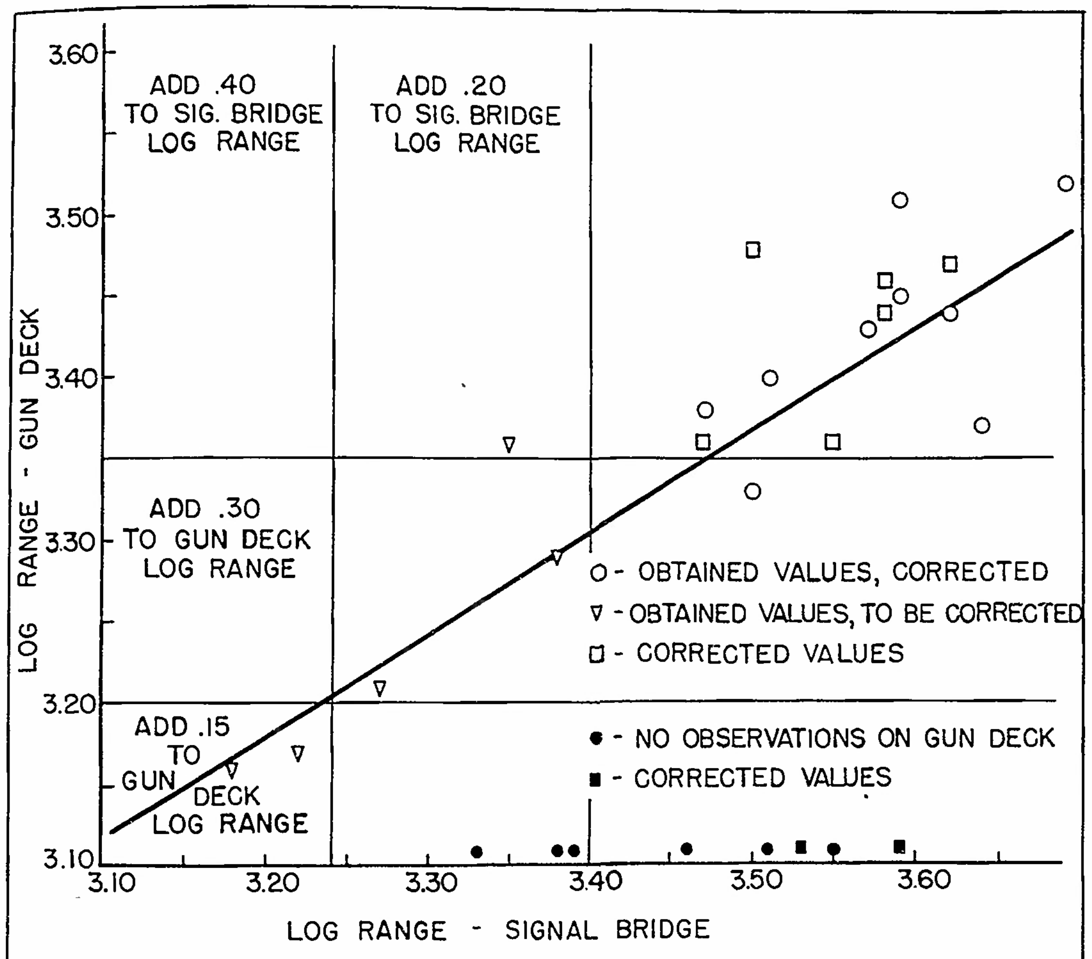
* Greater starting ranges were chosen when high-power equipment was under test.



SCATTER PLOT OF MEDIAN 7X50X7 °H.H. LOG RANGES FOR EACH OPERATING NIGHT

WITH CORRECTION FACTORS INDICATED

Figure B-33.

but this, too, yielded uninterpretable results, since the various runs of a single set were often made under widely varying visibility.

Final Analysis: The mode of analysis for visibility which proved most satisfactory derives from the data themselves, and is based upon inference from the high correlation between log ranges obtained on the signal bridge and gun deck. The 7x50x7° HH night data on discrimination 3-100 are employed.

Method: Since the visibility, on any one night, remained relatively constant, except over the last one or two runs on a very few nights, analysis is made in terms of date.

TABLE B-45

AVERAGE LOG RANGE (YARDS) OF TARGET 3-100, BY DATE AND OBSERVATION LEVEL

Date		SIGNAL BRIDGE		GUN DECK	
		Mean	Median	Mean	Median
September	4	3.52	3.51		
	5	3.35	3.46		
	6	3.36	3.33		
	7	3.37	3.38		
	12	3.53	3.55		
	13	3.37	3.39		
October	4	3.64	3.65	3.35	3.39
	5	3.41	3.35	3.35	3.36
	7	3.50	3.50	3.34	3.33
	8	3.29	3.27	3.21	3.21
	9	3.57	3.62	3.51	3.44
	10	3.56	3.59	3.46	3.51
	11	3.53	3.57	3.41	3.43
November	1	3.58	3.59	3.46	3.45
	2	3.24	3.22	3.19	3.17
	5	3.52	3.51	3.42	3.40
	8	3.35	3.38	3.31	3.29
	9	3.50	3.47	3.38	3.38
	26	3.62	3.64	3.38	3.37
	27	3.68	3.69	3.50	3.52
December	8	3.27	3.27	3.26	3.21
	9	3.22	3.18	3.21	3.16

$\epsilon^2 = 0.455$ $\epsilon^2 = 0.356$

$p < 0.01$ $p < 0.01$

TABLE B-46

ϵ^2 ANALYSIS OF 7x50x7° LOG RANGES, BY COURSE AND DATE (NIGHT OBSERVATIONS ONLY)

Observation Position	Course	ϵ^2	p
Signal Bridge	210T	0.561	Less than 0.01
Signal Bridge	065T	0.481	0.01
Signal Bridge	Both	0.455	0.01
Gun Deck	210T	0.443	0.01
Gun Deck	065T	0.527	0.01
Gun Deck	Both	0.356	0.01

The values of ϵ^2 indicate that significant differences appear in performance from night to night. Note that lumping data from the two courses together depresses the values of ϵ^2, indicating the effect of an additional source of variability.

For each night, the median and mean range for the standard discrimination was determined for both the signal bridge and gun deck. A scatter plot of median signal bridge range vs. gun deck range for each night was then made.

Results: The median and mean* values for both signal bridge and gun deck are given in Table B-45, and the two scatters are presented in Figs. B-33 and B-34. Values of ϵ^2 (Table B-46) were computed from the mean values and found highly significant. Straight lines, described by equations

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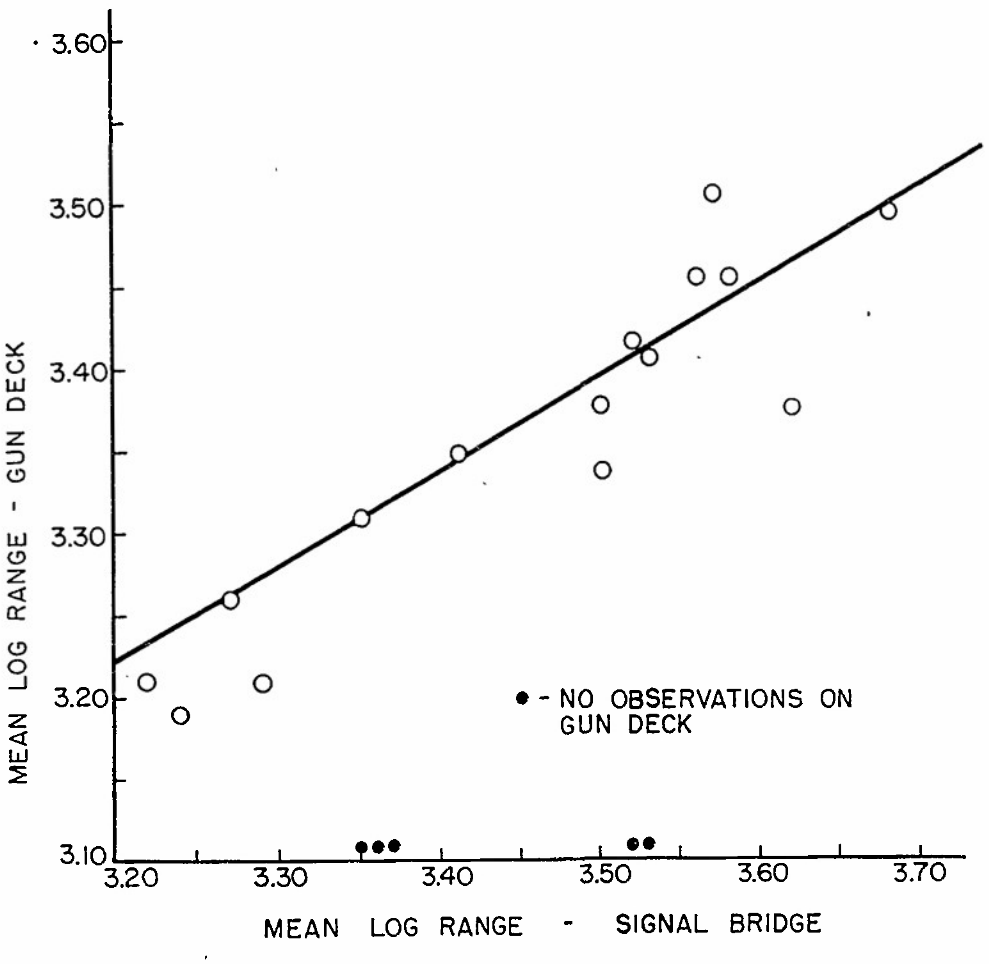
* The means include the hypothetical values based upon end-of-run ranges where observers failed to seethe target at all. This is necessary here, since failure to include such approximate values would eliminate all data obtained under very poor visibility.



SCATTER PLOT OF MEAN 7X50X7 ° H.H. LOG RANGES FOR EACH OPERATING NIGHT

Figure B-34.

(a) and (b), were fitted to the scatter plots by the method of least squares.

(a) (means) $\log R_{GD} = .60 \log R_{SB} + 1.30$

(b) (medians) $\log R_{GD} = .62 \log R_{SB} + 1.20$

In these equations R_{GD} and R_{SB} are ranges from gun deck and signal bridge, respectively.

In interpreting these data, it must be emphasized that meteorological visibility is only one of the factors establishing the values obtained. Individual differences in observers also play a part, since only a few observers are included in any one night, and successive dates have no observers in common. This is evidenced by the fact that the night of October 5, when visibility was decidedly unlimited, falls into a middle category. However, there was no alternative to employing this analysis until the data can be more extensively treated.

From Fig. B-33, it is evident that median ranges vary considerably from night to night, from a minimum of 3.08 to 3.68, on the signal bridge, and from 3.12 to 3.52 on the gun deck. The .60 l.u. range found on the signal bridge represents a spread of 4:1 in the median range for the same target.

Correction Factors: For many analyses it was necessary to attempt to eliminate the effect of visibility changes on the absolute ranges obtained with the 7x50x7° HH binocular, by developing correction factors. Such factors were needed so that data under several different visibility conditions could be treated together. Since mean values were not available when correction factors were first found necessary, median values were employed. These correction factors were made by date and by observation level according to the markings on the scatter plot of Fig. B-33, and provide fixed log unit values which are added to each separate range according to date and observation level; they serve to yield the results which might have been obtained if all our data had been obtained under conditions of good visibility. That they were at least in part effective is indicated by the reduced variability in the mean log ranges given in the section on position effects, where they were necessarily employed. The effect of the correction is to reduce the standard deviation from approximately .16 log units to .10 log units, which is approximately the size of the standard deviation of a single night's observations.

Meteorological Visibility: Day Runs:

The small number of days and runs occurring in the day observations reduce sharply the variety of analyses which may be made. Moreover, the visibility conditions under which the observations were made did not vary exceedingly, but were relative homogeneous.

The logarithmic ranges of three targets were selected for treatment and ϵ^2 and ϵ_c^2* calculated for correlation of ranges with runs and with days. High and statistically significant values of ϵ_c^2 will be associated with variations in visibility from run to run, and day to day. Where meteorological visibility plays a limited role, the variability will not be associated with runs so much as with individuals, and the ϵ_c^2 values will approach zero.

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* The correction is for the use of broad categories, and is necessary where only a few categories of one variable are used (here 5 for days and 13 for runs).

TABLE B-47

ϵ_c^2 ANALYSIS OF DIFFERENCES BETWEEN MEAN RANGES, RUNS, AND DAYS, FOR THREE DISCRIMINATIONS

	Discrimination 7-G (4x4 Black Drum)	Level of Significance (%)	Discrimination 8-100 (Flagpole)	Level of Significance (%)	Discrimination D-PI (Acuity Target)	Level of Significance (%)
Mean Log Range	4.12		4.08		3.49	
ϵ_c^2-Runs	0.796	1	0.343	1	0.177	>5
ϵ_c^2-Days	0.594	1	0.261	1	0.233	1

TABLE B-48

MEAN LOG RANGES FOR EACH RUN OF EACH OF THREE DISCRIMINATIONS.

DAY OBSERVATIONS

Date	Run	Discrimination 7-G	Discrimination 8-100	Discrimination D-PI
		M	M	M
11/21	1	4.12	4.12	3.61
	2	4.29	4.22	3.51
	3	4.29	4.01	3.55
11/23	1	3.94	4.01	3.44
	2	4.06	4.05	3.53
	3	4.11	3.88*	3.41
12/8	1	4.20	4.15	3.25
	2	4.09	4.05	3.45
12/13	1	4.15	4.20	3.46
	2	4.17	4.18	3.53
	3	4.10	4.15	3.61
12/15	1	3.94	3.92	3.62

*This mean is depressed by one extremely low value.

(A thirteenth run was not included because only three men observed and data are not sufficient for computation of means. All other values represent four observations.)

The results are given in Table B-47.

Visibility clearly varies systematically from day to day and run to run, and its effect varies as the mean log range of the target on which it is evaluated. Discriminations which can be made only at 3,000 yards are less affected by changes in visibility than are discriminations made at 12,000 yards. This is in keeping with the exponential nature of the visibility function.

An estimate of the magnitude of the effect may be obtained from Table B-48 which gives the mean log ranges of the three discriminations for each of 12 runs.

It is interesting to compute the visual angle subtended by the interspace of Target D, the orientation of which has to be called correctly. At 3,090 yards, viewed through a seven-power glass, this target subtends an angle of 1.3 minutes, and a visual acuity value of .77 is obtained.

Analysis in Terms of β, the Coefficient of Atmospheric Attenuation

It has been shown that some systematic factor which varies from observation night to observation night, and from day to day, determines in large part the numerical values of the ranges obtained. This factor is presumed to be the meteorological visibility. Although the records kept by the quartermasters failed to establish the fact, it was clear to all observers that on some nights, visibility was unlimited, and lights as distant as 30-40 miles could be identified, and on others, the visibility was so reduced that such nearby land as Plum Island was not visible and that the fort itself could not be detected at ranges as small as 5,000 yards. so that operations were necessarily suspended.

Data obtained under such a wide variety of visibility conditions make possible analysis of the data on Target 3-100 in terms of Beta, the coefficient of atmospheric extinction, provided certain explicit assumptions be made.

Analysis, data on course 210 T; Signal Bridge only:

Assumption I

The relationship:

$$C_x = C_o e^{-\beta x}$$

Where C_x is the contrast of a target at range x

C_o is the contrast of a target at range o

e is the base of the natural logarithm

β is the coefficient of atmospheric extinction

x is the range, in sea miles

is equally valid on a moonless night as by day.

Assumption II - On the night yielding the highest average mean log range*, the value of β should closely approximate .10, corresponding to a daylight visual range of approximately 37 sea miles, which is a maximum value for the operating area.

Assumption III - That, by employing the observed range, x, C_x of Target 3 may be calculated from the experimental results** relating log liminal contrast to log visual angle, with background brightness equal to 10^{-4} millilamberts (5.00 log$\mu\mu$l).

Then, C_o of the target may be calculated, and a curve relating β to the visual range of Target 3-100 may be drawn. The value of C_o so derived must be close to but greater (because of the Purkinje phenomenon) than that calculated from the transmission-reflectance of Target 3, as measured in daylight, which is .405. The curve relating β to range must be such as to yield a value of β corresponding to 2-3 miles daylight visual range for the minimum mean log range obtained on any one observation night, and corresponding to an average "clear" daylight visual range for the average range obtained throughout the night observations. Finally, a minimum number of ranges, or none at all, should appear in our total distribution of ranges requiring a value β = 0, or less.

Table B-49 gives the computations entering into the derivation of C_o, and Fig. B-35 the curve relating β to the range for discrimination 3-100. These results, although they represent only an approximation, are in

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* Both courses. Data on both courses were used because of the smallness of the sample on one course alone.

** Figure 9 "Log Liminal Contrast", Blackwell, H.R. Laboratory Studies of the Visibility of Targets. Minutes and Proceedings of the Army-Navy NRC Vision Committee, 15th Meeting, 12-13 February 1945, pp. 82-90.

TABLE B-49

CALCULATION OF β FROM DISCRIMINATION 3-100 RANGES

(USING TIFFANY FOUNDATION DATA AND FORMULA $C_x = C_o e^{-\beta x}$)

MAGNIFICATION - 7X

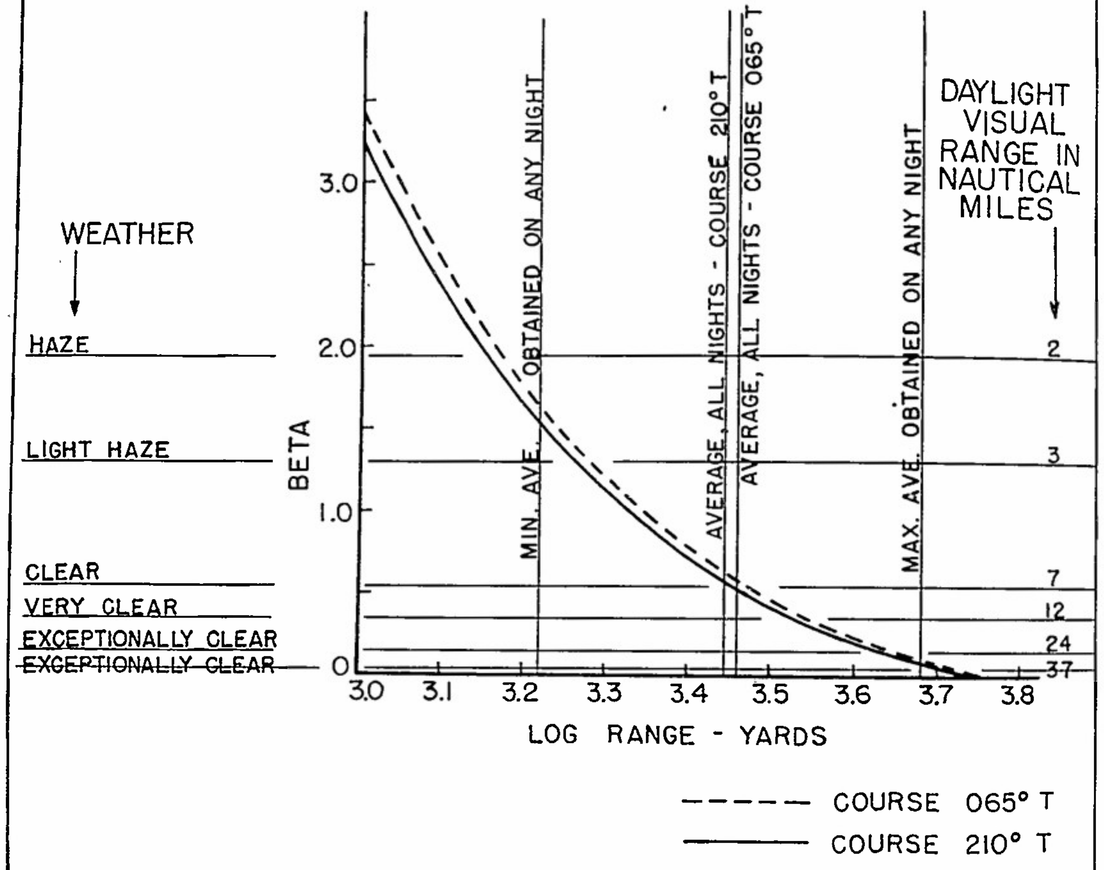
A. COURSE 210T Contrast 0.405; average log range in yards, 3.446; maximum average log range in yards for any night, 3.68.

Range (Sea Miles)	Log Range	Tan θ	Log θ (min)	Log Cx	C_x	β	V (Sea Miles)	Weather
.500	3.000	8.5721(-10)	2.161	$\bar{2}.98$	.096	3.27	1-2 Miles	Thin fog-haze
.630	3.100	8.4721	2.061	$\bar{1}.05$	.112	2.34	1-2 "	Thin fog-haze
.830	3.220	8.3521	1.941	$\bar{1}.14$	.138	1.52	2-3 "	Haze-light haze
1.000	3.301	8.2711	1.860	$\bar{1}.21$	.162	1.11	3-4 "	Light haze
1.396	3.446	8.1261	1.715	$\bar{1}.34$	.219	.578	6-7 "	Light haze-clear
1.500	3.477	8.0950	1.684	$\bar{1}.37$	.234	.491	8 "	Clear
1.580	3.500	8.0721	1.661	$\bar{1}.40$	.251	.423	9-10 "	Clear
2.000	3.602	7.9700	1.559	$\bar{1}.51$	.324	.207	18-20 "	Very clear
2.395	3.680	7.8921	1.481	$\bar{1}.59$	.389	.096	38 miles	Exc. clear
2.500	3.699	7.8731	1.462	$\bar{1}.62$	.417	.064	40-70 "	Exc. clear
2.752	3.741	7.8215	1.410	$\bar{1}.69$	.490	.000	-	Vacuum
B.	COURSE 065 T	Contrast, 0.575; average log range in yards, 3.459.						
.500	3.000	8.5271	2.116	$\bar{1}.01$	.102	3.46	1-2 miles	Thin fog-haze
.630	3.100	8.4271	2.016	$\bar{1}.08$	.120	2.48	1-2 "	Thin fog-haze
.830	3.220	8.3071	1.896	$\bar{1}.18$	.151	1.61	2-3 "	Haze-light haze
1.000	3.301	8.2261	1.815	$\bar{1}.25$	.178	1.18	3-4 "	Light haze
1.439	3.459	8.0681	1.657	$\bar{1}.40$	.250	.578	6-7 "	Light haze-clear
1.500	3.477	8.0500	1.639	$\bar{1}.42$	.263	.521	7-8 "	Clear
1.580	3.500	8.0271	1.616	$\bar{1}.45$	.282	.452	8-9 "	Clear
2.000	3.602	7.9250	1.514	$\bar{1}.56$	.363	.230	16-18"	Very clear
2.395	3.680	7.8471	1.436	$\bar{1}.66$	.457	.096	38 "	Exc. clear
2.500	3.699	7.8281	1.417	$\bar{1}$ 68	.479	.074	40-70"	Exc. clear
2.820	3.751	7.7765	1.360	$\bar{1}.76$	.575	.000	-	Vacuum

accord with the criteria which have been set up. They indicate that the present results are in reasonable agreement with laboratory data, and should yield, if the time and money are available for this analysis, data of substantial utility in visibility.

Analysis, Data on Course 065 T:

If one additional assumption is made, C_o of Target 3 on course 065 T, which, it will be remembered, is greater than on



"BETA" AS DETERMINED FROM THE MEAN LOG RANGE OF TARGET 3-100 USING 7X50X7 ° H.H. BINOCULARS

Figure B-35.

course 210 T, may be computed, and an analagous table and graph derived. This assumption is that the value of β corresponding to the average of all observations on course 065 T must be identical with that corresponding to the average of all observations on course 210 T, since runs were alternated. Table B-49 and Fig. B-35 give the results obtained when this assumption is made. These are in good conformity with the findings, and show that, in all cases, the range of Target 3-100 should be slightly greater on course 065 T.

TABLE B-50

EXTREME RANGES AT WHICH DISCRIMINATION 3-100 WAS REPORTED

Log Range, Yards	Course (T)
3.70	065
3.70	210
3.71	065
3.71	210
3.72	065
3.73	210
3.76	065
3.77	065
3.77	065
*3.80	065
*3.85	065
*3.90	210

* Impossible

That this analysis is nearly, but not quite, adequate to the data is indicated by the contents of Table B-50, which are the extreme ranges at which discrimination 3-100 was made. Only six of 172 reports give values requiring β to be zero. These are almost all on course 065 T, and are only slightly over the theroetical maximum. It is suggested that with further analysis of the data, these extreme values may be fully accounted for. The analysis seems basically sound.

Reliability of Independent Evaluations of β:

With the results of the graph of Fig. B-35, it is possible to determine for each night the value of β for the mean log ranges of the observations on course 210 T, and on course 065 T, and to determine the reliability of such estimates from the two independent samples of each of the 21 nights. The coefficient of correlation obtained from 21 nights (with several runs determining the average on each course each night) is found to be .56 for signal bridge data and .52 for the gun deck. While these are not high correlations, they are of the same order of magnitude as that presented earlier, between gun deck and signal bridge data on single runs, which also gives an estimate of the contribution of visibility to the results. When the large effect of individual variability is considered, it is a very satisfactory index value indeed.

Discussion:

The analysis which has been presented is based upon many assumptions, and it can hardly be said that the findings validate the laboratory results* on visibility in

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* e.g., the present results are based on a 7-power binocular; the Tiffany data on naked-eye observations. The field test has established the 7x50x7° naked-eye range ratio

full. Clearly, the identical analysis should be made for each target, and for each optical instrument, so that a more reliable value of β may be established for each night of observation. If many such evaluations of β can be obtained, it should be possible, on the one hand, to eliminate visibility as a source of variability in the data, permitting more satisfactory secondary analyses, and on the other hand, to evaluate the performance of each instrument under several conditions of visibility.

B. Wind:

Wind proved to be a problem on only one course, 210 T, since the prevailing winds of the operating area proved to be southerly. An analysis has been made of 7x50x7° ·HH log ranges on 25 runs in which the wind exceeded 5 knots, and blew in the faces of the observers, and 30 runs where the wind velocity was less than 5 knots, or where its direction was such that it did not bother the observers. The results are given in Table B-51.

TABLE B-51

THE EFFECT OF WIND

Wind	Number of Runs	Mean Log Range	S. D.
None	30	3.43	0.13
Five knots or more	25	3.43	0.18

The wind had no effect on the mean ranges obtained but, on the other hand, it did increase variability.

TABLE B-52

BRIGHTNESS DATA

	Mean (log micro-micro lamberts)	SD	Range
1. Sky Brightness above fort	5.1	0.20	4.6 - 5.6
2. Sea Brightness below horizon at fort	4.7	0.40	4.1 - 5.5
Mean log sky/sea ratio			0.40
Mean sky/sea ratio			2.50
Range sky/sea ratio			0 - 8.50

In one instance, the wind had a very serious effect. On the night of Oct. 4-5, the wind was the strongest and most difficult encountered throughout the experiment. The staff officer's log is quoted:

> "Wind was very bad on all Constellation Rock runs. It bothered some of the men to the extent of causing excessive watering of the eyes and probably interfering with their observing. The wind and cold were sufficiently punishing that we couldn't have made any more runs on that course, and the boys weren't too happy about making the last one."

The block being run on this course on the date in question was M(1)D, and when the data were analyzed, it was evident that something was very awry with it: two high-powered instruments behaved extremely poorly, the 20x120x3° giving a RRP of 120, and the 10x70x7° one of 102. In view of the officer's comment (and this was the only instance in which such comment was made), and the striking anomolous results, the data from this block were not included in combined RRP curves.

C. Sky Brightness:

No comprehensive analysis of the data with respect to sky brightness and sea brightness, as measured by the O'Brien Low Level Photometer is presented.

Data on brightness as measured over 124 runs by crew members, are summarized in Table B-52.

The mean values are in good agreement with those obtained elsewhere, but the sky brightnesses obtained occasionally are greater than those reported for moonless nights.

The analysis which must ultimately be performed on the data should relate the visibility of targets to sky brightness and to the sky-sea brightness ratio, and both of the latter to meteorological visibility and cloud-coverage, on which data are also available.

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as 2.5. It is apparent, then, that the thresholds obtained at Tiffany are correspondingly lower by .40 log units than those here reported.

INDIVIDUAL DIFFERENCES

In all, 76 different individuals served, at one time or another, as observers. The number of observations made by each varied widely, as did the visibility conditions under which observations were made, so that a large body of comparable data is not yet available on each man. Consequently, analysis of the data does not yet permit any extensive comparison of the results of the tests given the observers with the RRP derived from field performance.

General Characteristics of Observers:

Enlisted Men: The fifteen men of the original group of observers were all candidates for Submarine School, for which they were physically and psychologically qualified With two exceptions, they had had extensive sea experience on surface craft. The remaining 49 enlisted men were all experienced submarine men. With the possible exception of a few of the older men, all had been through the rigorous selection program for submarine duty.

The average age of 59 of the 64 enlisted men was 23.1 years; the average GCT of 50* of them was 59.7. Almost all the men were petty officers; their distribution by rate is given in Table B-53.

The enlisted men, then, constitute a homogeneous group, superior to the Navy average in intelligence (as measured by the GCT), experience, and rating.

Motivation: Although almost every observer was about to be discharged, they remained, as a group, well motivated, but only as a result of extremely careful handling.

Experience: 42 of the 64 had attended Lookout School and 40 had stood lookout or quartermaster watches. 17 had had neither, and only 6 of these did not get the intensive program of training followed at the beginning of the program. This group was formed into two 3-man sections, b and c, which made many observations, and whose performance could be compared with that of

*Data was not available on the others.

TABLE B-53

DISTRIBUTION OF ENLISTED OBSERVERS BY RATE

	Rate										
	TM	GM	QM	SM	FC	EM	MoMM	RM	RT	PhM	Total
First Class	1		1	3	1	2	2		1	1	12
Second Class	8	2	4	3		2	6	5			30
Third Class	2		4		1	5	4	1			17
S 1/c (QM)											4
F 1/c											1
Total											64

the others.

Technically Qualified Observers:

All 12 technically-qualified observers were skilled in precise visual observations under laboratory conditions. They were professional men, including physiologists, psychologists, and physicists. Four of the five naval officers and a like number of the seven civilians were young men in their late twenties or early thirties. None had had extensive practical experience.

Results on Test Battery:

With a few exceptions, almost all the 76 observers received the full battery of tests. The results, for the group, are given in column 1 of Table B-55, and they may be compared with the average of large naval populations in column 5 of the same table. The observers constitute a superior group with respect to almost every measure made.

Criterion of Performance:

In attempting to evaluate the performance of the observers, certain difficulties arose from the varying meteorological visibility and the great discrepancies among the observers with respect to the number of runs on which each observed. Difficulty also arose from the necessary practice of employing observer-recorder teams. A poor recorder, who failed to prompt carefully, tended to handicap the observer in his reports. As a consequence, it was very difficult to obtain satisfactory indices of performance, permitting the grading of the observers with respect to their ability in the task.

However, it is possible to show that statistically significant individual differences exist, and an attempt was made to select, by several statistical devices, those men whose performance tended to be outstandingly good, and those whose performance tended to be poor.

(1) The existence of stable individual differences: By use of the ϵ^2 technique, it may be shown that there are significant differences among the mean log ranges made by the observers. This statistical method was applied to the 3-100 log ranges after the corrections for visibility and observation post, described earlier, had been

applied. The value of ϵ^2 obtained was 0.414, which is significantly greater than 0 at less than the 1% level of probability.

(2) The selection of superior and inferior observers: Several different methods of analysis were employed in separating individuals of superior and inferior performance. The results produced by one method were not necessarily in close agreement with those of another. As a consequence, three different methods were used, and the final lists of "best" and "poorest" observers were established on the basis of all three methods. The individual was placed on the "good" or "poor" list only when he was so classified by at least two of the three methods. These methods were:

Method A: The mean of the mean log ranges for 73 different individuals, when the corrections had been applied, was 3.52 log units, with a standard deviation of .12 log units. Individuals whose mean ranges fell more than 1 standard deviation away from the mean, were classified "good" or "poor" according to the direction.

Method B: Those individuals obtaining, on any night, 7x50x7° ranges on 3-100 which were .20 log units or more (approximately 1.25 S.D.) greater and less than the median range of the night's runs were classified "good" and "poor", respectively.

Method C: A set-by-set census of the Latin Square results on each discrimination (excluding positive identifications*) on which F-values for inter-observer variance were significant at the 5% and 1% levels were made. The number of times each man appeared as best or worse in these squares where significant differences appeared was enumerated, and some men were classed "good" and "poor" accordingly.

When all three sets of lists were compared, 9 observers were classed as "good" and 13 as "poor".

A third sub-group was also found. This group of 4 men must be classed as "variable". They appeared, in fact, more than once in both "good" and "poor" lists. This seems to be a genuine phenomenon; one can observe the variability in the data themselves. One man, an observer in set VD, obtained ranges in the last three runs of the set only half as great as those obtained in the first three runs. Approximately three weeks separated the two groups of three runs, but this had no effect on the ranges of the other five observers. It has not been possible to relate the variability of these four men to any systematic factor.

Performance and Test Scores:

Columns 2, 3, and 4 of Table B-54 give the mean scores on several of the tests of the battery by each of the three groups distinguished, and the number and percentage of men of each group falling into various categories on others, together with the results on the whole group, for purposes of comparison.

The table yields suggestive results: the "poor" men and the "good" men distinguish themselves in phoria measurements, with the "good" men showing no phoria, and

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* Positive identification data were not considered since apparent differences among observers would be based in part on the particular criterion each used in positively identifying a target, so that consistent differences which appeared would be based on non-visual differences.

the "poor" men a higher incidence of hyperphoria and esophoria, and on the RPA test which only one "poor" man failed but on which the extraordinarily high percentage of 67% failed to score 10/10 on a first administration of the test (tetrachoric "r" = .91). A high percentage (33%) of the officers and technical observers appear on the "poor" list.

These results are suggestive only, and further work, directed at partialing out the effect of recorder differences and visibility, must be performed before final conclusions may be drawn.

Training:

The results on training await analysis. Preliminary findings indicate that the mean ranges of relatively untrained men start at approximately half the means of experienced groups observing simultaneously, but that they rapidly (over several runs) climb to the average value.

Special Analysis: Pupil Diameter:

Special treatment was accorded the results on pupil diameter, since this might be expected to relate to performance with instruments of varying exit pupils.

The 45 men whose dark-adapted pupil-

TABLE B-54

TEST SCORES AND PERFORMANCES

OF OBSERVERS

	1 All Observers (N = 76)			2 "Good" Group (N = 9)		3 "Poor" Group (N = 13)		4 "Variable" Group (N = 4)		5 General Navy Population	
Test or Measure	No.	M	SD	No.	M	No.	M	No.	M	M	SD
1. Age* (years)	59	23.1	3.3	8	23.0	9	21.6	4	21.0	-	-
2. GCT* (Score)	50	59.7	7.9	6	58.8	8	61.9	4	60.3	50.0	10.0
3. Interpupillary Distance (mm)	73	64.7	3.0	9	64.5	12	64.6	4	61.3	64.5	2.5
4. Pupil Diameter (mm)	46	6.9	1.0	6	6.7	9	6.6	4	7.5	7.4	0.8
5. Far Acuity (Right Eye)	73	1.09	0.17	9	1.07	11	1.10	4	1.13	1.05	0.03
6. Far Acuity (Left Eye)	73	1.07	0.16	9	1 05	11	1.07	4	1.16		
7. RCN Adapt.	72	2.45	0.20	9	2.48	12	2.39	4	2.36	2.4	0.2

*No civilians or officers included in average.

	No. (total)	No. Making Score	% Making Score	No. (total)	No. Making Scr.	% Making Scr.	No. (total)	No. Making Scr.	% Making Scr.	No. (total)	No. Making Scr.	% Making Scr.	
1. Hyperphoria present	73	6	8.2	9	0	0	11	2	18	4	0	0	No Data Available
Exophoria present	73	15	20.5	9	0	0	11	1	9	4	0	0	
Esophoria present	73	8	13.7	9	0	0	11	3	27	4	0	0	
2. RPA Score 10/10	72	45	62.5	9	6	67	12	4	33	3	3	100	60 (app.)
RPA Score 16/20-19/20	72	24	33.3	9	3	33	12	7	59	3	0	0	30 (App.)
RPA Score 15/20 & Less (Fail)	72	3	4.2	9	0	0	12	1	8	3	0	0	10 (app.)

TABLE B-54 (CONTINUED

Test or Measure	No. (total)	No. Making Score	% Making Score	No. (total)	No. in Grp.	% in Grp.	No. (total)	No. in Grp.	% in Grp.	No. (total)	No. in Grp.	% in Grp.
3. Officers and Civilians	76	12	15.8	9	1	11	13	4	30.6	4	0	0
4. Enlisted Men	76	64	84.2	9	8	89	13	9	69.4	4	4	100
5. L. O. School	64*	7	10.9	8	1	12 5	9	1	11.1	4	1	25
L. O. or QM Watch	64	24	37.5	8	3	39.5	9	4	44.4	4	2	50
Both	64	16	25.0	8	2	25	9	3	33.3	4	0	0
Neither	64	17	26.6	8	2	25	9	1	11.1	4	1	25

* Enlisted men only.

TABLE B-55

MEAN LOG RANGES (3-100) OBTAINED WITH BINOCULARS VARYING IN EXIT PUPIL, BY OBSERVERS HAVING VARIOUS DARK-ADAPTED PUPIL DIAMETERS

GROUP	Pupil Diameter in Millimeters	Total	Number of Men	10x50x7° MTD	10x70x7° MTD	10x80x7° MTD
I	7.51+	12	a. 5	3.61	3.74	3.78
			b. 8	3.60	3.69	
II	6.51 - 7.50	17	a. 5	3.62	3.66	3.69
			b. 7	3.66	3.71	
III	5.51 - 6.50	14	a 0			
			b. 4	3.67	3.77	
IV	5.50 and less			INSUFFICIENT DATA		

diameters were measured* were divided into four groups on the basis of pupil size. The mean performance on three mounted binoculars, 10x50x7°, 10x70x7°, and 10x80x7°, of those of each group who had used them, was calculated after the correction for visibility had been made. The results are given in Table B-55.

These data permit no conclusions to be drawn. It is not at all evident that the three groups systematically perform differently.

It is unfortunate that time was not available to permit more thorough analysis of the data, with extension to other discriminations from this point of view, since, it will be recalled, pupil diameter seemed the only variable related to the findings on interaction.

Interaction:

It has not been possible to extend the findings on interaction to men other than those of sections A and F.

FINAL DISCUSSION

This report has presented the results of an ambitious program of field experimentation. These results, with respect to the basic problem under investigation, are unequivocal, yet several secondary problems remain unsolved, either for lack of data, or for lack of time to evaluate them. Certain new phenomena appear in the data which call for further investigation. In any event, certain clear-cut conclusions with respect to the feasibility and requirements for field experiments may be drawn from the experience with this one.

It may be stated that a properly designed and executed field experiment can produce meaningful and useful data even on problems where laboratory control is difficult. To achieve this, however, the experiment must be planned to produce results on the specific problems in question. Incidental data may be obtained on problems not directly related to that under investigation, but they will necessarily not be so satisfactory as they would have been had the experiment been designed to study them.

The advantages of a field experiment have been presented in the introduction to this report. The results of this experiment emphasize the advantages cited, in that they are practical and realistic, have direct application to the problems posed, and require a minimum of interpretation.

From experience with the present experiment, it is clear that, in many respects, the technique can be further improved. A larger group working on statistics would enable the data to be treated fully almost concurrently with the execution of the experiment, and so improve efficiency in the scheduling of it, and bring to light phenomena requiring further investigation as soon as they appeared, permitting study or control of them to begin immediately.

Again, if such experiments are performed in the future, very substantial targets should be provided and consistent and reliable methods of measuring visibility used, if only in terms of the performance of a small group of men always using a standard glass. But on the whole, despite such shortcomings of technique and the grave difficulties encountered owing to demobilization, which interfered greatly with the original plans, the method employed has been eminently successful.

The results of this study point to three suggestions for future work: (a) further analysis of the present data, (b) specific phenomena noted in the results which should be subjected to further study both in the field and in the laboratory, and (c) establishment of a permanent field station where such studies can be undertaken routinely.

Further Study of the Present Results:

Before further field work on binoculars, visibility, or other visual variables, should be undertaken, it is proposed that these data, which have only been partly treated in the report, be subjected to further intensive analyses, along the following lines:

(1) A complete visibility analysis, on each discrimination, and all the instruments should make it possible to establish the most probable value of β for each night's operations. This analysis should take into consideration the measured sky-brightness of each date, and the transmission and contrast rendition of each binocular.

(2) With visibility values available, the data should be corrected throughout to equate each run with respect to visibility.

(3) The corrected data should then be analyzed for observer-recorder differences, and a fresh effort made to evaluate observers, and at the same time, to obtain "individual" corrections. The problem of interaction should be re-examined in the light of these findings, and an attempt made to extend interaction analysis to other individuals and instruments.

(4) When individual corrections have been applied to the data, each optical instrument should be re-evaluated.

Problems Requiring Further Field Research:

Certain of the results clearly show new phenomena on which further research is needed. Again, certain other of the results are incomplete, and should be extended.

Interaction: The finding that the same binocular may be better or worse than another, depending on who is using it, is an important one, in that it has implications not only for optical design, but also for the selection of personnel to use a particular instrument. This experiment should be repeated and extended, with the use of a much larger group of subjects, and with measurement on each observer of such visual variables as the extent of the blind spot, the constants of the areal function, and the acuity functions at low levels of illumination. The design of the experiment must be such as to establish whether superior observers consistently perform better on a particular instrument,

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*By Dr. I. B. Wagman, of the Johnson Foundation for Medical Physics.

and to discover the underlying retinal variables which lead to a preference for one or another binocular. The series of binoculars studied should also be extended, in order to determine the limits within which the interaction effect may reduce the superiority of an instrument.

The establishment of the fact of observer-instrument interaction is one of the most important of this experiment, both in its practical implications and its theoretical significance.

Search and Field Size: The present study on search is not fully satisfactory, since it proved that the manoeuvers required of the observation vessel did not provide for search of a sufficiently wide sector of the horizon, so that it is not impossible that an advantage possessed by wide-field binoculars may have been obscured. Such an advantage may have determined the finding that instruments of high magnification, which all had relatively small fields, did not show, in the search problem, the advantage displayed where the targets to be detected always appeared in known positions. Thus, it appears that not only should the operational problem be altered, but also that a rather different series of instruments than were available should be used. Provision of internal field stops and objective stops to standard instruments should permit the manufacture of a series of instruments of the same powers, 7 and 10, with the same exit pupils, but of two, and possibly three, field sizes. Such a series might include:

(From the 7x50x10°):

1. 7x42x3°; 2. 7x42x7°; 3. 7x42x10°.

(From the 10x80x7°):

4. 10x60x3°; 5. 10x60x7°.

6. 20x120x3°

If such instruments could be procured, it should be possible to obtain unequivocal results.

Fixed Focus: Further studies of fixed focuses should be made on large populations of observers, with a view of relating performance-preferred focus to variations in refraction of the observers' eyes, and to their focuses as measured by several methods. The effects of fatigue and eyestrain should be investigated.

A Permanent Field Station

If there existed a station at which field studies were routinely undertaken, not only could the problems outlined above be expeditiously studied, but any anomolies of performance of optics or men could be immediately taken under investigation, with a consequent elimination of doubt with respect to the validity of findings. Certain of the presented results, such as the difference in the performance at night of the 10x50x7° on the signal bridge and on the gun deck could be accounted for in short order. The observing personnel of such a station not only could be very thoroughly studied in the laboratory so that relevant properties of their retinas could be known, but also, being experienced, they should turn out data much more consistent than observers whose experience is shorter, and motivation less stable.

APPENDIX C

APPENDIX C

Appendix C presents, in tabular form, relevant data on each set of runs of the experiment.

These data include:

a. The instruments tested, their mode of use (i. e., HH, Indication of fixed focus, etc.) and their serial numbers when available.

b. The position on the bridge in which each was employed. Where the instruments systematically shifted position is indicated by the word "varied."

c. The 90%* and 50%* RRP's of each instrument, as determined in the set.

d. The serial numbers of the runs of the set.

e. The sets which were being performed simultaneously on each run. This information is not given for day runs.

f. The date on which each run was made.

g. The number of the run for that date.

h. The course of the run.

i. The presence of wind greater than five knots, blowing into the observers' faces, is denoted by W.

j. The observer's name. On night runs the name of the observer who used the 7x50x7^{O}HH binocular on each run appears opposite the number of the run. In day runs the observer listed is not necessarily the one who made the observation opposite his name.

k. The 7x50x7^{O}HH range (in yards) for target 3-100 on each run.

l. Designation of the search target, and the 100% range of sighting, with the 7x50x7^{O}HH.

m. A tabular summary of results of the analysis of variance, giving the total number of discriminations on which the analyses were made, and the number of these on which significant F-values were obtained, with respect to differences between runs, between instruments, and between observers.

n. The discriminations of closest range made on which data were sufficiently complete for analysis.

o. Mean 7x50x7^{O}HH ranges, in yards, for each discrimination. Each mean includes results of all six runs, with a different observer on each. Where visibility prevented the collection of sufficient data to compute, this is indicated by the letters N. S. D. (not sufficient data).

These tables should enable interested persons to recompute some of the results, or to attempt further analysis of their own.

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* Referred to as .90 and .50 RRP's in text.

DATA ON RUNS FOR SET BA

SUMMARY OF INSTRUMENTS

	Instruments		Position	90% RRP	50% RRP
1.	7x50x7 HH	144989	5	83.0	100.0
2.	7x50x7 Mtd.	146576	2A	97.5	115.0
3.	10x50x7 Mtd.	3	2	109.5	127.5
4.	7x50x7 VFA	-	4A	98.5	116.8
5.	7x50x7 HHR	259896	6	95.0	112.0
6.	10x50x7 HH	49	1	83.0	100.0

RANGES

Runs	Simult. Set	Date	No. on Date	Course	Wind	Observer Sect. A	Target 3-100 Range (yds)	Search Target	Search Range (yds)
80	Fb-1	10-9	9	065	-	Casper	4200	SM	3250
82	Fb-1	10-9	11	065	W	Anderson	1900	SM	-
83	Fb-1	10-10	1	210	-	Coleman	3200	SC	4430
89	Fb-2	10-10	7	065	W	Brau	3300	SM	-
91	Fb-2	10-10	9	065	W	Atchison	5280	SM	-
103	Fb-2	11-1	5	210	-	Barberio	3750	SC	-

SUMMARY OF OCCURRENCE OF SIGNIFICANT "F" VALUES ON DISCRIMINATIONS

	Runs			Observers			Instruments		
	Not Sig.	5%	1%	Not Sig.	5%	1%	Not Sig.	5%	1%
Target 1G and 100			2	1		1	2		
Other Discriminations	1	3	6	1	2	7	8	2	
Total Discriminations Calculable	12			12			12		
Total Discriminations Observed	12			12			12		
Closest Discrimination Calculable: 6PI									

ARITHMETIC MEANS 7 x 50 x 7 HH BY DISCRIMINATION

Discrimination	Mean Range (yds)	Discrimination	Mean Range (yds)	Discrimination	Mean Range (yds)
1-G	8525	4-G	4358		
1-100	7642	4-100	3050		
1-PI	4830	4-PI	2233		
3-G	5610	6-G	3772		
3-100	3605	6-100	2438		
3-PI	2233	6-PI	1677		

APPENDIX C

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b. The position on the bridge in which each was employed. Where the instruments systematically shifted position is indicated by the word "varied."

c. The 90%* and 50%* RRP's of each instrument, as determined in the set.

d. The serial numbers of the runs of the set.

e. The sets which were being performed simultaneously on each run. This information is not given for day runs.

f. The date on which each run was made.

g. The number of the run for that date.

h. The course of the run.

i. The presence of wind greater than five knots, blowing into the observers' faces, is denoted by W.

j. The observer's name. On night runs the name of the observer who used the 7x50x7°HH binocular on each run appears opposite the number of the run. In day runs the observer listed is not necessarily the one who made the observation opposite his name.

k. The 7x50x7°HH range (in yards) for target 3-100 on each run.

l. Designation of the search target, and the 100% range of sighting, with the 7x50x7°HH.

m. A tabular summary of results of the analysis of variance, giving the total number of discriminations on which the analyses were made, and the number of these on which significant F-values were obtained, with respect to differences between runs, between instruments, and between observers.

n. The discriminations of closest range made on which data were sufficiently complete for analysis.

o. Mean 7x50x7°HH ranges, in yards, for each discrimination. Each mean includes results of all six runs, with a different observer on each. Where visibility prevented the collection of sufficient data to compute, this is indicated by the letters N. S. D. (not sufficient data).

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RANGES

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80	Fb-1	10-9	9	065	-	Casper	4200	SM	3250
82	Fb-1	10-9	11	065	W	Anderson	1900	SM	-
83	Fb-1	10-10	1	210	-	Coleman	3200	SC	4430
89	Fb-2	10-10	7	065	W	Brau	3300	SM	-
91	Fb-2	10-10	9	065	W	Atchison	5280	SM	-
103	Fb-2	11-1	5	210	-	Barberio	3750	SC	-

SUMMARY OF OCCURRENCE OF SIGNIFICANT "F" VALUES ON DISCRIMINATIONS

	Runs			Observers			Instruments		
	Not Sig.	5%	1%	Not Sig.	5%	1%	Not Sig.	5%	1%
Target 1G and 100			2	1		1	2		
Other Discriminations	1	3	6	1	2	7	8	2	
Total Discriminations Calculable	12			12			12		
Total Discriminations Observed	12			12			12		

Closest Discrimination Calculable: 6PI

ARITHMETIC MEANS 7 x 50 x 7 HH BY DISCRIMINATION

Discrimination	Mean Range(yds)	Discrimination	Mean Range(yds)	Discrimination	Mean Range(yds)
1-G	8525	4-G	4358		
1-100	7642	4-100	3050		
1-PI	4830	4-PI	2233		
3-G	5610	6-G	3772		
3-100	3605	6-100	2438		
3-PI	2233	6-PI	1677		

DATA ON RUNS FOR SET BB

SUMMARY OF INSTRUMENTS

Instruments			Position	90% RRP	50% RRP
1. 7x50x7	HH	144989	5		
2. 7x50x7	Mtd.	146576	2A	RANDOMIZING	
3. 10x50x7	Mtd.	3	2	OFF	
4. 7x50x7	VFA	-	4A	EXCLUDED	
5. 7x50x7	HHR	-	1		
6. 10x50x7	HH	49	6		

RANGES

Runs	Simult. Set	Date	No. on Date	Course	Wind	Observer Sect. B	Target 3-100 Range(yds)	Search Target	Search Range (yds)
[illegible]	Fa-1	10-9	6	065	W	Hughs	2100	SC	-
81	Fa-1	10-9	10	210	W	Jagelewski	4600	SC	-
84	Fa-1	10-10	2	065	-	Bamford	2900	SM	-
86	Fa-2	10-10	4	065	-	Pedersen	5030	SM	-
88	Fa-2	10-10	6	065	-	Parker	3880	SC	[illegible]
104	Fa-2	11-1	6	065	-	Bridges	2900	SM	-

SUMMARY OF OCCURRENCE OF SIGNIFICANT "F" VALUES ON DISCRIMINATIONS

	Runs			Observers			Instruments		
	Not Sig.	5%	1%	Not Sig.	5%	1%	Not Sig.	5%	1%
Target 1G and 100									
Other Discriminations									
Total Discriminations Calculable									
Total Discriminations Observed									

Closest Discrimination Calculable:

ARITHMETIC MEANS 7 x 50 x 7 HH BY DISCRIMINATION

Discrimination	Mean Range(yds)	Discrimination	Mean Range(yds)	Discrimination	Mean Range(yds)
1-G	[illegible]	4-100	[illegible]		
1-100	[illegible]	4-PI	[illegible]		
1-PI	[illegible]	6-G	[illegible]		
3-G	[illegible]	6-100	[illegible]		
3-100	[illegible]	6-PI	[illegible]		
3-PI	[illegible]				
4-G	[illegible]				

DATA ON RUNS FOR SET BD

SUMMARY OF INSTRUMENTS

Instruments			Position	90% RRP	50% RRP
1. 7x50x7	HH	144989	1	86.0	100.0
2. 7x50x7	Mtd.	146576	2A	105.5	117.0
3. 10x50x7	Mtd.	3	2	122.5	135.2
4. 7x50x7	VFA	-	4A	110.5	122.8
5. 7x50x7	HHR	259896	5A	103.0	113.5
6. 10x50x7	HH	49	6	94.5	104.0

RANGES

Runs	Simult. Set	Date	No. on Date	Course	Wind	Observer Sect. D	Target 3-100 Range(yds)	Search Target	Search Range (yds)
62	Fe-1	10-7	7	210	W	Louderbach	3020	SC	2500
64	Fe-1	10-8	1	210	W	Zachmann	1800	SC	2800
66	Fe-2	10-8	3	210	W	Roark	1920	SC	2600
68	Fe-2	10-8	5	210	W	Klooz	1550	SC	2600
70	Fe-2	10-8	7	210	W	Shoemaker	1900	SC	1000
92	Wg-1	10-11	1	210	W	Ritter	3550	SC	-

SUMMARY OF OCCURRENCE OF SIGNIFICANT "F" VALUES ON DISCRIMINATIONS

	Runs			Observers			Instruments		
	Not Sig.	5%	1%	Not Sig.	5%	1%	Not Sig.	5%	1%
Target 1G and 100			2	2			1	1	
Other Discriminations	1	1	8		1	7	3	1	6
Total Discriminations Calculable	12			10			12		
Total Discriminations Observed	12			12			12		

Closest Discrimination Calculable: 5-PI

ARITHMETIC MEANS 7 x 50 x 7 HH BY DISCRIMINATION

Discrimination	Mean Range(yds)	Discrimination	Mean Range(yds)	Discrimination	Mean Range(yds)
1-G	4493	4-G	2377		
1-100	3542	4-100	1808		
1-PI	2715	4-PI	1492		
3-G	2782	6-G	1892		
3-100	2293	6-100	1538		
3-PI	1635	6-PI	1573		

DATA ON RUNS FOR SET BE

SUMMARY OF INSTRUMENTS

	Instruments			Position	90% RRP	50% RRP
1.	7x50x7	HH	144989	1	86.0	100.0
2.	7x50x7	Mtd.	146576	2A	96.0	109.0
3.	10x50x7	Mtd.	3	2	102.5	116.0
4.	7x50x7	VFA	101	4A	93.5	107.0
5.	7x50x7	HHR	259896	5A	98.5	112.0
6.	10x50x7	HH	49	6	104.5	118.0

RANGES

Runs	Simult. Set	Date	No. on Date	Course	Wind	Observer Sect. E	Target 3-100 Range (yds)	Search Target	Search Range (yds)
61	Ff-1	10-7	6	065	-	Webb	2350	SM	3170
63	Ff-1	10-7	8	065	-	Shook	1900	SM	3300
65	Ff-1	10-8	2	065	-	Pusateri (Curtis)	1700	SM	2300
67	Ff-2	10-8	4	065	-	Nixon	2800	SM	2380
69	Ff-2	10-8	6	065	-	Rice	1800	SM	-
71	Ff-2	10-8	8	065	-	Myers	2400	SM	-

SUMMARY OF OCCURRENCE OF SIGNIFICANT "F" VALUES ON DISCRIMINATIONS

	Runs			Observers			Instruments		
	Not Sig.	5%	1%	Not Sig.	5%	1%	Not Sig.	5%	1%
Target 1G and 100		1	1	2			2		
Other Discriminations	1	3	6	6	1	3	10		
Total Discriminations Calculable		12			12			12	
Total Discriminations Observed		12			12			12	

Closest Discrimination Calculable: 5-PI

ARITHMETIC MEANS 7 x 50 x 7 HH BY DISCRIMINATION

Discrimination	Mean Range (yds)	Discrimination	Mean Range (yds)	Discrimination	Mean Range (yds)
1-G	5393	4-100	1887		
1-100	4122	4-PI	1450		
1-PI	2730	6-G	1890		
3-G	2855	6-100	1633		
3-100	2158	6-PI	1365		
3-PI	1498				
4-G	2217				

DATA ON RUNS FOR SET B(1)X

SUMMARY OF INSTRUMENTS

	Instruments			Position	90% RRP	50% RRP
1.	6x33x8		3478	6	42.0	60.0
2.	7x50x7	HH	144989	5	81.5	100.0
3.	10x70x7	Mtd.	-	3	92.0	111.5
4.	7x50x7	Mtd.	146576	2A	63.0	82.5
5.	10x50x7	Mtd.	3	2	87.5	105.5
6.	7x50x7	VFA	-	4A	87.0	107.0

RANGES

Runs	Simult. Set	Date	No. on Date	Course	Wind	Observer Sect. X	Target 3-100 Range (yds)	Search Target	Search Range (yds)
74	Wz-1	10-9	3	210	W	Miles	3500	SC	3120
76	Wz-1	10-9	5	210	-	Williams	3850	SC	-
79	Wz-1	10-9	8	210	W	Hendley	7000	SC	-
85	Wz-2	10-10	3	210	-	Mueller	3850	SC	4180
87	Wz-2	10-10	5	210	-	Shlaer	4300	SM	-
90	Wz-2	10-10	8	210	-	Lamar		SC	-

SUMMARY OF OCCURRENCE OF SIGNIFICANT "F" VALUES ON DISCRIMINATIONS

	Runs			Observers			Instruments		
	Not Sig.	5%	1%	Not Sig.	5%	1%	Not Sig.	5%	1%
Target 1G and 100	1		1	1	1		1	1	
Other Discriminations		1	3			4		3	1
Total Discriminations Calculable		6			6			6	
Total Discriminations Observed		6			6			6	

Closest Discrimination Calculable: 3-PI

ARITHMETIC MEANS 7 x 50 x 7 HH BY DISCRIMINATION

Discrimination	Mean Range (yds)	Discrimination	Mean Range (yds)	Discrimination	Mean Range (yds)
1-G	7772	6-G	3627		
1-100	7060	6-100	2938		
1-PI	5288	6-PI	1722		
3-G	5097				
3-100	4072				
3-PI	2068				

DATA ON RUNS FOR SET B(s)A

SUMMARY OF INSTRUMENTS

	Instruments			Position	90% RRP	50% RRP
1.	7x50x7	HH	144989	6	84.0	100.0
2.	7x50x7	Mtd.	146576	2	115.5	129.5
3.	10x50x7	Mtd.	3	3	129.0	145.0
4.	7x50x7	VFA	-	4A	109.5	123.5
5.	7x50x7	HHR	259896	5A	111.5	126.0
6.	10x50x7	HH	49	1	101.5	115.5

RANGES

Runs	Simult. Set	Date	No. on Date	Course	Wind	Observer Sect. A	Target 3-100 Range(yds)	Search Target	Search Range (yds)
121	W(s)i-2	11-5	7	210	-	Anderson	2600	SC	5250
123	W(s)i-2	11-5	9	210	-	Brau	1450	SC	4700
125	W(s)i-3	11-6	3	210	-	Barberio	1950	SC	3800
127	W(s)i-3	11-6	5	210	-	Casper	1480	SC	5150
129	W(s)i-3	11-6	7	210	-	Coleman	1600	SC	3500
131	-	11-6	9	210	-	Atchison	2400	SC	4520

SUMMARY OF OCCURRENCE OF SIGNIFICANT "F" VALUES ON DISCRIMINATIONS

	Runs			Observers			Instruments		
	Not Sig.	5%	1%	Not Sig.	5%	1%	Not Sig.	5%	1%
Target 1G and 100	1		1	2			2		
Other Discriminations	2	3	4	7			4	2	3
Total Discriminations Calculable	11			11			11		
Total Discriminations Observed	11			11			11		
Closest Discrimination Calculable: 5-100									

ARITHMETIC MEANS 7 x 50 x 7 HH BY DISCRIMINATION

Discrimination	Mean Range(yds)	Discrimination	Mean Range(yds)	Discrimination	Mean Range(yds)
1-G	6942	5-100	1883		
1-100	5008	5-PI	1308		
1-PI	2788				
3-G	2788				
3-100	1913				
3-PI	1353				
5-G	2492				

DATA ON RUNS FOR SET B(s)F

SUMMARY OF INSTRUMENTS

	Instruments			Position	90% RRP	50% RRP
1.	7x50x7	HH	144989	6	81.0	100.0
2.	7x50x7	Mtd.	146576	2	87.5	108.0
3.	10x50x7	Mtd.	3	3	88.5	108.5
4.	7x50x7	VFA	-	4A	102.0	121.0
5.	7x50x7	HHR	259896	5A	95.5	114.0
6.	10x50x7	HH	49	1	88.0	106.5

RANGES

Runs	Simult. Set	Date	No. on Date	Course	Wind	Observer Sect. F	Target 3-100 Range(yds)	Search Target	Search Range (yds)
120	W(s)j-2	11-5	6	065	W	Lamontagne	3800	SM	-
122	W(s)j-2	11-5	8	065	W	Courtney	2550	SM	3150
126	W(s)j-2	11-6	4	065	-	Tucker	1980	SM	3020
128	W(s)j-3	11-6	6	065	-	Fillissey	2000	SM	1850
130	W(s)j-3	11-6	8	065	-	Miller	2280	SM	3050
132	W(s)j-3	11-6	10	065	-	Naumann	2300	SM	2650

SUMMARY OF OCCURRENCE OF SIGNIFICANT "F" VALUES ON DISCRIMINATIONS

	Runs			Observers			Instruments		
	Not Sig.	5%	1%	Not Sig.	5%	1%	Not Sig.	5%	1%
Target 1G and 100		1	1	1	1		2		
Other Discriminations	10		3	4	1	2	13		
Total Discriminations Calculable	15			9			15		
Total Discriminations Observed	15			15			15		
Closest Discrimination Calculable: 6-PI									

ARITHMETIC MEANS 7 x 50 x 7 HH BY DISCRIMINATION

Discrimination	Mean Range(yds)	Discrimination	Mean Range(yds)	Discrimination	Mean Range(yds)
1-G	7372	4-100	2003		
1-100	5652	4-PI	1492		
1-PI	3093	5-G	2745		
3-G	3317	5-100	2230		
3-100	2485	5-PI	1615		
3-PI	1635	6-G	1932		
4-G	2492	6-100	1605		
		6-PI	1325		

DATA ON RUNS FOR SET B(s)A

SUMMARY OF INSTRUMENTS

Instruments			Position	90% RRP	50% RRP
1. 7x50x7	HH	144989	6	84.0	100.0
2. 7x50x7	Mtd.	146576	2	115.5	129.5
3. 10x50x7	Mtd.	3	3	129.0	145.0
4. 7x50x7	VFA	-	4A	109.5	123.5
5. 7x50x7	HHR	259896	5A	111.5	126.0
6. 10x50x7	HH	49	1	101.5	115.5

				RANGES					
Runs	Simult. Set	Date	No. on Date	Course	Wind	Observer Sect. A	Target 3-100 Range(yds)	Search Target	Search Range (yds)
121	W(s)i-2	11-5	7	210	-	Anderson	2600	SC	5250
123	W(s)i-2	11-5	9	210	-	Brau	1450	SC	4700
125	W(s)i-3	11-6	3	210	-	Barberio	1950	SC	3800
127	W(s)i-3	11-6	5	210	-	Casper	1480	SC	5150
129	W(s)i-3	11-6	7	210	-	Coleman	1600	SC	3500
131	-	11-6	9	210	-	Atchison	2400	SC	4520

SUMMARY OF OCCURRENCE OF SIGNIFICANT "F" VALUES ON DISCRIMINATIONS

	Runs			Observers			Instruments		
	Not Sig.	5%	1%	Not Sig.	5%	1%	Not Sig.	5%	1%
Target 1G and 100	1		1	2			2		
Other Discriminations	2	3	4	7			4	2	3
Total Discriminations Calculable		11			11			11	
Total Discriminations Observed		11			11			11	

Closest Discrimination Calculable: 5-100

ARITHMETIC MEANS 7 x 50 x 7 HH BY DISCRIMINATION

Discrimination	Mean Range(yds)	Discrimination	Mean Range(yds)	Discrimination	Mean Range(yds)
1-G	6942	5-100	1883		
1-100	5008	5-PI	1308		
1-PI	2788				
3-G	2788				
3-100	1913				
3-PI	1353				
5-G	2492				

DATA ON RUNS FOR SET B(s)F

SUMMARY OF INSTRUMENTS

Instruments			Position	90% RRP	50% RRP
1. 7x50x7	HH	144989	6	81.0	100.0
2. 7x50x7	Mtd.	146576	2	87.5	108.0
3. 10x50x7	Mtd.	3	3	88.5	108.5
4. 7x50x7	VFA	-	4A	102.0	121.0
5. 7x50x7	HHR	259896	5A	95.5	114.0
6. 10x50x7	HH	49	1	88.0	106.5

				RANGES					
Runs	Simult. Set	Date	No. on Date	Course	Wind	Observer Sect. F	Target 3-100 Range(yds)	Search Target	Search Range (yds)
120	W(s)j-2	11-5	6	065	W	Lamontagne	3800	SM	-
122	W(s)j-2	11-5	8	065	W	Courtney	2550	SM	3150
126	W(s)j-2	11-6	4	065	-	Tucker	1980	SM	3020
128	W(s)j-3	11-6	6	065	-	Fillissey	2000	SM	1850
130	W(s)j-3	11-6	8	065	-	Miller	2280	SM	3050
132	W(s)j-3	11-6	10	065	-	Naumann	2300	SM	2650

SUMMARY OF OCCURRENCE OF SIGNIFICANT "F" VALUES ON DISCRIMINATIONS

	Runs			Observers			Instruments		
	Not Sig.	5%	1%	Not Sig.	5%	1%	Not Sig.	5%	1%
Target 1G and 100		1	1	1	1		2		
Other Discriminations	10		3	4	1	2	13		
Total Discriminations Calculable		15			9			15	
Total Discriminations Observed		15			15			15	

Closest Discrimination Calculable: 6-PI

ARITHMETIC MEANS 7 x 50 x 7 HH BY DISCRIMINATION

Discrimination	Mean Range(yds)	Discrimination	Mean Range(yds)	Discrimination	Mean Range(yds)
1-G	7372	4-100	2003		
1-100	5652	4-PI	1492		
1-PI	3093	5-G	2745		
3-G	3317	5-100	2230		
3-100	2485	5-PI	1615		
3-PI	1635	6-G	1932		
4-G	2492	6-100	1605		
		6-PI	1325		

DATA ON RUNS FOR SET EH

SUMMARY OF INSTRUMENTS

	Instruments		Position	90% RRP	50% RRP
1.	6x33x8	3478	6	71.5	85.5
2.	6x33x7	-	2	83.0	98.0
3.	6x33x7 Mon.	-	1	69.5	84.5
4.	6x50x7	-	3	78.5	92.0
5.	6x42x7	-	5	76.0	90.5
6.	7x50x7 HH	-	4	85.0	100.0

RANGES

Runs	Simult. Set	Date	No. on Date	Course	Wind	Observer Sect. H	Target 3-100 Range (yds)	Search Target	Search Range (yds)
160	D10o	12-8	1	210	W	Filissey	1300	SC	1700
162	D10o	12-8	3	210	W	Staton	1530	SC	1300
164	D10o	12-8	5	210	W	Anderson	2000	SC	4400
166	D12o	12-8	7	210	W	Hughs	1910	SC	1250
169	D12o	12-9	2	210	W	Naumann	2600	SM	5600
171	D12o	12-9	4	210	W	Roark	1630	SC	2100

SUMMARY OF OCCURRENCE OF SIGNIFICANT "F" VALUES ON DISCRIMINATIONS

	Runs			Observers			Instruments		
	Not Sig.	5%	1%	Not Sig.	5%	1%	Not Sig.	5%	1%
Target 1G and 100	1		1			2	1	1	
Other Discriminations	11					1	11		
Total Discriminations Calculable		13			3			13	
Total Discriminations Observed		13			3			13	

Closest Discrimination Calculable: 6-G

ARITHMETIC MEANS 7 x 50 x 7 HH BY DISCRIMINATION

Discrimination	Mean Range (yds)	Discrimination	Mean Range (yds)	Discrimination	Mean Range (yds)
1-G	3990	4-G	2178		
1-100	3255	4-100	1877		
1-PI	1927	4-PI	1273		
3-G	2165	6-G	2077		
3-100	1828	6-100	1593		
3-PI	1178	6-PI	1077		

DATA ON RUNS FOR SET EJ

SUMMARY OF INSTRUMENTS

	Instruments		Position	90% RRP	50% RRP
1.	6x33x8	3478	6	N.S.D.	N.S.D.
2.	6x33x7	-	2	60.5	78.0
3.	6x33x7 Mon.	-	1	N.S.D.	N.S.D.
4.	6x50x7	-	3	70.0	88.0
5.	6x42x7	-	5	73.5	90.0
6.	7x50x7 HH	-	4	82.5	100.0

RANGES

Runs	Simult. Set	Date	No. on Date	Course	Wind	Observer Sect. J	Target 3-100 Range (yds)	Search Target	Search Range (yds)
161	D10p	12-8	2	065	-	Saidikowski	3400	SM	2000
163	D10p	12-8	4	065	-	Farone	1820	SM	-
165	D10p	12-8	6	065	-	Milling	1110	SM	1200
167	D12p	12-8	8	065	-	Foley	2600	SM	2100
168	D12p	12-9	1	065	-	Parker	1300	SC	2000
170	D12p	12-9	3	065	-	Tucker	2100	SM	2800

SUMMARY OF OCCURRENCE OF SIGNIFICANT "F" VALUES ON DISCRIMINATIONS

	Runs			Observers			Instruments		
	Not Sig.	5%	1%	Not Sig.	5%	1%	Not Sig.	5%	1%
Target 1G and 100	2						1		1
Other Discriminations	3						3		
Total Discriminations Calculable		5			0			5	
Total Discriminations Observed		5			5			5	

Closest Discrimination Calculable: 3-100

ARITHMETIC MEANS 7 x 50 x 7 HH BY DISCRIMINATION

Discrimination	Mean Range (yds)	Discrimination	Mean Range (yds)	Discrimination	Mean Range (yds)
1-G	4150	4-100	1958		
1-100	3097	4-PI	-		
1-PI	2045				
3-G	2325				
3-100	2055				
3-PI	-				
4-G	2295				

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DATA ON RUNS FOR SET HA-1

SUMMARY OF INSTRUMENTS

Instruments	Position	90% RRP	50% RRP
1. 7x50x7 HH -	varied	83.0	100.0
2. 7x50x10 HH(HR) -	varied	85.0	101.0
3. 10x50x7 HH 20	varied	87.0	105.0
4. 8x60x9 HH(-1d) 2111187	varied	80.5	97.5
5. 7x50x7 Mon. HH 259898	varied	74.5	91.2
6. Naked Eye -	varied	-	-

RANGES

Runs	Simult. Set	Date	No. on Date	Course	Wind	Observer Sect. A	Target 3-100 Range(yds)	Search Target	Search Range (yds)
2	-	9-4	2	055	-	Casper	3700		-
3	-	9-4	3	055	-	Atchison	5230		-
5	-	9-4	5	055	W	Barberio	3900		-
8	-	9-5	2	055	-	Coleman	3200		-
16	-	9-6	2	055	-	Brau	2100		-
18	-	9-6	4	055	-	Anderson	2150		-

SUMMARY OF OCCURRENCE OF SIGNIFICANT "F" VALUES ON DISCRIMINATIONS

	Runs			Observers			Instruments		
	Not Sig.	5%	1%	Not Sig.	5%	1%	Not Sig.	5%	1%
Target 1G and 100			2	2					2
Other Discriminations	4		3	1	1		5		2
Total Discriminations Calculable		9			4			9	
Total Discriminations Observed		9			9			9	

Closest Discrimination Calculable: 4-PI

ARITHMETIC MEANS 7 x 50 x 7 HH BY DISCRIMINATION

Discrimination	Mean Range(yds)	Discrimination	Mean Range(yds)	Discrimination	Mean Range(yds)
1-G	5833	4-100	2113		
1-100	5600	4-PI	1475		
1-PI	4097				
3-G	4163				
3-100	3380				
3-PI	1882				
4-G	2672				

DATA ON RUNS FOR SET H(1)A-2

SUMMARY OF INSTRUMENTS

Instruments	Position	90% RRP	50% RRP
1. 7x50x7 HH -	varied	90.2	100.0
2. 7x50x7 HH(HR) -	varied	99.0	106.0
3. 10x50x7 HH 20	varied	96.0	102.0
4. 8x60x9 HH(-1d) 2111187	varied	96.0	103.0
5. 7x50x7 Mon. HH 259898	varied	87.5	95.0
6. 10x70x7 (JF) HH -	varied	85.0	92.5

RANGES

Runs	Simult. Set	Date	No. on Date	Course	Wind	Observer Sect. A	Target 3-100 Range(yds)	Search Target	Search Range (yds)
32	-	9-12	2	055	W	Brau	4780	-	-
33	-	9-12	3	055	-	Atchison	3980	-	-
35	-	9-12	6	055	W	Anderson	4350	-	-
115	-	11-5	1	210	-	Barberio	2500	SC	4300
124	WsI-2[3]	11-6	1	065	-	Coleman	2650	SC	3950
141	-	11-9	1	210	W	Casper	3100	SC	3050

SUMMARY OF OCCURRENCE OF SIGNIFICANT "F" VALUES ON DISCRIMINATIONS

	Runs			Observers			Instruments		
	Not Sig.	5%	1%	Not Sig.	5%	1%	Not Sig.	5%	1%
Target 1G and 100			2	2			1	1	
Other Discriminations			6	4	2		5	1	
Total Discriminations Calculable		8			8			8	
Total Discriminations Observed		8			8			8	

Closest Discrimination Calculable: 4-100

ARITHMETIC MEANS 7 x 50 x 7 HH BY DISCRIMINATION

Discrimination	Mean Range(yds)	Discrimination	Mean Range(yds)	Discrimination	Mean Range(yds)
1-G	6945	4-G	4093		
1-100	6343	4-100	3638		
1-PI	4493	4-PI	3002		
3-G	4222	6-G	3070		
3-100	3560	6-100	2657		
3-PI	2962	6-PI	-		

DATA ON RUNS FOR SET HC-1

SUMMARY OF INSTRUMENTS

Instruments	Position	90% RRP	50% RRP
1 7x50x7 HH -	varied	82.5	100.0
2 7x50x7 HH(HR) -	varied	94.8	110.0
3 10x50x7 HH 20	varied	96.0	112.5
4 8x60x9 HH(-1d) 2111187	varied	79.8	97.5
5 7x50x7 Mon. HH 59898	varied	70.0	87.5
6 Naked Eye -	varied	-	-

Runs	Simult. Set	Date	No. on Date	RANGES Course	Wind	Observer Sect. C	Target 3-100 Range(yds)	Search Target	Search Range (yds)
1	-	9-4	1	210	W	Parker	1800	-	-
4	-	9-4	4	210	-	Haskins	2800	-	-
6	-	9-4	6	210	-	Webster	3580	-	-
10	-	9-5	4	210	W	Lamontagne	2700	-	-
12	-	9-5	6	210	W	Kramer	3100	-	-
14	-	9-5	8	210	W	DeWitt	3050	-	-

SUMMARY OF OCCURRENCE OF SIGNIFICANT "F" VALUES ON DISCRIMINATIONS

	Runs			Observers			Instruments		
	Not Sig.	5%	1%	Not Sig.	5%	1%	Not Sig.	5%	1%
Target 1G and 100	2			2					2
Other Discriminations	7					1	5	1	1
Total Discriminations Calculable		9			3			9	
Total Discriminations Observed		9			9			9	

Closest Discrimination Calculable: 4-PI

ARITHMETIC MEANS 7 x 50 x 7 HH BY DISCRIMINATION

Discrimination	Mean Range(yds)	Discrimination	Mean Range(yds)	Discrimination	Mean Range(yds)
1-G	5858	4-G	2692		
1-100	5750	4-100	2492		
1-PI	3767	4-PI	1893		
3-G	3242				
3-100	2838				
3-PI	2178				

DATA ON RUNS FOR SET H(1) C-2

SUMMARY OF INSTRUMENTS

Instruments	Position	90% RRP	50% RRP
1. 7x50x7 HH -	varied	88.5	100.0
2. 7x50x10 HH (HR) -	varied	82.5	92.0
3. 10x50x7 HH 20	varied	88.0	97.5
4. 8x60x9 HH(-1d) 2111187	varied	96.0	106.0
5. 7x50x7 Mon. HH 259898	varied	72.0	82.0
6. 10x70x7 (JF) HH -	varied	79.0	88.5

Runs	Simult. Set	Date	No. on Date	RANGES Course	Wind	Observer Sect. C	Target 3-100 Range(yds)	Search Target	Search Range (yds)
31	-	9-12	1	210	-	Haskins	3130	-	-
34	-	9-12	4	210	-	Parker	1900	-	-
36	-	9-12	6	210	-	Lamontagne	2900	-	-
37	-	9-13	1	210	-	DeWitt	2600	-	-
38	-	9-13	2	210	-	Webster	2000	-	-
39	-	9-13	3	210	-	Carter	2450	-	-

SUMMARY OF OCCURRENCE OF SIGNIFICANT "F" VALUES ON DISCRIMINATIONS

	Runs			Observers			Instruments		
	Not Sig.	5%	1%	Not Sig.	5%	1%	Not Sig.	5%	1%
Target 1G and 100			2	2			2		
Other Discriminations	2	1	3	1		5	3	1	2
Total Discriminations Calculable		8			8			8	
Total Discriminations Observed		8			8			8	

Closest Discrimination Calculable: 4-100

ARITHMETIC MEANS 7 x 50 x 7 HH BY DISCRIMINATION

Discrimination	Mean Range(yds)	Discrimination	Mean Range(yds)	Discrimination	Mean Range(yds)
1-G	5238	4-G	2935		
1-100	4652	4-100	2472		
1-PI	3013	4-PI	1705		
3-G	3035				
3-100	2497				
3-PI	1750				

DATA ON RUNS FOR SET HY

SUMMARY OF INSTRUMENTS

	Instruments			Position	90% RRP	50% RRP
1.	7x50x7	HH	-	varied	83.0	100.0
2.	7x50x10	HH(HR)	-	varied	91.0	107.0
3.	10x50x7	HH	20	varied	97.5	113.0
4.	8x60x9	HH(-1d)	2111187	varied	93.5	111.5
5.	7x50x7	Mon. HH	259898	varied	72.3	90.0
6.	Naked Eye		-	varied	-	-

RANGES

Runs	Simult. Set	Date	No. on Date	Course	Wind	Observer Sect. Y	Target 3-100 Range(yds)	Search Target	Search Range (yds)
20	-	9-6	6	210	-	Ross	3000	-	-
23	-	9-7	2	055	-	Kern	1150	-	-
25	-	9-7	4	055	-	Miles	2700	-	-
26	-	9-7	5	210	W	Scott	2400	-	-
28	-	9-7	7	210	W	Reed	2800	-	-
30	-	9-7	9	210	-	Griffin	2200	-	-

SUMMARY OF OCCURRENCE OF SIGNIFICANT "F" VALUES ON DISCRIMINATIONS

	Runs			Observers			Instruments		
	Not Sig.	5%	1%	Not Sig.	5%	1%	Not Sig.	5%	1%
Target 1G and 100	2			2					2
Other Discriminations	5						3	2	
Total Discriminations Calculable		7			2			7	
Total Discriminations Observed		7			7			7	

Closest Discrimination Calculable: 4-G

ARITHMETIC MEANS 7 x 50 x 7 HH BY DISCRIMINATION

Discrimination	Mean Range(yds)	Discrimination	Mean Range(yds)	Discrimination	Mean Range(yds)
1-G	5083	4-G	2933		
1-100	4333	4-100	2333		
1-PI	3355	4-PI	1958		
3-G	3160				
3-100	2375				
3-PI	1790				

DATA ON RUNS FOR SET HZ-1

SUMMARY OF INSTRUMENTS

	Instruments			Position	90% RRP	50% RRP
1.	7x50x7	HH	-	varied	N.S.D	N.S.D.
2.	7x50x10	HH(HR)	-	varied	N.S.D.	N.S.D.
3.	10x50x7	HH	20	varied	N.S.D.	N.S.D.
4.	8x60x9	HH(-1d)	2111187	varied	N.S.D.	N.S.D.
5.	7x50x7	Mon. HH	259898	varied	N.S.D.	N.S.D.
6.	Naked Eye		-	varied	N.S.D.	N.S.D.

RANGES

Runs	Simult. Set	Date	No. on Date	Course	Wind	Observer Sect. Z	Target 3-100 Range(yds)	Search Target	Search Range (yds)
7	-	9-5	1	210	W	Dunham	1600	–	–
9	-	9-5	3	210	W	Williams	3550	–	–
11	-	9-5	5	055	-	Lamar	1300	–	–
13	-	9-5	7	055	-	Shlaer	1200	–	–
15	-	9-6	1	210	-	Mueller	2000	–	–
17	-	9-6	3	210	-	Hendley	2750	–	–

SUMMARY OF OCCURRENCE OF SIGNIFICANT "F" VALUES ON DISCRIMINATIONS

	Runs			Observers			Instruments		
	Not Sig.	5%	1%	Not Sig.	5%	1%	Not Sig.	5%	1%
Target 1G and 100			2			2			2
Other Discriminations									
Total Discriminations Calculable		2			2			2	
Total Discriminations Observed		2			2			2	

Closest Discrimination Calculable: 1-100

ARITHMETIC MEANS 7 x 50 x 7 HH BY DISCRIMINATION

Discrimination	Mean Range(yds)	Discrimination	Mean Range(yds)	Discrimination	Mean Range(yds)
IG	5833	4-G	3058		
1-100	5167	4-100	2177		
1-PI	3158	4-PI	1500		
3-G	2675				
3-100	2067				
3-PI	1287				

DATA ON RUNS FOR SET HZ-2

SUMMARY OF INSTRUMENTS

Instruments	Position	90% RRP	50% RRP
1. 7x50x7 HH -	varied	76.5	100.0
2. 7x50x10 HH(HR) 2	varied	81.5	106.0
3. 10x50x7 HH 20	varied	86.0	111.5
4. 8x60x9 HH(-1d) 2111187	varied	78.0	104.0
5. 7x50x7 Mon. HH 259898	varied	57.5	83.5
6. Naked Eye -	varied	-	-

RANGES

Runs	Simult. Set	Date	No. on Date	Course	Wind	Observer Sect. Z	Target 3-100 Range(yds)	Search Target	Search Range (yds)
19	-	9-6	5	055	-	Williams	3500	-	-
21	-	9-6	7	055	-	Shlaer	1200	-	-
22	-	9-7	1	210	W	Curtis	1850	-	-
24	-	9-7	3	210	W	Hendley	3050	-	-
27	-	9-7	6	055	-	Mueller	4000	-	-
29	-	9-7	8	055	-	Lamar	2000	-	-

SUMMARY OF OCCURRENCE OF SIGNIFICANT "F" VALUES ON DISCRIMINATIONS

	Runs			Observers			Instruments		
	Not Sig.	5%	1%	Not Sig.	5%	1%	Not Sig.	5%	1%
Target 1G and 100	1	1			1	1			2
Other Discriminations	6	1					7		
Total Discriminations Calculable		9			2			9	
Total Discriminations Observed		9			9			9	

Closest Discrimination Calculable: 4-PI

ARITHMETIC MEANS 7 x 50 x 7 HH BY DISCRIMINATION

Discrimination	Mean Range(yds)	Discrimination	Mean Range(yds)	Discrimination	Mean Range(yds)
1-G	4780	4-PI	1657		
1-100	4468				
1-PI	3042				
3-G	3338				
3-100	2600				
3-PI	1640				
4-G	3280				
4-100	2583				

DATA ON RUNS FOR SET MA

SUMMARY OF INSTRUMENTS

Instruments	Position	90% RRP	50% RRP
1. 6x33x8 3478	6	42.3	63.0
2. 4x28x10 -	5	40.0	59.0
3. 6x30x8.5 -	1	34.5	51.0
4. 7x50x7 HH 144989	4	83.5	100.0
5. 10x70x7 (NDRC)Mtd -	3	110.5	129.0
6. 10x50x7 Mtd. 3	2	94.0	110.2

RANGES

Runs	Simult. Set	Date	No. on Date	Course	Wind	Observer Sect. A	Target 3-100 Range(yds)	Search Target	Search Range (yds)
48	Aa-1	10-5	1	210	W	Coleman	2130	SC	3500
50	Aa-1	10-5	3	210	W	Brau	1760	SC	5800
52	Aa-1	10-5	5	210	W	Atchison	3630	SM	2350
54	Aa-2	10-5	7	065	-	Barberio	2300	SM	3500
72	Aa-2	10-9	1	210	W	Anderson	2450	SC	-
78	Aa-2	10-9	7	065	-	Casper	4700	SM	3850

SUMMARY OF OCCURRENCE OF SIGNIFICANT "F" VALUES ON DISCRIMINATIONS

	Runs			Observers			Instruments		
	Not Sig.	5%	1%	Not Sig.	5%	1%	Not Sig.	5%	1%
Target 1G and 100	1		1	2				1	1
Other Discriminations			4	1			1		3
Total Discriminations Calculable		6			3			6	
Total Discriminations Observed		6			6			6	

Closest Discrimination Calculable: 3-PI

ARITHMETIC MEANS 7 x 50 x 7 HH BY DISCRIMINATION

Discrimination	Mean Range(yds)	Discrimination	Mean Range(yds)	Discrimination	Mean Range(yds)
1-G	7092				
1-100	6667				
1-PI	3895				
3-G	4677				
3-100	2828				
3-PI	1743				

DATA ON RUNS FOR SET MB

SUMMARY OF INSTRUMENTS

	Instruments		Position	90% RRP	50% RRP
1.	6x33x8	3478	6	38.5	61.8
2.	4x28x10	-	5	23.5	45.0
3.	6x30x8.5	-	1	18.0	47.0
4.	7x50x7 HH	144989	4	77.0	100.0
5.	10x70x7 (NDRC)Mtd		3	85.5	110.0
6.	10x50x7 Mtd.	3	2	88.0	112.0

RANGES

Runs	Simult. Set	Date	No. on Date	Course	Wind	Observer Sect. B	Target 3-100 Range(yds)	Search Target	Search Range (yds)
49	Ab-1	10-5	2	065	-	Pedersen	3380	SM	2790
51	Ab-1	10-5	4	065	-	Bamford	2200	SM	-
53	Ab-1	10-5	6	210	W	Hughs	1950	SC	2470
55	Ab-2	10-5	8	210	W	Jagelewski	3800	SC	4200
73	Ab-2	10-9	2	065	-	Parker	3630	SM	-
75	Ab-2	10-9	4	065	-	Bridges	5750	SC	2950

SUMMARY OF OCCURRENCE OF SIGNIFICANT "F" VALUES ON DISCRIMINATIONS

	Runs			Observers			Instruments		
	Not Sig.	5%	1%	Not Sig.	5%	1%	Not Sig.	5%	1%
Target 1G and 100			2	2				1	1
Other Discriminations	7		3	1				4	2
Total Discriminations Calculable	12			4			12		
Total Discriminations Observed	12			12			12		
Closest Discrimination Calculable: 5-PI									

ARITHMETIC MEANS 7 x 50 x 7 HH BY DISCRIMINATION

Discrimination	Mean Range(yds)	Discrimination	Mean Range(yds)	Discrimination	Mean Range(yds)
1-G	8162	4-G	2845		
1-100	6383	4-100	2272		
1-PI	3992	4-PI	1447		
3-G	4432	6-G	3102		
3-100	3452	6-100	2535		
3-PI	1965	6-PI	1800		

DATA ON RUNS FOR SET M(1)D

SUMMARY OF INSTRUMENTS

	Instruments		Position	90% RRP	50% RRP
1.	6x33x8	-	6		
2.	4x28x10	-	5		
3.	6x30x8.5	-	1	EXCLUDED -	
4.	7x50x7 HH	144989	2	HIGH WINDS	
5.	20x120x3	-	4		
6.	10x70x7 (NDRC) Mtd	-	3		

RANGES

Runs	Simult. Set	Date	No. on Date	Course	Wind	Observer Sect. D	Target 3-100 Range(yds)	Search Target	Search Range (yds)
42	Ac-1	10-4	3	210	W	Louderback	3650	-	-
44	Ac-1	10-4	5	210	W	Zachmann	5400	-	-
46	Ac-2	10-4	7	210	W	Roark	4430	-	-
56	Ac-2	10-7	1	210	W	Shoemaker	5050	SC	3400
58	Ac-2	10-7	3	210	W	Ritter	2400	SC	2300
60	Fe-1	10-7	5	065	W	Klooz	4800	-	-

SUMMARY OF OCCURRENCE OF SIGNIFICANT "F" VALUES ON DISCRIMINATIONS

	Runs			Observers			Instruments		
	Not Sig.	5%	1%	Not Sig.	5%	1%	Not Sig.	5%	1%
Target 1G and 100			2		1	1			2
Other Discriminations		1	2	1					3
Total Discriminations Calculable	5			3			5		
Total Discriminations Observed	5			5			5		
Closest Discrimination Calculable: 3-100									

ARITHMETIC MEANS 7 x 50 x 7 HH BY DISCRIMINATION

Discrimination	Mean Range(yds)	Discrimination	Mean Range(yds)	Discrimination	Mean Range(yds)
1-G	6808	4-G	4590		
1-100	6350	4-100	4185		
1-PI	5120	4-PI	2968		
3-G	4868	6-G	3330		
3-100	4288	6-100	3038		
3-PI	3180	6-PI	2027		

DATA ON RUNS FOR SET M(1)E

SUMMARY OF INSTRUMENTS

Instruments			Position	90% RRP	50% RRP
1.	6x33x8	-	6	34.5	57.0
2.	4x28x10	-	5	N.S.D.	N.S.D.
3.	6x30x8.5	-	1	N.S.D.	N.S.D.
4.	7x50x7 HH	144989	2	76.0	100.0
5.	20x120x3	-	4	151.0	183.0
6.	10x70x7 (NDRC) Mtd.		3	112.0	136.0

RANGES

Runs	Simult. Set	Date	No. on Date	Course	Wind	Observer Sect. E	Target 3-100 Range(yds)	Search Target	Search Range (yds)
41	Ad-1	10-4	2	065	-	Shook	5850		
43	Ad-1	10-4	4	065	-	Myers	5900		
45	Ad-1	10-4	6	065	-	Pusateri	3230		
47	Ad-2	10-4	8	065	-	Webb	3300		
57	Ad-2	10-7	2	065	-	Rice	3700		
59	Ad-2	10-7	4	065	-	Nixon	3200		

SUMMARY OF OCCURRENCE OF SIGNIFICANT "F" VALUES ON DISCRIMINATIONS

	Runs			Observers			Instruments		
	Not Sig.	5%	1%	Not Sig.	5%	1%	Not Sig.	5%	1%
Target 1G and 100			2		1	1			2
Other Discriminations	6	1	3	2					10
Total Discriminations Calculable	12			4			12		
Total Discriminations Observed	12			12			12		
Closest Discrimination Calculable: 5-PI									

ARITHMETIC MEANS 7 x 50 x 7 HH BY DISCRIMINATION

Discrimination	Mean Range(yds)	Discrimination	Mean Range(yds)	Discrimination	Mean Range(yds)
1-G	7088	4-G	3988		
1-100	6867	4-100	3043		
1-PI	4608	4-PI	1857		
3-G	5148	6-G	3255		
3-100	4197	6-100	2778		
3-PI	2317	6-PI	1900		

DATA ON RUNS FOR SET P(1)A

SUMMARY OF INSTRUMENTS

Instruments			Position	90% RRP	50% RRP
1.	7x50x7 HH	408395	3	77.8	100.0
2.	20x120x3	-	4	157.0	189.0
3.	25x100x3.6	-	2	142.5	167.0
4.	10x80x7	-	5	116.5	138.5
5.	21x76x2.8	-	1	69.0	84.5
6.	24x96x2.2	-	6	101.0	119.0

RANGES

Runs	Simult. Set	Date	No. on Date	Course	Wind	Observer Sect. A	Target 3-100 Range(yds)	Search Target	Search Range (yds)
143	D(5)i	11-9	3	210	W	Casper	2400	SC	4700
145	D(5)i	11-9	5	210	W	Coleman	2500	SC	4100
147	D(5)i	11-9	7	210	W	Barberio	2530	SC	4200
149	D(10)n	11-26	1	210	W	Anderson	5650	SC	6270
151	D(10)n	11-26	3	210	W	Atchison	4700	SC	6300
153	D(10)n	11-26	5	210	W	Brau	4410	SC	6400

SUMMARY OF OCCURRENCE OF SIGNIFICANT "F" VALUES ON DISCRIMINATIONS

	Runs			Observers			Instruments		
	Not Sig.	5%	1%	Not Sig.	5%	1%	Not Sig.	5%	1%
Target 1G and 100	2			2					2
Other Discriminations	9	2	5	3	1			2	14
Total Discriminations Calculable	18			6			18		
Total Discriminations Observed	18			18			18		
Closest Discrimination Calculable: 7-PI									

ARITHMETIC MEANS 7 x 50 x 7 HH BY DISCRIMINATION

Discrimination	Mean Range(yds)	Discrimination	Mean Range(yds)	Discrimination	Mean Range(yds)
1-G	9790	4-G	4522	7-G	2638
1-100	8325	4-100	3228	7-100	1922
1-PI	5243	4-PI	1993	7-PI	1412
3-G	5742	6-G	2440	5-G	4600
3-100	3698	6-100	1738	5-100	3532
3-PI	2023	6-PI	1348	5-PI	2002

DATA ON RUNS FOR SET PD

SUMMARY OF INSTRUMENTS

	Instruments		Position	90% RRP	50% RRP
1.	7x50x7 HH	108395	3	77.0	100.0
2.	20x120x3	-	4	153.0	180.0
3.	25x100x3.6	-	2	141.5	170.0
4.	10x80x7	-	5	108.0	135.0
5.	21x76x2.8	-	1	52.5	73.0
6.	16x96x2.8	-	6	93.0	117.0

Runs	Simult. Set	Date	No. on Date	Course	Wind	Observer Sect. D	RANGES Target 3-100 Range(yds)	Search Target	Search Range (yds)
133	Hk	11-8	3	210	-	Roark	1700	SC	3250
135	Hk	11-8	5	210	-	Klooz	2400	SC	1950
137	-	11-8	7	210	-	Louderback	2800	SC	3900
139	-	11-8	9	210	-	Zachmann	2400	SC	4200
154	D(5)k	11-27	1	210	-	Ritter	4900	SC	4750
156	D(5)k	11-27	3	210	-	Shoemaker	5150	SC	4600

SUMMARY OF OCCURRENCE OF SIGNIFICANT "F" VALUES ON DISCRIMINATIONS

	Runs			Observers			Instruments		
	Not Sig.	5%	1%	Not Sig.	5%	1%	Not Sig.	5%	1%
Target 1G and 100			2	2					2
Other Discriminations	1	3	9	2	1	1		3	10
Total Discriminations Calculable		15			6			15	
Total Discriminations Observed		15			15			15	

Closest Discrimination Calculable: 7-PI

ARITHMETIC MEANS 7 x 50 x 7 HH BY DISCRIMINATION

Discrimination	Mean Range(yds)	Discrimination	Mean Range(yds)	Discrimination	Mean Range(yds)
1-G	6958	4-G	3200	7-G	2168
1-100	6125	4-100	2452	7-100	1707
1-PI	4083	4-PI	1805	7-PI	1363
3-G	3942	6-G	2477		
3-100	3225	6-100	2080		
3-PI	2200	6-PI	1492		

DATA ON RUNS FOR SET P(1)F

SUMMARY OF INSTRUMENTS

	Instruments		Position	90% RRP	50% RRP
1.	7x50x7 HH	408395	3	72.5	100.0
2.	20x120x3	-	4	137.5	171.5
3.	25x100x3.6	-	2	152.0	191.0
4.	10x80x7	-	5	91.0	116.0
5.	21x76x2.8	-	1	45.0	71.5
6.	24x96x2.2	-	6	103.0	132.0

Runs	Simult. Set	Date	No. on Date	Course	Wind	Observer Sect. F	RANGES Target 3-100 Range(yds)	Search Target	Search Range (yds)
142	D(5)j	11-9	2	065	-	Fillissey	2730	SM	3250
144	D(5)j	11-9	4	065	-	Tucker	3680	SM	2300
146	D(5)j	11-9	6	065	-	Miller	4450	SM	3370
148	D(10)j	11-9	8	065	-	Courtney	4500	SM	1320
150	D(10)j	11-26	2	065	-	Lamontagne	2500	SM	4100
152	D(10)k	11-26	4	065	-	Naumann	3230	SM	3900

SUMMARY OF OCCURRENCE OF SIGNIFICANT "F" VALUES ON DISCRIMINATIONS

	Runs			Observers			Instruments		
	Not Sig.	5%	1%	Not Sig.	5%	1%	Not Sig.	5%	1%
Target 1G and 100	2			1	1				2
Other Discriminations	12	1		4				4	9
Total Discriminations Calculable		15			6			15	
Total Discriminations Observed		15			15			15	

Closest Discrimination Calculable: 7-PI

ARITHMETIC MEANS 7 x 50 x 7 HH BY DISCRIMINATION

Discrimination	Mean Range(yds)	Discrimination	Mean Range(yds)	Discrimination	Mean Range(yds)
1-G	8947	6-G	2895		
1-100	7013	6-100	2493		
1-PI	4165	6-PI	1760		
3-G	4288	7-G	1980		
3-100	3515	7-100	1760		
3-PI	2288	7-PI	1417		

DATA ON RUNS FOR SET PG

SUMMARY OF INSTRUMENTS

	Instruments		Position	90% RRP	50% RRP
1.	7x50x7 HH	408395	3	72.8	100.0
2.	20x120x3	-	4	149.0	187.5
3.	25x100x3.6	-	2	156.0	191.8
4.	10x80x7	-	5	85.0	114.0
5.	21x76x2.8	-	1	80.0	110.0
6.	16x96x3.2	-	6	85.5	115.0

RANGES

Runs	Simult. Set	Date	No. on Date	Course	Wind	Observer Sect. G	Target 3-100 Range(yds)	Search Target	Search Range (yds)
134	H1	11-8	4	065	W	Myers	2150	SM	2400
136	H1	11-8	6	065	W	Rice	2330	SM	4500
138	-	11-8	8	065	W	Milling	1630	SM	3800
140	-	11-8	10	065	W	Pusateri	2930	SM	5050
155	D(5)m	11-27	2	065	W	Staton	4330	SM	3700
157	D(5)m	11-27	4	065	W	Foley	4800	SM	2400

SUMMARY OF OCCURRENCE OF SIGNIFICANT "F" VALUES ON DISCRIMINATIONS

	Runs			Observers			Instruments		
	Not Sig.	5%	1%	Not Sig.	5%	1%	Not Sig.	5%	1%
Target 1G and 100	1		2		2				2
Other Discriminations		2	6	4	1		3		5
Total Discriminations Calculable		10			7			10	
Total Discriminations Observed		10			10			10	

Closest Discrimination Calculable: 5-G

ARITHMETIC MEANS 7 x 50 x 7 HH BY DISCRIMINATION

Discrimination	Mean Range(yds)	Discrimination	Mean Range(yds)	Discrimination	Mean Range(yds)
1-G	6422	4-G	3423	7-G	2448
1-100	6008	4-100	2847	7-100	1752
1-PI	3788	4-PI	2003	7-PI	1327
3-G	3938	6-G	2800		
3-100	3028	6-100	2222		
3-PI	1967	6-PI	1585		

DATA ON RUNS FOR SET VD

SUMMARY OF INSTRUMENTS

	Instruments			Position	90% RRP	50% RRP
1.	7x50x7	HH	408395	1	96.0	115.0
2.	7x50x7	HH	259904	2	60.0	91.5
3.	7x50x7	HH	408382	3	70.0	101.0
4.	7x50x7	HH	408385	4	75.0	107.0
5.	7x50x7	HH	408389	5	53.5	85.5
6.	7x50x7	HH	259902	6	66.0	97.5

RANGES

Runs	Simult. Set	Date	No. on Date	Course	Wind	Observer Sect. D	* Target 3-100 Range(yds)	Search Target	Search Range (yds)
94	Wg-1	10-11	3	210	-	Roark	4480	SC	-
96	Wg-1	10-11	5	210	-	Klooz	3690	SC	-
98	Wg-2	10-11	7	210	-	Lauderback	2000	SC	-
99	Wg-2	11-1	1	210	-	Ritter	4000	SC	3600
101	Wg-2	11-1	3	210	-	Zachmann	3650	SC	3800
105	-	11-1·	7	210		Shoemaker	4200	SC	5150

*Taken from Position 3.

SUMMARY OF OCCURRENCE OF SIGNIFICANT "F" VALUES ON DISCRIMINATIONS

	Runs			Observers			Instruments		
	Not Sig.	5%	1%	Not Sig.	5%	1%	Not Sig.	5%	1%
Target 1G and 100			2	2			2		
Other Discriminations	8	2		7			10		
Total Discriminations Calculable		12			9			12	
Total Discriminations Observed		12			12			12	

Closest Discrimination Calculable: 5-PI

ARITHMETIC MEANS 7 x 50 x 7 HH BY DISCRIMINATION

Discrimination	Mean Range(yds)	Discrimination	Mean Range(yds)	Discrimination	Mean Range(yds)
1-G	7223	4-G	4499		
1-100	6557	4-100	3840		
1-PI	4713	4-PI	3158		
3-G	4828	6-G	3238		
3-100	4065	6-100	2567		
3-PI	2952	6-PI	2070		

DATA ON RUNS FOR SET VE

SUMMARY OF INSTRUMENTS

	Instruments		Position	90% RRP	50% RRP
1.	7x50x7 HH	408395	1	88.0	101.8
2.	7x50x7 HH	259904	2	86.5	97.0
3.	7x50x7 HH	408382	3	92.5	103.3
4.	7x50x7 HH	408385	4	86.8	99.0
5.	7x50x7 HH	408389	5	93.5	104.0
6.	7x50x7 HH	259902	6	83.0	94.0

RANGES

Runs	Simult. Set	Date	No. on Date	Course	Wind	Observer Sect. E	Target 3-100 Range(yds)	Search Target	Search Range (yds)
93	Wh-1	10-11	2	065	-	Rice	2580	SM	-
95	Wh-1	10-11	4	065	-	Webb	4080	SM	-
97	Wh-1	10-11	6	065	-	Myers	3600	SM	-
100	Wh-2	11-1	2	065	-	Farone	4400	SM	-
102	Wh-2	11-1	4	065	-	Shook	4000	SM	-
106	Wh-2	11-1	8	065	-	Nixon	4500	SM	-

SUMMARY OF OCCURRENCE OF SIGNIFICANT "F" VALUES ON DISCRIMINATIONS

	Runs			Observers			Instruments		
	Not Sig.	5%	1%	Not Sig.	5%	1%	Not Sig.	5%	1%
Target 1G and 100			2	2			2		
Other Discriminations	8		2	1	1	5	10		
Total Discriminations Calculable		12			9			12	
Total Discriminations Observed		12			12			12	

Closest Discrimination Calculable: 5-PI

ARITHMETIC MEANS 7 x 50 x 7 HH BY DISCRIMINATION

Discrimination	Mean Range(yds)	Discrimination	Mean Range(yds)	Discrimination	Mean Range(yds)
1-G	7723	4-G	4222		
1-100	7612	4-100	3495		
1-PI	4478	4-PI	2250		
3-G	5297	6-G	2700		
3-100	4122	6-100	1932		
3-PI	2203	6-PI	1378		

DATA ON RUNS FOR SET Aa-1

SUMMARY OF INSTRUMENTS

	Instruments		Position	90% RRP	50% RRP
1.	7x50x7 HH	-	varied	75.0	100.0
2.	7x50x10 HH	MZ5069	varied	71.0	97.0
3.	7x50x10 HH(HR)	BG-831	varied	79.0	103.0
4.					
5.					
6.					

RANGES

Runs	Simult. Set	Date	No. on Date	Course	Wind	Observer Sect. a	Target 3-100 Range(yds)	Search Target	Search Range (yds)
48	MA	10-5	1	210	W	Zink	1700	SC	4000
50	MA	10-5	3	210	W	Lamontagne	3500	SC	4420
52	MA	10-5	5	210	W	Phillips	1980	SM	-

SUMMARY OF OCCURRENCE OF SIGNIFICANT "F" VALUES ON DISCRIMINATIONS

	Runs			Observers			Instruments		
	Not Sig.	5%	1%	Not Sig.	5%	1%	Not Sig.	5%	1%
Target 1G and 100	2			2			2		
Other Discriminations	4			4			4		
Total Discriminations Calculable		6			6			6	
Total Discriminations Observed		6			6			6	

Closest Discrimination Calculable: 3 PI

ARITHMETIC MEANS 7 x 50 x 7 HH BY DISCRIMINATION

Discrimination	Mean Range(yds)	Discrimination	Mean Range(yds)	Discrimination	Mean Range(yds)
1-0	7267	3-G	3600		
1-100	6200	3-100	2393		
1-PI	2950	3-PI	1767		
6-G	2067	6-PI	1060		
3 (6x6 Blk)100	1590				

DATA ON RUNS FOR SET Aa-2

SUMMARY OF INSTRUMENTS

Instruments			Position	90% RRP	50% RRP
1.	7x50x7 HH	-	varied	82.0	100.0
2.	7x50x10 HH	MZ5069	varied	92.0	106.0
3.	7x50x10 HH(HR)	BG-831	varied	87.0	97.0
4.					
5.					
6.					

RANGES

Runs	Simult. Set	Date	No. on Date	Course	Wind	Observer Sect. a	Target 3-100 Range(yds)	Search Target	Search Range (yds)
54	MA	10-5	7	065	-	Zink	2600	SM	3370
72	MA	10-9	1	210	W	Lamontagne	3200	SC	-
78	MA	10-9	7	065	-	Phillips	3550	SM	4250

SUMMARY OF OCCURRENCE OF SIGNIFICANT "F" VALUES ON DISCRIMINATIONS

	Runs			Observers			Instruments		
	Not Sig.	5%	1%	Not Sig.	5%	1%	Not Sig.	5%	1%
Target 1G and 100		1	1	2			2		
Other Discriminations	3		1	4			4		
Total Discriminations Calculable	6			6			6		
Total Discriminations Observed	6			6			6		
Closest Discrimination Calculable: 3-PI									

ARITHMETIC MEANS 7 x 50 x 7 HH BY DISCRIMINATION

Discrimination	Mean Range(yds)	Discrimination	Mean Range(yds)	Discrimination	Mean Range(yds)
1-G	7033	6-G	2737		
1-100	6967	6-100	2193		
1-PI	3700	6-PI	1623		
3-G	3900				
3-100	3117				
3-PI	1963				

DATA ON RUNS FOR SET Ab-1

SUMMARY OF INSTRUMENTS

Instruments			Position	90% RRP	50% RRP
1.	7x50x7 HH	-	varied	81.0	100.0
2.	7x50x10 HH	MZ5069	varied	89.0	105.0
3.	7x50x10 HH(HR)	BG-831	varied	82.0	95.0
4.					
5.					
6.					

RANGES

Runs	Simult. Set	Date	No. on Date	Course	Wind	Observer Sect. b	Target 3-100 Range(yds)	Search Target	Search Range (yds)
49	MB	10-5	2	065	-	Brazil	2900	SM	2980
51	MB	10-5	4	065	-	Brown	2200	SM	-
53	MB	10-5	6	210	W	Hambrick	1310	SC	2920

SUMMARY OF OCCURRENCE OF SIGNIFICANT "F" VALUES ON DISCRIMINATIONS

	Runs			Observers			Instruments		
	Not Sig.	5%	1%	Not Sig.	5%	1%	Not Sig.	5%	1%
Target 1G and 100		1	1	2			2		
Other Discriminations	7	1	1	6	2	1	8		1
Total Discriminations Calculable	11			11			11		
Total Discriminations Observed	15			15			15		
Closest Discrimination Calculable: 6-PI									

ARITHMETIC MEANS 7 x 50 x 7 HH BY DISCRIMINATION

Discrimination	Mean Range(yds)	Discrimination	Mean Range(yds)	Discrimination	Mean Range(yds)
1-G	6477	6-G	2510		
1-100	5357	6-100	2043		
1-PI	3400	6-PI	1483		
3-G	3110	7-G	1300		
3-100	2203	7-100	1223		
3-PI	1780	7-PI	1077		

DATA ON RUNS FOR SET Ab-2

SUMMARY OF INSTRUMENTS

	Instruments		Position	90% RRP	50% RRP
1.	7x50x7 HH	-	varied	75.0	100.0
2.	7x50x10 HH	MZ5069	varied	85.0	104.0
3.	7x50x10 HH (HR)	BG-832	varied	90.0	110.0
4.					
5.					
6.					

RANGES

Runs	Simult. Set	Date	No. on Date	Course	Wind	Observer .Sect. b	Target 3-100 Range(yds)	Search Target	Search Range (yds)
55	MB	10-5	8	210	W	Brazil	2330	SC	4000
73	MB	10-9	2	065	---	Hambrick	2690	SM	4000
75	MB	10-9	4	065	---	Brown	2700	SM	4000

SUMMARY OF OCCURRENCE OF SIGNIFICANT "F" VALUES ON DISCRIMINATIONS

	Runs			Observers			Instruments		
	Not Sig.	5%	1%	Not Sig.	5%	1%	Not Sig.	5%	1%
Target 1G and 100	1		1	2			2		
Other Discriminations	6	3		9			9		
Total Discriminations Calculable		11			11			11	
Total Discriminations Observed		15			15			15	

Closest Discrimination Calculable: 6-PI

ARITHMETIC MEANS 7 x 50 x 7 HH BY DISCRIMINATION

Discrimination	Mean Range(yds)	Discrimination	Mean Range(yds)	Discrimination	Mean Range(yds)
1-G	7417	4-G	2253		
1-100	7200	4-100	2010		
1-PI	3920	4-PI	1720		
3-G	3693	6-G	2777		
3-100	2573	6-100	2107		
3-PI	2077	6-PI	1670		

DATA ON RUNS FOR SET Ac-1

SUMMARY OF INSTRUMENTS

	Instruments		Position	90% RRP	50% RRP
1.	7x50x7 HH	-	varied	83.0	100.0
2.	7x50x10 HH	-	varied	90.0	106.0
3.	7x50x10 HH(HR)	-	varied	112.0	143.0
4.					
5.					
6.					

RANGES

Runs	Simult. Set	Date	No. on Date	Course	Wind	Observer Sect. c	Target 3-100 Range(yds)	Search Target	Search Range (yds)
40	-	10-21	1	210	W	Sagaser	1400		
42	M(1)D	10-4	3	210	W	Stroud	1200		
44	M(1)D	10-4	5	210	W	Cole	1850		

SUMMARY OF OCCURRENCE OF SIGNIFICANT "F" VALUES ON DISCRIMINATIONS

	Runs			Observers			Instruments		
	Not Sig.	5%	1%	Not Sig.	5%	1%	Not Sig.	5%	1%
Target 1G and 100		2		1	1		2		
Other Discriminations	3	1		2	2		4		
Total Discriminations Calculable		6			6			6	
Total Discriminations Observed		9			9			9	

Closest Discrimination Calculable: 4-PI

ARITHMETIC MEANS 7 x 50 x 7 HH BY DISCRIMINATION

Discrimination	Mean Range(yds)	Discrimination	Mean Range(yds)	Discrimination	Mean Range(yds)
1-G	6197				
1-100	5977				
1-PI	3030				
3-G	1583				
3-100	1483				
3-PI	1120				

DATA ON RUNS FOR SET Ac-2

SUMMARY OF INSTRUMENTS

	Instruments		Position	90% RRP	50% RRP
1.	7x50x7 HH	-	varied	72.0	100.0
2.	7x50x10 HH	-	varied	-	69.0
3.	7x50x10 HHR	-	varied	52.0	84.0
4.					
5.					
6.					

RANGES

Runs	Simult. Set	Date	No. on Date	Course	Wind	Observer Sect. c	Target 3-100 Range(yds)	Search Target	Search Range (yds)
46	M(1)D	10-4	7	210	W	Sagaser	3100	-	-
56	M(1)D	10-7	1	210	W	Cole	2140	SC	1250
58	M(1)D	10-7	3	210	W	Stroud	2150	-	-

SUMMARY OF OCCURRENCE OF SIGNIFICANT "F" VALUES ON DISCRIMINATIONS

	Runs			Observers			Instruments		
	Not Sig.	5%	1%	Not Sig.	5%	1%	Not Sig.	5%	1%
Target 1G and 100	2			2			2		
Other Discriminations	5			5			5		
Total Discriminations Calculable	7			7			7		
Total Discriminations Observed	9			9			9		

Closest Discrimination Calculable: 4-PI

ARITHMETIC MEANS 7 x 50 x 7 HH BY DISCRIMINATION

Discrimination	Mean Range(yds)	Discrimination	Mean Range(yds)	Discrimination	Mean Range(yds)
1-G	5667	4-G	2390		
1-100	4893	4-100	2030		
1-PI	2427	4-PI	1097		
3-G	2783				
3-100	2463				
3-PI	1420				

DATA ON RUNS FOR SET Ad-1

SUMMARY OF INSTRUMENTS

	Instruments		Position	90% RRP	50% RRP
1.	7x50x7 HH	-	varied	71.0	100.0
2.	7x50x10 HH	-	varied	69.0	98.5
3.	7x50x10 HH(HR)	-	varied	85.0	114.0
4.					
5.					
6.					

RANGES

Runs	Simult. Set	Date	No. on Date	Course	Wind	Observer Sect. d	Target 3-100 Range(yds)	Search Target	Search Range (yds)
41	M(1) E	10-4	2	065	-	Venski	2850	-	-
43	M(1) E	10-4	4	065	-	Saidikowski	2330	-	-
45	M(1) E	10-4	6	065	-	Vedovato	3450	-	-

SUMMARY OF OCCURRENCE OF SIGNIFICANT "F" VALUES ON DISCRIMINATIONS

	Runs			Observers			Instruments		
	Not Sig.	5%	1%	Not Sig.	5%	1%	Not Sig.	5%	1%
Target 1G and 100	1	1		2			2		
Other Discriminations	12	1		12	1		13		
Total Discriminations Calculable	15			15			15		
Total Discriminations Observed	15			15			15		

Closest Discrimination Calculable: 6 PI

ARITHMETIC MEANS 7 x 50 x 7 HH BY DISCRIMINATION

Discrimination	Mean Range(yds)	Discrimination	Mean Range(yds)	Discrimination	Mean Range(yds)
1-G	8040	4G	4070		
1-100	7267	4-100	2850		
1-PI	4427	4-PI	2043		
3-G	4927	6-G	2670		
3-100	2877	6-100	2083		
3-PI	1727	6-PI	1490		

DATA ON RUNS FOR SET Ad-2

SUMMARY OF INSTRUMENTS

	Instruments		Position	90% RRP	50% RRP
1.	7x50x7 HH	-	varied	83.0	100.0
2.	7x50x10 HH	-	varied	82.0	94.0
3.	7x50x10 HH(HR)	-	varied	82.0	95.5
4.					
5.					
6.					

RANGES

Runs	Simult. Set	Date	No. on Date	Course	Wind	Observer Sect. d	Target 3-100 Range(yds)	Search Target	Search Range (yds)
47	M(1)E	10-4	8	055	-	Venski	2560	-	-
57	M(1)E	10-7	2	065	-	Saidikowski	3400	SM	-
59	M(1)E	10-7	4	065	-	Vedovato	2600	SM	-

SUMMARY OF OCCURRENCE OF SIGNIFICANT "F" VALUES ON DISCRIMINATIONS

	Runs			Observers			Instruments		
	Not Sig.	5%	1%	Not Sig.	5%	1%	Not Sig.	5%	1%
Target 1G and 100		1	1	2			2		
Other Discriminations	12	1		11	2		13		
Total Discriminations Calculable		15			15			15	
Total Discriminations Observed		15			15			15	

Closest Discrimination Calculable: 6 PI

ARITHMETIC MEANS 7 x 50 x 7 HH BY DISCRIMINATION

Discrimination	Mean Range(yds)	Discrimination	Mean Range(yds)	Discrimination	Mean Range(yds)
1-G	7347	4-G	3283		
1-100	6727	4-100	2653		
1-PI	3817	4-PI	1850		
3-G	3650	6-G	2770		
3-100	2853	6-100	2257		
3-PI	1967	6-PI	1610		

DATA ON RUNS FOR SET D(5)1

SUMMARY OF INSTRUMENTS

	Instruments		Position	90% RRP	50% RRP
1.	7x50x7 HH	408395	8	76.0	100.0
2.	9x63x5.7 HH	3464	7	104.0	119.0
3.	9x63x5.7 Mtd.	3463	9	105.0	119.0
4.					
5.					
6.					

RANGES

Runs	Simult. Set	Date	No. on Date	Course	Wind	Observer Sect. 1	Target 3-100 Range(yds)	Search Target	Search Range (yds)
143	P(1)A	11-9	3	210	W	Hughs	1650	SC	2350
145	P(1)A	11-9	5	210	W	Bridges	2300	SC	3750
147	P(1)A	11-9	7	210	W	Farone	2400	SC	3500

SUMMARY OF OCCURRENCE OF SIGNIFICANT "F" VALUES ON DISCRIMINATIONS

	Runs			Observers			Instruments		
	Not Sig.	5%	1%	Not Sig.	5%	1%	Not Sig.	5%	1%
Target 1G and 100	2			2			2		
Other Discriminations	5	1	1	5	1	1	5	2	
Total Discriminations Calculable		9			9			9	
Total Discriminations Observed		12			12			12	

Closest Discrimination Calculable: 7-PI

ARITHMETIC MEANS 7 x 50 x 7 HH BY DISCRIMINATION

Discrimination	Mean Range(yds)	Discrimination	Mean Range(yds)	Discrimination	Mean Range(yds)
1-G	7850	7-G	3377		
1-100	6633	7-100	1577		
1-PI	2767	7-PI	1253		
3-G	3617				
3-100	2117				
3-PI	1310				

DATA ON RUNS FOR SET D(5)j

SUMMARY OF INSTRUMENTS

	Instruments			Position	90% RRP	50% RRP
1.	7x50x7	HH	408395	8	83.0	100.0
2.	9x63x5.7	HH	3464	7	97.0	109.0
3.	9x63x5.7	Mtd.	3463	9	104.0	118.0
4.						
5.						
6.						

RANGES

Runs	Simult. Set	Date	No. on Date	Course	Wind	Observer Sect. j	Target 3-100 Range(yds)	Search Target	Search Range (yds)
142	P(1)F	11-9	2	065		Jagelewski	3650	SM	3800
144	P(1)F	11-9	4	065		Bamford	2330	SM	3250
146	P(1)F	11-9	6	065		Parker	3000	SM	3620

SUMMARY OF OCCURRENCE OF SIGNIFICANT "F" VALUES ON DISCRIMINATIONS

	Runs			Observers			Instruments		
	Not Sig.	5%	1%	Not Sig.	5%	1%	Not Sig.	5%	1%
Target 1G and 100	1	1		2			2		
Other Discriminations	9	1		8	2		8	2	
Total Discriminations Calculable	12			12			12		
Total Discriminations Observed	12			12			12		

Closest Discrimination Calculable: 7-PI

ARITHMETIC MEANS 7 x 50 x 7 HH BY DISCRIMINATION

Discrimination	Mean Range(yds)	Discrimination	Mean Range(yds)	Discrimination	Mean Range(yds)
1-G1	8550	G	3120		
1-100	6677	100	2583		
1-PI	3267	PI	1793		
3-G	4633	G	2577		
3-100	2993	100	1910		
3-PI	2077	PI	1593		

DATA ON RUNS FOR SET D(5)k

SUMMARY OF INSTRUMENTS

	Instruments			Position	90% RRP	50% RRP
1.	7x50x7	HH	408395	7	76.0	100.0
2.	9x63x5.7	HH	3464	8	84.0	104.0
3.	9x63x5.7	Mtd.	3463	9	81.0	102.0
4.						
5.						
6.						

RANGES

Runs	Simult. Set	Date	No. on Date	Course	Wind	Observer Sect. k	Target 3-100 Range(yds)	Search Target	Search Range (yds)
154	PD	11-27	1	210	-	Barger	2150	SC	4170
156	PD	11-27	3	210	-	Pauli	4030	SC	5450
158	-	11-27	5	210	W	Stroud	1800	SC	5100

SUMMARY OF OCCURRENCE OF SIGNIFICANT "F" VALUES ON DISCRIMINATIONS

	Runs			Observers			Instruments		
	Not Sig.	5%	1%	Not Sig.	5%	1%	Not Sig.	5%	1%
Target 1G and 100	1		1	2			2		
Other Discriminations	15	1		15	1		16		
Total Discriminations Calculable	18			18			18		
Total Discriminations Observed	18			18			18		

Closest Discrimination Calculable: 7 PI

ARITHMETIC MEANS 7 x 50 x 7 HH BY DISCRIMINATION

Discrimination	Mean Range(yds)	Discrimination	Mean Range(yds)	Discrimination	Mean Range(yds)
1-G	9487	4-PI	1467	7-100	2637
1-100	9260	5-G	3883	7-PI	1573
1-PI	3267	5-100	2567		
3-G	6203	5-PI	1480		
3-100	2660	6-G	3127		
3-PI	1990	6-100	2143		
4-G	4167	6-PI	1280		
4-100	2610	7-G	3293		

DATA ON RUNS FOR SET D(10)n

SUMMARY OF INSTRUMENTS

	Instruments		Position	90% RRP	50% RRP
1.	7x50x7 HH	408395	8	76.0	100.0
2.	7x50x10 HH	MZ5069	7	84.0	96.0
3.	7x50x10 Mtd	BG8533	9	85.0	100.0
4.					
5.					
6.					

RANGES

Runs	Simult. Set	Date	No. on Date	Course	Wind	Observer Sect. n	Target 3-100 Range(yds)	Search Target	Search Range (yds)
149	P(1)A	11-26	1	210	W	Farone	3350	SC	5350
151	P(1)A	11-26	3	210	W	Hughs	1900	SC	3820
153	P(1)A	11-26	5	210	W	Sagaser	2300	SC	4300

SUMMARY OF OCCURRENCE OF SIGNIFICANT "F" VALUES ON DISCRIMINATIONS

	Runs			Observers			Instruments		
	Not Sig.	5%	1%	Not Sig.	5%	1%	Not Sig.	5%	1%
Target 1G and 100	2			2			2		
Other Discriminations	12	1	1	12	2		14		
Total Discriminations Calculable	16			16			16		
Total Discriminations Observed	18			18			18		

Closest Discrimination Calculable: 7 PI

ARITHMETIC MEANS 7 x 50 x 7 HH BY DISCRIMINATION

Discrimination	Mean Range(yds)	Discrimination	Mean Range(yds)	Discrimination	Mean Range(yds)
1-G	9443	4-PI	1600	7-100	1617
1-100	8433	5-G	2633	7-PI	1020
1-PI	3067	5-100	1967		
3-G	3610	5-PI	1440		
3-100	2517	6-G	1883		
3-PI	1613	6-100	1517		
4-G	3910	6-PI	--		
4-100	2700	7-G	1950		

DATA ON RUNS FOR SET D(10)o

SUMMARY OF INSTRUMENTS

	Instruments		Position	90% RRP	50% RRP
1.	7x50x7 HH	408395	varied	84.0	100.0
2.	7x50x10 HH	MZ5069	varied	85.0	96.0
3.	7x50x10 Mtd.	BG8533	varied	96.0	102.0
4.					
5.					
6.					

RANGES

Runs	Simult. Set	Date	No. on Date	Course	Wind	Observer Sect. o	Target 3-100 Range(yds)	Search Target	Search Range (yds)
160	EH	12-8	1	210	W	Meadnis	-	SC	1700
162	EH	12-8	3	210	W	Vedovato	-	SC	2250
164	EH	12-8	5	210	W	Luce	1600	SC	1900

SUMMARY OF OCCURRENCE OF SIGNIFICANT "F" VALUES ON DISCRIMINATIONS

	Runs			Observers			Instruments		
	Not Sig.	5%	1%	Not Sig.	5%	1%	Not Sig.	5%	1%
Target 1G and 100	2			2			2		
Other Discriminations	4	1		4		1	4	1	
Total Discriminations Calculable	7			7			7		
Total Discriminations Observed	12			12			12		

Closest Discrimination Calculable: 6 PI

ARITHMETIC MEANS 7 x 50 x 7 HH BY DISCRIMINATION

Discrimination	Mean Range(yds)	Discrimination	Mean Range(yds)	Discrimination	Mean Range(yds)
1-G	4397	6-G	1700		
1-100	2833	6-100	1313		
1-PI	1583	6-PI	-		
4-G	1817				
4-100	1513				
4-PI	--				

DATA ON RUNS FOR SET D(10)p

SUMMARY OF INSTRUMENTS

	Instruments		Position	90% RRP	50% RRP
1.	7x50x7 HH	408395	varied	79.0	100.0
2.	7x50x10 HH	MZ5069	varied	103.0	117.0
3.	7x50x10 Mtd.	BT6826	9	103.0	117.0
4.					
5.					
6.					

RANGES

Runs	Simult. Set	Date	No. on Date	Course	Wind	Observer Sect. p	Target 3-100 Range(yds)	Search Target	Search Range (yds)
161	EJ	12-8	2	065	-	Stanley	1800	SM	1630
163	EJ	12-8	4	065	-	Lemaster	1650	SM	-
165	EJ	12-8	6	065	-	Strickland	2100	SM	3500

SUMMARY OF OCCURRENCE OF SIGNIFICANT "F" VALUES ON DISCRIMINATIONS

	Runs			Observers			Instruments		
	Not Sig.	5%	1%	Not Sig.	5%	1%	Not Sig.	5%	1%
Target 1G and 100	2			2			2		
Other Discriminations	10			10			10		
Total Discriminations Calculable	12			12			12		
Total Discriminations Observed	12			12			12		

Closest Discrimination Calculable: 6 PI

ARITHMETIC MEANS 7 x 50 x 7 HH BY DISCRIMINATION

Discrimination	Mean Range(yds)	Discrimination	Mean Range(yds)	Discrimination	Mean Range(yds)
1-G	4993	4-100	1767		
1-100	4377	4-PI	1120		
1-PI	2150	6-G	1950		
3-G	1950	6-100	1767		
3-100	1850	6-PI	1120		
3-PI	1090				
4-G	2083				

DATA ON RUNS FOR SET D(12)o

SUMMARY OF INSTRUMENTS

	Instruments		Position	90% RRP	50% RRP
1.	7x50x7 HH	408395	varied	-	100.0
2.	6x42x12 HH	-	varied	-	-
3.	6x42x12 Mtd.	-	varied	-	-
4.					
5.					
6.					

RANGES

Runs	Simult. Set	Date	No. on Date	Course	Wind	Observer Sect. o	Target 3-100 Range(yds)	Search Target	Search Range (yds)
166	EH	12-8	7	210	W	Luce	1500	SC	-
169	EH	12-9	2	210	W	Meadnis	-	SM	1300
171	EH	12-9	4	210	W	Vedovato	-	SC	1250

SUMMARY OF OCCURRENCE OF SIGNIFICANT "F" VALUES ON DISCRIMINATIONS

	Runs			Observers			Instruments		
	Not Sig.	5%	1%	Not Sig.	5%	1%	Not Sig.	5%	1%
Target 1G and 100									
Other Discriminations									
Total Discriminations Calculable									
Total Discriminations Observed									

Closest Discrimination Calculable:

ARITHMETIC MEANS 7 x 50 x 7 HH BY DISCRIMINATION

Discrimination	Mean Range(yds)	Discrimination	Mean Range(yds)	Discrimination	Mean Range(yds)
1-G	3590				
1-100	3480				
1-PI	1683				
3-G	-				
3-100	-				
3-PI	-				

DATA ON RUNS FOR SET D(12)p

SUMMARY OF INSTRUMENTS

	Instruments		Position	90% RRP	50% RRP
1.	7x50x7 HH	408395	varied	-	100.0
2.	6x42x12 HH	-	varied	-	-
3.	6x42x12 Mtd.	-	varied	-	-
4.					
5.					
6.					

RANGES

Runs	Simult. Set	Date	No. on Date	Course	Wind	Observer Sect. p	Target 3-100 Range(yds)	Search Target	Search Range (yds)
167	EJ	12-8	8	065	-	Lemaster	2100	SM	4050
168	EJ	12-9	1	065	-	Stanley	1430	SC	1400
170	EJ	12-9	3	065	-	Strickland	2700	SM	-

SUMMARY OF OCCURRENCE OF SIGNIFICANT "F" VALUES ON DISCRIMINATIONS

	Runs			Observers			Instruments		
	Not Sig.	5%	1%	Not Sig.	5%	1%	Not Sig.	5%	1%
Target 1G and 100									
Other Discriminations									
Total Discriminations Calculable									
Total Discriminations Observed									
Closest Discrimination Calculable:									

ARITHMETIC MEANS 7 x 50 x 7 HH BY DISCRIMINATION

Discrimination	Mean Range(yds)	Discrimination	Mean Range(yds)	Discrimination	Mean Range(yds)
1-G	3350				
1-100	2733				
1-PI	2167				
3-G	2250				
3-100	2077				
3-PI					

DATA ON RUNS FOR SET D(12)q

SUMMARY OF INSTRUMENTS

	Instruments		Position	90% RRP	50% RRP
1.	7x50x7 HH	408395	8	-	100.0
2.	6x42x12 HH	-	7	-	-
3.	6x42x12 Mtd.	3	-	-	-
4.					
5.					
6.					

RANGES

Runs	Simult. Set	Date	No. on Date	Course	Wind	Observer Sect. q	Target 3-100 Range(yds)	Search Target	Search Range (yds)
173	Ep	12-9	6	210	W	Hughs	-	SC	4500
175	Ep	12-9	8	210	W	Staton	-	SC	-
177	Ep	12-9	10	210	W	Anderson	1700	SC	4070

SUMMARY OF OCCURRENCE OF SIGNIFICANT "F" VALUES ON DISCRIMINATIONS

	Runs			Observers			Instruments		
	Not Sig.	5%	1%	Not Sig.	5%	1%	Not Sig.	5%	1%
Target 1G and 100									
Other Discriminations									
Total Discriminations Calculable									
Total Discriminations Observed									
Closest Discrimination Calculable:									

ARITHMETIC MEANS 7 x 50 x 7 HH BY DISCRIMINATION

Discrimination	Mean Range(yds)	Discrimination	Mean Range(yds)	Discrimination	Mean Range(yds)
1-G	4900				
1-100	2727				
1-PI	2377				
3-G	-				
3-100	-				
3-PI	-				

DATA ON RUNS FOR SET D(12)r

SUMMARY OF INSTRUMENTS

	Instruments		Position	90% RRP	50% RRP
1.	7x50x7 HH	48395	8	-	100.0
2.	6x42x12 HH	-	7	-	-
3.	6x42x12 Ntd.	-	9	-	-
4.					
5.					
6.					

RANGES

Runs	Simult. Set	Date	No. on Date	Course	Wind	Observer Sect. r	Target 3-100 Range(yds)	Search Target	Search Range (yds)
172	Ns	12-9	5	065	-	Roark	1250	SM	2100
174	Ns	12-9	[illegible]	065	-	Naumann	1420	SM	-
176	Ns	12-9	9	065	-	Filissey	1820	SM	3750

SUMMARY OF OCCURRENCE OF SIGNIFICANT "F" VALUES ON DISCRIMINATIONS

	Runs			Observers			Instruments		
	Not Sig.	5%	1%	Not Sig.	5%	1%	Not Sig.	5%	1%
Target 1G and 100									
Other Discriminations									
Total Discriminations Calculable									
Total Discriminations Observed									

Closest Discrimination Calculable:

ARITHMETIC MEANS 7 x 50 x 7 HH BY DISCRIMINATION

Discrimination	Mean Range(yds)	Discrimination	Mean Range(yds)	Discrimination	Mean Range(yds)
1-2	[illegible]				
1-100	[illegible]				
[illegible]	[illegible]				
[illegible]	-				
[illegible]	-				
[illegible]	-				

DATA ON RUNS FOR SET Ep

SUMMARY OF INSTRUMENTS

	Instruments	Position	90% RRP	50% RRP
1.	6x33x7	2		
2.	6x50x7	3	Not sufficient data	
3.	6x42x7	5		
4.				
5.				
6.				

RANGES

Runs	Simult. Set	Date	No. on Date	Course	Wind	Observer Sect. p	Target 3-100 Range(yds)	Search Target	Search Range (yds)
173	D12q	12-9	6	210	W	Lemaster	-	SC	-
175	D12q	12-9	8	210	W	Stanley	-	SC	-
177	D12q	12-9	10	210	W	Strickland	-	SC	-

SUMMARY OF OCCURRENCE OF SIGNIFICANT "F" VALUES ON DISCRIMINATIONS

	Runs			Observers			Instruments		
	Not Sig.	5%	1%	Not Sig.	5%	1%	Not Sig.	5%	1%
Target 1G and 100	N.S.D.								
Other Discriminations									
Total Discriminations Calculable									
Total Discriminations Observed									

Closest Discrimination Calculable:

ARITHMETIC MEANS 7 x 50 x 7 HH BY DISCRIMINATION

Discrimination	Mean Range(yds)	Discrimination	Mean Range(yds)	Discrimination	Mean Range(yds)
N.S.D.					

DATA ON RUNS FOR SET Fa-1

SUMMARY OF INSTRUMENTS

Instruments				Position	90% RRP	50% RRP
1.	7x50x7	HH	-	varied	84.0	100.0
2.	8x60x9	HH(-1d)	2111187	varied	96.0	113.0
3.	8x60x9	HH(-2d)	-	varied	101.0	109.0
4.						
5.						
6.						

RANGES

Runs	Simult. Set	Date	No. on Date	Course	Wind	Observer Sect. a	Target 3-100 Range(yds)	Search Target	Search Range (yds)
[illegible]	BB	10-9	[illegible]	065	W	Zink	4450	SC	-
[illegible]	BB	10-9	[illegible]	210	W	Lemontagne	2750	SC	5200
[illegible]	BB	10-10	[illegible]	065	-	Phillips	5300	SM	-

SUMMARY OF OCCURRENCE OF SIGNIFICANT "F" VALUES ON DISCRIMINATIONS

	Runs			Observers			Instruments		
	Not Sig.	5%	1%	Not Sig.	5%	1%	Not Sig.	5%	1%
Target 1G and 100		2		2			2		
Other Discriminations	3	5	2	9	1		9	1	
Total Discriminations Calculable	12			12			12		
Total Discriminations Observed	12			12			12		

Closest Discrimination Calculable: 6-PI

ARITHMETIC MEANS 7 x 50 x 7 HH BY DISCRIMINATION

Discrimination	Mean Range(yds)	Discrimination	Mean Range(yds)	Discrimination	Mean Range(yds)
1-G	[illegible]	4-100	[illegible]		
1-100	[illegible]	4-PI	[illegible]		
1-PI	[illegible]	6-G	[illegible]		
3-G	[illegible]	6-100	[illegible]		
3-100	[illegible]	6-PI	[illegible]		
3-PI	[illegible]				
4-G	[illegible]				

DATA ON RUNS FOR SET Fa-2

SUMMARY OF INSTRUMENTS

Instruments				Position	90% RRP	50% RRP
1.	7x50x7	HH	-	varied	83.0	100.0
2.	8x60x9	HH(-1d)	2111187	varied	97.0	106.0
3.	8x60x9	HH(-2d)	-	varied	101.0	108.0
4.						
5.						
6.						

RANGES

Runs	Simult. Set	Date	No. on Date	Course	Wind	Observer Sect. a	Target 3-100 Range(yds)	Search Target	Search Range (yds)
86	BB	10-10	4	065	-	Phillips	3600	'SM	-
88	BB	10-10	6	065	-	Zink	4200	SC	-
104	BB	11-1	6	065	-	Lamontagne	3900	SM	-

SUMMARY OF OCCURRENCE OF SIGNIFICANT "F" VALUES ON DISCRIMINATIONS

	Runs			Observers			Instruments		
	Not Sig.	5%	1%	Not Sig.	5%	1%	Not Sig.	5%	1%
Target 1G and 100			2	2			2		
Other Discriminations	7	2	1	10			10		
Total Discriminations Calculable	12			12			12		
Total Discriminations Observed	12			12			12		

Closest Discrimination Calculable: 6-PI

ARITHMETIC MEANS 7 x 50 x 7 HH BY DISCRIMINATION

Discrimination	Mean Range(yds)	Discrimination	Mean Range(yds)	Discrimination	Mean Range(yds)
1-G	8227	4-G	4817		
1-100	8227	4-100	3183		
1-PI	5683	4-PI	2527		
3-G	5900	6-G	3410		
3-100	3900	6-100	2860		
3-PI	2677	6-PI	2383		

DATA ON RUNS FOR SET Fb-1

SUMMARY OF INSTRUMENTS

	Instruments			Position	90% RRP	50% RRP
1.	7x50x7	HH		Varied	78.0	100.0
2.	8x60x7(-1d)	HH	2111187	Varied	74.0	97.0
3.	8x60x7(-2d)	HH		Varied	84.0	104.0
4.						
5.						
6.						

RANGES

Runs	Simult. Set	Date	No. on Date	Course	Wind	Observer Sect. b	Target 3-100 Range(yds)	Search Target	Search Range (yds)
80	BA	10-9	9	065	-	Brazil	4200	SM	4670
82	BA	10-9	11	065	W	Brown	2200	SM	-
83	BA	10-10	1	210	-	Hambrick	1800	SC	3820

SUMMARY OF OCCURRENCE OF SIGNIFICANT "F" VALUES ON DISCRIMINATIONS

	Runs			Observers			Instruments		
	Not Sig.	5%	1%	Not Sig.	5%	1%	Not Sig.	5%	1%
Target 1G and 100									
Other Discriminations									
Total Discriminations Calculable									
Total Discriminations Observed									

Closest Discrimination Calculable: 6-PI

ARITHMETIC MEANS 7 x 50 x 7 HH BY DISCRIMINATION

Discrimination	Mean Range(yds)	Discrimination	Mean Range(yds)	Discrimination	Mean Range(yds)
1-G	[illegible]				
1-100	[illegible]				
1-PI	[illegible]				
3-G	[illegible]				
3-100	[illegible]				
3-PI	[illegible]				
6-G	[illegible]				
6-100	[illegible]				
6-PI	[illegible]				

DATA ON RUNS FOR SET Fb-2

SUMMARY OF INSTRUMENTS

	Instruments			Position	90% RRP	50% RRP
1.	7x50x7	HH	-	varied	77.0	100.0
2.	8x60x9	HH(-1d)	2111187	varied	90.0	109.0
3.	8x60x9	HH(-2d)	-	varied	83.0	103.0
4.						
5.						
6.						

RANGES

Runs	Simult. Set	Date	No. on Date	Course	Wind	Observer Sect. b	Target 3-100 Range(yds)	Search Target	Search Range (yds)
89	BA	10-10	7	065	W	Brown	2400	SM	-
91	BA	10-10	9	065	W	Brazil	4000	SM	3830
103	BA	11-1	5	210	-	Hambrick	2480	SC	3600

SUMMARY OF OCCURRENCE OF SIGNIFICANT "F" VALUES ON DISCRIMINATIONS

	Runs			Observers			Instruments		
	Not Sig.	5%	1%	Not Sig.	5%	1%	Not Sig.	5%	1%
Target 1G and 100	1		1	1	1		2		
Other Discriminations	10			9	1		10		
Total Discriminations Calculable	12			12			12		
Total Discriminations Observed	12			12			12		

Closest Discrimination Calculable: 6 PI

ARITHMETIC MEANS 7 x 50 x 7 HH BY DISCRIMINATION

Discrimination	Mean Range(yds)	Discrimination	Mean Range(yds)	Discrimination	Mean Range(yds)
1-G	8110	6-G	2783		
1-100	8083	6-100	2083		
1-PI	5450	6-PI	1633		
3-G	3667				
3-100	2960				
3-PI	1960				

DATA ON RUNS FOR SET Fe-1

SUMMARY OF INSTRUMENTS

	Instruments			Position	90% RRP	50% RRP
1.	7x50x7	HH	-	varied	76.0	100.0
2.	8x60x9	HH(-1d)	2111187	varied	101.0	124.0
3.	8x60x9	HH(-2d)	-	varied	97.0	119.0
4.						
5.						
6.						

RANGES

Runs	Simult. Set	Date	No. on Date	Course	Wind	Observer Sect. e	Target 3-100 Range(yds)	Search Target	Search Range (yds)
60	M(1)D	10-7	5	065	W	Venski	1780	SC	3000
62	BD	10-7	7	210	W	Stroud	1950	SC	2600
64	BD	10-8	1	210	W	Saidikowski	1390	SC	-

SUMMARY OF OCCURRENCE OF SIGNIFICANT "F" VALUES ON DISCRIMINATIONS

	Runs			Observers			Instruments		
	Not Sig.	5%	1%	Not Sig.	5%	1%	Not Sig.	5%	1%
Target 1G and 100	1	1		2			2		
Other Discriminations	6			6			5	1	
Total Discriminations Calculable		8			8			8	
Total Discriminations Observed		9			9			9	

Closest Discrimination Calculable: 4 PI

ARITHMETIC MEANS 7 x 50 x 7 HH BY DISCRIMINATION

Discrimination	Mean Range(yds)	Discrimination	Mean Range(yds)	Discrimination	Mean Range(yds)
1-G	[illegible]	4-G	1680		
1-100	[illegible]	4-100	1420		
1-PI	[illegible]	4-PI			
3-G	[illegible]				
3-100	[illegible]				
3-PI					

DATA ON RUNS FOR SET Fe-2

SUMMARY OF INSTRUMENTS

	Instruments			Position	90% RRP	50% RRP
1.	7x50x7	HH	-	varied	82.0	100.0
2.	8x60x9	HH(-1d)	2111187	varied	85.0	97.0
3.	8x60x9	HH(-2d)	-	varied	86.0	96.0
4.						
5.						
6.						

RANGES

Runs	Simult. Set	Date	No. on Date	Course	Wind	Observer Sect. e	Target 3-100 Range(yds)	Search Target	Search Range (yds)
66	BD	10-8	3	210	W	Stroud	1430	SC	-
68	BD	10-8	5	210	W	Venski	1300	SC	2600
70	BD	10-8	7	210	W	Saidikowski	1680	SC	-

SUMMARY OF OCCURRENCE OF SIGNIFICANT "F" VALUES ON DISCRIMINATIONS

	Runs			Observers			Instruments		
	Not Sig.	5%	1%	Not Sig.	5%	1%	Not Sig.	5%	1%
Target 1G and 100		2		2			2		
Other Discriminations	5	1	1	6	1		7		
Total Discriminations Calculable		9			9			9	
Total Discriminations Observed		9			9			9	

Closest Discrimination Calculable: 4-PI

ARITHMETIC MEANS 7 x 50 x 7 HH BY DISCRIMINATION

Discrimination	Mean Range(yds)	Discrimination	Mean Range(yds)	Discrimination	Mean Range(yds)
1-G	3570	4-G	1900		
1-100	2817	4-100	1427		
1-PI	1563	4-PI	1183		
3-G	1927				
3-100	1470				
3-PI	1240				

DATA ON RUNS FOR SET Ff-1

SUMMARY OF INSTRUMENTS

	Instruments	Position	90% RRP	50% RRP
1.	7x50x7 HH 259898	varied	73.0	100.0
2.	8x60x9 HH(-1d) 2111187	varied	83.0	93.0
3.	8x60x9 HH(-2d) -	varied	101.0	107.0
4.				
5.				
6.				

RANGES

Runs	Simult. Set	Date	No. on Date	Course	Wind	Observer Sect. f	Target 3-100 Range(yds)	Search Target	Search Range (yds)
61	BE	10-7	6	065	-	Farone	1400	SM	2300
63	BE	10-7	8	065	-	Sagaser	2300	SM	2500
65	BE	10-8	2	065	-	Vedovato	1610	SM	2300

SUMMARY OF OCCURRENCE OF SIGNIFICANT "F" VALUES ON DISCRIMINATIONS

	Runs			Observers			Instruments		
	Not Sig.	5%	1%	Not Sig.	5%	1%	Not Sig.	5%	1%
Target 1G and 100	2			2			2		
Other Discriminations	12		1	13			13		
Total Discriminations Calculable		15			15			15	
Total Discriminations Observed		15			15			15	

Closest Discrimination Calculable: 6-PI

ARITHMETIC MEANS 7 x 50 x 7 HH BY DISCRIMINATION

Discrimination	Mean Range(yds)	Discrimination	Mean Range(yds)	Discrimination	Mean Range(yds)
1-G	5187	4-G	2167		
1-100	4460	4-100	1733		
1-PI	2433	4-PI	1300		
3-G	2193	6-G	1977		
3-100	1767	6-100	1500		
3-PI	1300	6-PI	1127		

DATA ON RUNS FOR SET Ff-2

SUMMARY OF INSTRUMENTS

	Instruments	Position	90% RRP	50% RRP
1.	7x50x7 HH 259898	varied	83.0	100.0
2.	8x60x9 HH(-1d) 2111187	varied	91.0	101.0
3.	8x60x9 HH(-2d) -	varied	91.0	100.0
4.				
5.				
6.				

RANGES

Runs	Simult. Set	Date	No. on Date	Course	Wind	Observer Sect. f	Target 3-100 Range(yds)	Search Target	Search Range (yds)
67	BE	10-8	4	065	-	Farone(Cole)	1780	SM	2200
69	BE	10-8	6	065	-	Vedovato	1610	SM	-
71	BE	10-8	8	065	-	Sagaser	2400	SM	2900

SUMMARY OF OCCURRENCE OF SIGNIFICANT "F" VALUES ON DISCRIMINATIONS

	Runs			Observers			Instruments		
	Not Sig.	5%	1%	Not Sig.	5%	1%	Not Sig.	5%	1%
Target 1G and 100	2			2			2		
Other Discriminations	12	1		13			13		
Total Discriminations Calculable		15			15			15	
Total Discriminations Observed		15			15			15	

Closest Discrimination Calculable: 6 PI

ARITHMETIC MEANS 7 x 50 x 7 HH BY DISCRIMINATION

Discrimination	Mean Range(yds)	Discrimination	Mean Range(yds)	Discrimination	Mean Range(yds)
1-G	4593	4-G	2060		
1-100	4027	4-100	1780		
1-PI	2100	4-PI	1200		
3-G	2760	6-G	1747		
3-100	1930	6-100	1567		
3-PI	1317	6-PI	1250		

DATA ON RUNS FOR SET Hj

SUMMARY OF INSTRUMENTS

	Instruments		Position	90% RRP	50% RRP
1.	7x50x7 HH	-	varied	60.0	100.0
2.	7x50x10 HH	-	varied	79.0	104.0
3.	10x50x7 HH	-	varied	91.0	116.0
4.					
5.					
6.					

RANGES

Runs	Simult. Set	Date	No. on Date	Course	Wind	Observer Sect. j	Target 3-100 Range(yds)	Search Target	Search Range (yds)
114	1 (A)F	11-2	8	065	-	Parker	1830	SM	-
116	1 (A)F	11-5	2	065	W	Bamford	3280	SM	3200
118	1 (A)F	11-5	4	065	W	Jagelewski	4330	SM	2600

SUMMARY OF OCCURRENCE OF SIGNIFICANT "F" VALUES ON DISCRIMINATIONS

	Runs			Observers			Instruments		
	Not Sig.	5%	1%	Not Sig.	5%	1%	Not Sig.	5%	1%
Target 1G and 100		1	1	1	1		1	1	
Other Discriminations	3	1	1	5			5		
Total Discriminations Calculable		7			7			7	
Total Discriminations Observed		11			11			11	

Closest Discrimination Calculable: 5-100

ARITHMETIC MEANS 7 x 50 x 7 HH BY DISCRIMINATION

Discrimination	Mean Range(yds)	Discrimination	Mean Range(yds)	Discrimination	Mean Range(yds)
1-G	6350				
1-100	6133				
1-PI	3227				
3-G	4453				
3-100	3147				
3-PI	2053				

DATA ON RUNS FOR SET Hk

SUMMARY OF INSTRUMENTS

	Instruments		Position	90% RRP	50% RRP
1.	7x50x7 HH	-	varied	77.0	100.0
2.	7x50x10 HH	BT6826	varied	51.0	83.0
3.	10x50x7 HH	-	varied	86.0	106.0
4.					
5.					
6.					

RANGES

Runs	Simult. Set	Date	No. on Date	Course	Wind	Observer Sect. k	Target 3-100 Range(yds)	Search Target	Search Range (yds)
133	PD	11-8	3	210	-	Stroud	1400	SC	2550
135	PD	11-8	5	210	-	Pauli	1900	SC	2200
133 A	-	11-8	1	210	-	Barger	1450	SC	2350

SUMMARY OF OCCURRENCE OF SIGNIFICANT "F" VALUES ON DISCRIMINATIONS

	Runs			Observers			Instruments		
	Not Sig.	5%	1%	Not Sig.	5%	1%	Not Sig.	5%	1%
Target 1G and 100	2			2			2		
Other Discriminations	4			4			3	1	
Total Discriminations Calculable		6			6			6	
Total Discriminations Observed		14			14			14	

Closest Discrimination Calculable: 6-100

ARITHMETIC MEANS 7 x 50 x 7 HH BY DISCRIMINATION

Discrimination	Mean Range(yds)	Discrimination	Mean Range(yds)	Discrimination	Mean Range(yds)
1-G	5200				
1-100	3860				
1-PI	2397				
3-G	2540				
3-100	1583				
3-PI	-				

DATA ON RUNS FOR SET H1

SUMMARY OF INSTRUMENTS

	Instruments		Position	90% RRP	50% RRP
1.	7x50x7 HH	-	varied	79.0	100.0
2.	7x50x10 HH	BT-6826	varied	91.0	108.0
3.	10x50x7 HH	-	varied	104.0	117.0
4.					
5.					
6.					

RANGES

Runs	Simult. Set	Date	No. on Date	Course	Wind	Observer Sect. 1	Target 3-100 Range(yds)	Search Target	Search Range (yds)
134	PG	11-8	4	065	W	Saidikowski	2000	SM	3450
136	PG	11-8	6	065	W	Mikolay	3000	SM	3900
133B	-	11-8	2	065	W	Vedovato	1300	SC	2250

SUMMARY OF OCCURRENCE OF SIGNIFICANT "F" VALUES ON DISCRIMINATIONS

	Runs			Observers			Instruments		
	Not Sig.	5%	1%	Not Sig.	5%	1%	Not Sig.	5%	1%
Target 1G and 100	1		1	2			1	1	
Other Discriminations	8	4		10	2		10	2	
Total Discriminations Calculable	14			14			14		
Total Discriminations Observed	14			14			14		

Closest Discrimination Calculable: 6-100

ARITHMETIC MEANS 7 x 50 x 7 HH BY DISCRIMINATION

Discrimination	Mean Range(yds)	Discrimination	Mean Range(yds)	Discrimination	Mean Range(yds)
1-G	6993	4-PI	1297		
1-100	5077	6-G	1983		
1-PI	2527	6-100	1343		
3-G	3117	6-PI	1140		
3-100	2100	7-G	1283		
3-PI	1570	7-100	1017		
4-G	2627	7-PI	-		
4-100	1827				

DATA ON RUNS FOR SET Wg-1

SUMMARY OF INSTRUMENTS

	Instruments		Position	90% RRP	50% RRP
1.	7x50x7 HH	-	varied	84.0	100.0
2.	7x50x10 HH	BT6826	varied	86.0	100.0
3.	6x42x12 HH	"B"	varied	95.0	104.0
4.					
5.					
6.					

RANGES

Runs	Simult. Set	Date	No. on Date	Course	Wind	Observer Sect. 8	Target 3-100 Range(yds)	Search Target	Search Range (yds)
92	BD	10-11	1	210	W	Venski	1900	SC	-
94	VD	10-11	3	210	-	Cole	2690	SC	-
96	VD	10-11	5	210	-	Sagaser	2450	SC	-

SUMMARY OF OCCURRENCE OF SIGNIFICANT "F" VALUES ON DISCRIMINATIONS

	Runs			Observers			Instruments		
	Not Sig.	5%	1%	Not Sig.	5%	1%	Not Sig.	5%	1%
Target 1G and 100	1	1		2			2		
Other Discriminations	8	2		8	2		10		
Total Discriminations Calculable	12			12			12		
Total Discriminations Observed	12			12			12		

Closest Discrimination Calculable: 5-PI

ARITHMETIC MEANS 7 x 50 x 7 HH BY DISCRIMINATION

Discrimination	Mean Range(yds)	Discrimination	Mean Range(yds)	Discrimination	Mean Range(yds)
1-G	6690	4-G	2403		
1-100	6010	4-100	1780		
1-PI	2880	4-PI	1203		
3-G	3253	6-G	2460		
3-100	2348	6-100	1937		
3-PI	1610	6-PI	1413		

DATA ON RUNS FOR SET Wg-2

SUMMARY OF INSTRUMENTS

	Instruments		Position	90% RRP	50% RRP
1.	7x50x7 HH	-	varied	83.0	100.0
2.	7x50x10 HH	BT6826	varied	79.0	95.0
3.	6x42x12 HH	"B"	varied	83.0	99.0
4.					
5.					
6.					

RANGES

Runs	Simult. Set	Date	No. on Date	Course	Wind	Observer Sect. g	Target 3-100 Range(yds)	Search Target	Search Range (yds)
98	VD-3	10-11	7	210	-	Venski	2900	SC	-
99	VD-4	11-1	1	210	-	Cole	2550	SC	4100
101	VD-5	11-1	3	210	-	Sagaser	3080	SC	3900

SUMMARY OF OCCURRENCE OF SIGNIFICANT "F" VALUES ON DISCRIMINATIONS

	Runs			Observers			Instruments		
	Not Sig.	5%	1%	Not Sig.	5%	1%	Not Sig.	5%	1%
Target 1G and 100	2			2			2		
Other Discriminations	6	1		7			7		
Total Discriminations Calculable		9			9			9	
Total Discriminations Observed		12			12			12	

Closest Discrimination Calculable: 5-PI

ARITHMETIC MEANS 7 x 50 x 7 HH BY DISCRIMINATION

Discrimination	Mean Range(yds)	Discrimination	Mean Range(yds)	Discrimination	Mean Range(yds)
1-G	7127	4-G	3143		
1-100	6683	4-100	2453		
1-PI	3793	4-PI	1593		
3-G	3883				
3-100	2843				
3-PI	1743				

DATA ON RUNS FOR SET Wh-1

SUMMARY OF INSTRUMENTS

	Instruments		Position	90% RRP	50% RRP
1.	7x50x7 HH	-	varied	80.0	100.0
2.	7x50x10 HH	BT6826	varied	84.0	102.0
3.	6x42x12 HH	"B"	varied	75.0	92.0
4.					
5.					
6.					

RANGES

Runs	Simult. Set	Date	No. on Date	Course	Wind	Observer Sect. h	Target 3-100 Range(yds)	Search Target	Search Range (yds)
93	VE	10-11	2	065	-	Saidikowski	3500	SM	3450
95	VE	10-11	4	065	-	Stroud	2100	SM	-
97	VE	10-11	6	065	-	Vedovato	2800	SM	3210

SUMMARY OF OCCURRENCE OF SIGNIFICANT "F" VALUES ON DISCRIMINATIONS

	Runs			Observers			Instruments		
	Not Sig.	5%	1%	Not Sig.	5%	1%	Not Sig.	5%	1%
Target 1G and 100	2			2			2		
Other Discriminations	10			9	1		10		
Total Discriminations Calculable		12			12			12	
Total Discriminations Observed		12			12			12	

Closest Discrimination Calculable: 5-PI

ARITHMETIC MEANS 7 x 50 x 7 HH BY DISCRIMINATION

Discrimination	Mean Range(yds)	Discrimination	Mean Range(yds)	Discrimination	Mean Range(yds)
1-G	7243	4-G	3967		
1-100	7113	4-100	2700		
1-PI	2510	4-PI	1877		
3-G	4776	6-G	2843		
3-100	2800	6-100	2087		
3-PI	1557	6-PI	1343		

DATA ON RUNS FOR SET Wh-2

SUMMARY OF INSTRUMENTS

	Instruments		Position	90% RRP	50% RRP
1.	7x50x7 HH	-	varied	85.0	100.0
2.	7x50x10 HH	BT6826	varied	79.0	93.0
3.	6x42x12 HH	"B"	varied	69.0	83.0
4.					
5.					
6.					

RANGES

Runs	Simult. Set	Date	No. on Date	Course	Wind	Observer Sect. h	Target 3-100 Range(yds)	Search Target	Search Range (yds)
100	VE	11-1	2	065	-	Saidikowski	3550	SM	-
102	VE	11-1	4	065	-	Stroud	2300	SM	-
106	VE	11-1	8	065	-	Vedovato	2800	SM	-

SUMMARY OF OCCURRENCE OF SIGNIFICANT "F" VALUES ON DISCRIMINATIONS

	Runs			Observers			Instruments		
	Not Sig.	5%	1%	Not Sig.	5%	1%	Not Sig.	5%	1%
Target 1G and 100	1		1	2			2		
Other Discriminations	7			3	4		6	1	
Total Discriminations Calculable		9			9			9	
Total Discriminations Observed		12			12			12	

Closest Discrimination Calculable: 5-PI

ARITHMETIC MEANS 7 x 50 x 7 HH BY DISCRIMINATION

Discrimination	Mean Range(yds)	Discrimination	Mean Range(yds)	Discrimination	Mean Range(yds)
1-G	8267	4-G	4083		
1-100	8267	4-100	3017		
1-PI	3683	4-PI	1817		
3-G	5033				
3-100	2863				
3-PI	1447				

DATA ON RUNS FOR SET Wi-1

SUMMARY OF INSTRUMENTS

	Instruments		Position	90% RRP	50% RRP
1.	7x50x7 HH	-	7	84.0	100.0
2.	7x50x10 HH	BT6826	8	83.0	94.0
3.	6x42x12 HH	"A"	9	88.0	96.0
4.					
5.					
6.					

RANGES

Runs	Simult. Set	Date	No. on Date	Course	Wind	Observer Sect. i	Target 3-100 Range(yds)	Search Target	Search Range (yds)
107	1 A(F)	11-2	1	210	W	Hughs	2180	SC	2200
109	1 A(F)	11-2	3	210	W	Farone	1300	SC	2120
111	1 A(F)	11-2	5	210	W	Bridges	1370	SC	-

SUMMARY OF OCCURRENCE OF SIGNIFICANT "F" VALUES ON DISCRIMINATIONS

	Runs			Observers			Instruments		
	Not Sig.	5%	1%	Not Sig.	5%	1%	Not Sig.	5%	1%
Target 1G and 100			2			2	1		1
Other Discriminations	2		3	4		1	4		1
Total Discriminations Calculable		7			7			7	
Total Discriminations Observed		11			11			11	

Closest Discrimination Calculable: 5-100

ARITHMETIC MEANS 7 x 50 x 7 HH BY DISCRIMINATION

Discrimination	Mean Range(yds)	Discrimination	Mean Range(yds)	Discrimination	Mean Range(yds)
1-G	4027	5-G	1557		
1-100	3120	5-100	1393		
1-PI	1750	-PI	-		
3-G	1993				
3-100	1617				
3-PI	-				

DATA ON RUNS FOR SET W(s)1-2

SUMMARY OF INSTRUMENTS

	Instruments		Position	90% RRP	50% RRP
1.	7x50x7 HH	-	varied	-	100.0
2.	7x50x10 HH	BT6826	varied	-	-
3.	6x42x12 HH	"A"	varied	-	-
4.					
5.					
6.					

RANGES

Runs	Simult. Set	Date	No. on Date	Course	Wind	Observer Sect. 1	Target 3-100 Range(yds)	Search Target	Search Range (yds)
121	B(s)A	11-5	7	210	-	Farone	2050	SC	4250
123	B(s)A	11-5	9	210	-	Hughs	1300	SM	-
124	H(1)A-2	11-6	1	065	-	Bridges	2130	SC	-

SUMMARY OF OCCURRENCE OF SIGNIFICANT "F" VALUES ON DISCRIMINATIONS

	Runs			Observers			Instruments		
	Not Sig.	5%	1%	Not Sig.	5%	1%	Not Sig.	5%	1%
Target 1G and 100									
Other Discriminations									
Total Discriminations Calculable									
Total Discriminations Observed									

Closest Discrimination Calculable:

ARITHMETIC MEANS 7 x 50 x 7 HH BY DISCRIMINATION

Discrimination	Mean Range(yds)	Discrimination	Mean Range(yds)	Discrimination	Mean Range(yds)
3-G	-				
3-100	2667				
3-PI	-				

DATA ON RUNS FOR SET W(s)1-3

SUMMARY OF INSTRUMENTS

	Instruments		Position	90% RRP	50% RRP
1.	7x50x7 HH	-	9	80.0	100.0
2.	7x50x10 HH	BT6826	8	94.0	105.0
3.	6x42x12 HH	"A"	7	78.0	89.0
4.					
5.					
6.					

RANGES

Runs	Simult. Set	Date	No. on Date	Course	Wind	Observer Sect. 1	Target 3-100 Range(yds)	Search Target	Search Range (yds)
125	B(s)A	11-6	3	210	-	Hughs	1950	SM	3500
127	B(s)A	11-6	5	210	-	Bridges	1900	SC	3100
129	B(s)A	11-6	7	210	-	Farone	1250	SC	2500

SUMMARY OF OCCURRENCE OF SIGNIFICANT "F" VALUES ON DISCRIMINATIONS

	Runs			Observers			Instruments		
	Not Sig.	5%	1%	Not Sig.	5%	1%	Not Sig.	5%	1%
Target 1G and 100	2			2			2		
Other Discriminations	10	1	1	10	2		10	2	
Total Discriminations Calculable		14			14			14	
Total Discriminations Observed		14			14			14	

Closest Discrimination Calculable: 6-100

ARITHMETIC MEANS 7 x 50 x 7 HH BY DISCRIMINATION

Discrimination	Mean Range(yds)	Discrimination	Mean Range(yds)	Discrimination	Mean Range(yds)
1-G	7033	4-FI	-		
1-100	3693	5-G	2083		
1-PI	1983	5-100	1377		
3-G	2183	5-PI	-		
3-100	1700	6-G	1817		
3-PI	-	6-100	1333		
4-G	2233	6-FI	-		
4-100	1420				

DATA ON RUNS FOR SET Wj-1

SUMMARY OF INSTRUMENTS

	Instruments		Position	90% RRP	50% RRP
1.	7x50x7 HH	-	7	86.0	100.0
2.	7x50x10 HH	BT6826	8	92.0	97.0
3.	6x42x12 HH	"A"	9	84.0	91.0
4.					
5.					
6.					

RANGES

Runs	Simult. Set	Date	No. on Date	Course	Wind	Observer Sect. j	Target 3-100 Range(yds)	Search Target	Search Range (yds)
108	1(A)F	11-2	2	065	-	Jagelewski	2000	-	-
110	1(A)F	11-2	4	065	W	Parker	1170	-	-
112	1(A)F	11-2	6	065	-	Bamford	1500	-	-

SUMMARY OF OCCURRENCE OF SIGNIFICANT "F" VALUES ON DISCRIMINATIONS

	Runs			Observers			Instruments		
	Not Sig.	5%	1%	Not Sig.	5%	1%	Not Sig.	5%	1%
Target 1G and 100			2			2			2
Other Discriminations		1	2			3	1	1	1
Total Discriminations Calculable		5			5			5	
Total Discriminations Observed		11			11			11	

Closest Discrimination Calculable: 5-100

ARITHMETIC MEANS 7 x 50 x 7 HH BY DISCRIMINATION

Discrimination	Mean Range(yds)	Discrimination	Mean Range(yds)	Discrimination	Mean Range(yds)
1-G	5733				
1-100	2993				
1-PI	1750				
3-G	2030				
3-100	1557				
3-PI	-				

DATA ON RUNS FOR SET W(s)j-2

SUMMARY OF INSTRUMENTS

	Instruments		Position	90% RRP	50% RRP
1.	7x50x7 HH	-	varied	-	100.0
2.	7x50x10 HH	BT6826	varied	-	-
3.	6x42x12 HH	"A"	varied	-	-
4.					
5.					
6.					

RANGES

Runs	Simult. Set	Date	No. on Date	Course	Wind	Observer Sect. j	Target 3-100 Range(yds)	Search Target	Search Range (yds)
120	B(s)F	11-5	6	065	W	Bamford	2700	SM	3050
122	B(s)F	11-5	8	065	W	Parker	2400	SM	3400
126	B(s)F	11-6	4	065	-	Jagelewski	3650	SC	2300

SUMMARY OF OCCURRENCE OF SIGNIFICANT "F" VALUES ON DISCRIMINATIONS

	Runs			Observers			Instruments		
	Not Sig.	5%	1%	Not Sig.	5%	1%	Not Sig.	5%	1%
Target 1G and 100									
Other Discriminations									
Total Discriminations Calculable									
Total Discriminations Observed									

Closest Discrimination Calculable:

ARITHMETIC MEANS 7 x 50 x 7 HH BY DISCRIMINATION

Discrimination	Mean Range(yds)	Discrimination	Mean Range(yds)	Discrimination	Mean Range(yds)
3-G	-				
3-100	2450				
3-PI	-				

DATA ON RUNS FOR SET W(s)j-3

SUMMARY OF INSTRUMENTS

	Instruments		Position	90% RRP	50% RRP
1.	7x50x7 HH	144989	9	84.0	100.0
2.	7x50x10 HH	BT6826	8	80.0	89.0
3.	6x42x12 HH	"B"	7	71.0	76.0
4.					
5.					
6.					

RANGES

Runs	Simult. Set	Date	No. on Date	Course	Wind	Observer Sect. j	Target 3-100 Range(yds)	Search Target	Search Range (yds)
128	B(s)F	11-6	6	065	-	Jagelewski	3100	SM	2720
132	B(s)F	11-6	10	065	-	Parker	1900	SM	3200
130	B(s)F	11-6	8	065	-	Bamford	2150	SM	2710

SUMMARY OF OCCURRENCE OF SIGNIFICANT "F" VALUES ON DISCRIMINATIONS

	Runs			Observers			Instruments		
	Not Sig.	5%	1%	Not Sig.	5%	1%	Not Sig.	5%	1%
Target 1G and 100	2			2			2		
Other Discriminations	9	1		8	1	1	8		2
Total Discriminations Calculable	12			12			12		
Total Discriminations Observed	14			14			14		

Closest Discrimination Calculable: 6-100

ARITHMETIC MEANS 7 x 50 x 7 HH BY DISCRIMINATION

Discrimination	Mean Range(yds)	Discrimination	Mean Range(yds)	Discrimination	Mean Range(yds)
1-G	6800	4-PI	1400		
1-100	4310	5-G	2203		
1-PI	2333	5-100	1530		
3-G	3010	5-PI	-		
3-100	2383	7-G	1900		
3-PI	1560	7-100	1610		
4-G	2800	7-PI	-		
4-100	1833				

DATA ON RUNS FOR SET Wz-1

SUMMARY OF INSTRUMENTS

	Instruments		Position	90% RRP	50% RRP
1.	7x50x7 HH	-	varied	73.0	100.0
2.	7x50x10 HH	BT6826	varied	80.0	100.0
3.	6x42x12 HH	"B"	varied	74.0	94.0
4.					
5.					
6.					

RANGES

Runs	Simult. Set	Date	No. on Date	Course	Wind	Observer Sect. z	Target 3-100 Range(yds)	Search Target	Search Range (yds)
74	B(1)X	10-9	3	210	W	Griffin	2950	SC	2720
76	B(1)X	10-9	5	210	-	Lee	1950	SC	-
79	B(1)X	10-9	8	210	W	Ross	4580	SC	4150

SUMMARY OF OCCURRENCE OF SIGNIFICANT "F" VALUES ON DISCRIMINATIONS

	Runs			Observers			Instruments		
	Not Sig.	5%	1%	Not Sig.	5%	1%	Not Sig.	5%	1%
Target 1G and 100	1	1		2			2		
Other Discriminations	6	1		6	1		7		
Total Discriminations Calculable	9			9			9		
Total Discriminations Observed	9			9			9		

Closest Discrimination Calculable: 7-PI

ARITHMETIC MEANS 7 x 50 x 7 HH BY DISCRIMINATION

Discrimination	Mean Range(yds)	Discrimination	Mean Range(yds)	Discrimination	Mean Range(yds)
1-G	7533	7-G	2650		
1-100	7170	7-100	1717		
1-PI	5120	7-PI	1550		
3-G	5017				
3-100	3160				
3-PI	2133				

DATA ON RUNS FOR SET Wz-2

SUMMARY OF INSTRUMENTS

	Instruments		Position	90% RRP	50% RRP
1.	7x50x7 HH		varied	76.0	100.0
2.	7x50x10 HH	BT6826	varied	79.0	95.0
3.	6x42x12 HH	"B"	varied	80.0	88.0
4.					
5.					
6.					

RANGES

Runs	Simult. Set	Date	No. on Date	Course	Wind	Observer Sect. z	Target 3-100 Range(yds)	Search Target	Search Range (yds)
85	B(1)X	10-10	3	210	-	Ross	2280	SC	2400
87	B(1)X	10-10	5	210	-	Lee	1400	SM	2300
90	B(1)X	10-10	8	210	-	Griffin	3250	SC	3420

SUMMARY OF OCCURRENCE OF SIGNIFICANT "F" VALUES ON DISCRIMINATIONS

	Runs			Observers			Instruments		
	Not Sig.	5%	1%	Not Sig.	5%	1%	Not Sig.	5%	1%
Target 1G and 100	2			2			2		
Other Discriminations	7			7			7		
Total Discriminations Calculable	9			9			9		
Total Discriminations Observed	9			9			9		

Closest Discrimination Calculable: 7 PI

ARITHMETIC MEANS 7 x 50 x 7 HH BY DISCRIMINATION

Discrimination	Mean Range(yds)	Discrimination	Mean Range(yds)	Discrimination	Mean Range(yds)
1-G	6627	7-G	2383		
1-100	5900	7-100	2177		
1-PI	4483	7-PI	1667		
3-G	3320				
3-100	2310				
3-PI	1530				

DATA ON RUNS FOR SET bR

SUMMARY OF INSTRUMENTS

	Instruments	Position	90% RRP	50% RRP
1.	7x50x7 HH	8	76.0	100.0
2.	7x50x7 Mtd.	9	75.0	99.0
3.	7x50x7 VFA	7	96.0	119.0
4.				
5.				
6.				

RANGES

Runs	Simult. Set	Date	No. on Date	Course	Wind	Observer Sect. r'	Target 3-100 Range(yds)	Search Target	Search Range (yds)
4		11-23	1		W	Barger	11250		
5		11-23	2		W	Stroud	11000		
6		11-23	3		W	Courtney	2750		

SUMMARY OF OCCURRENCE OF SIGNIFICANT "F" VALUES ON DISCRIMINATIONS

	Runs			Observers			Instruments		
	Not Sig.	5%	1%	Not Sig.	5%	1%	Not Sig.	5%	1%
Target 1G and 100	2			2			2		
Other Discriminations	21	3	4	22	4	2	26	2	
Total Discriminations Calculable	30			30			30		
Total Discriminations Observed	30			30					

Closest Discrimination Calculable: F -PI

ARITHMETIC MEANS 7 x 50 x 7 HH BY DISCRIMINATION

Discrimination	Mean Range(yds)	Discrimination	Mean Range(yds)	Discrimination	Mean Range(yds)
1-G	12250	9-G	12640	E-G	6086
1-100	12130	9-100	12460	E-100	5843
1-PI	11750	9-PI	8346	E-PI	4567
3-G	12580	C-G	6986	F-G	4300
3-100	12330	C-100	6093	F-100	3833
3-PI	10030	C-PI	5016	F-PI	1617
4-G	12500	D-G	3000		
4-100	10970	D-100	3300		
4-PI	9160	D-PI	2460		
A-G	12460	10-G	8606		
A-100	12210	10-100	8333		
A-PI	4043	10-PI	6250		

DATA ON RUNS FOR SET c(1)A

SUMMARY OF INSTRUMENTS

Instruments	Position	90% RRP	50% RRP
1. 7x50x7 HH	10	86.0	100.0
2. 7x50x7 Mon.	11	92.0	100.0
3. 10x50x7 HH	12	93.0	102.0
4.			
5.			
6.			

RANGES

Runs	Simult. Set	Date	No. on Date	Course	Wind	Observer Sect. a'	Target 3-100 Range(yds)	Search Target	Search Range (yds)
4		11-23	1		W	Saidikowski	9450		
5		11-23	2		W	Vedovato	10300		
6		11-23	3		W	Bombard	11100		

SUMMARY OF OCCURRENCE OF SIGNIFICANT "F" VALUES ON DISCRIMINATIONS

	Runs			Observers			Instruments		
	Not Sig.	5%	1%	Not Sig.	5%	1%	Not Sig.	5%	1%
Target 1G and 100	2			2			2		
Other Discriminations	16	7	3	22	3	1	22	3	1
Total Discriminations Calculable	28			28			28		
Total Discriminations Observed	45			45			45		

Closest Discrimination Calculable: F-PI

ARITHMETIC MEANS 7 x 50 x 7 HH BY DISCRIMINATION

Discrimination	Mean Range(yds)	Discrimination	Mean Range(yds)	Discrimination	Mean Range(yds)
1-G	12100	9-G	10073	E-G	6900
1-100	11727	9-100	9700	E-100	6710
1-PI	10133	9-PI	8960	E-PI	2627
3-G	11677	C-G	4050	F-G	2700
3-100	11443	C-100	3410	F-100	2567
3-PI	9516	C-PI	2970	F-PI	1783
4-G	11510	D-G	-		
4-100	10593	D-100	-		
4-PI	9167	D-PI	2850		
A-G	10327	10-G	10850		
A-100	9983	10-100	10283		
A-PI	5277	10-PI	9333		

DATA ON RUNS FOR SET bS

SUMMARY OF INSTRUMENTS

Instruments	Position	90% RRP	50% RRP
1. 7x50x7 HH	11	78.0	100.0
2. 7x50x7 Mtd.	12	91.0	108.0
3. 7x50x7 VFA	10	99.0	117.0
4.			
5.			
6.			

RANGES

Runs	Simult. Set	Date	No. on Date	Course	Wind	Observer Sect. s'	Target 3-100 Range(yds)	Search Target	Search Range (yds)
7		12-8	2		W	Foley	12150		
8		12-8	3		W	Farone	15200		
9		12-13	4		-	Milling	10600		

SUMMARY OF OCCURRENCE OF SIGNIFICANT "F" VALUES ON DISCRIMINATIONS

	Runs			Observers			Instruments		
	Not Sig.	5%	1%	Not Sig.	5%	1%	Not Sig.	5%	1%
Target 1G and 100									
Other Discriminations	23	1		24			23	1	
Total Discriminations Calculable	24			24			24		
Total Discriminations Observed	33			33			33		

Closest Discrimination Calculable: F-PI

ARITHMETIC MEANS 7 x 50 x 7 HH BY DISCRIMINATION

Discrimination	Mean Range(yds)	Discrimination	Mean Range(yds)	Discrimination	Mean Range(yds)
A-G	10610	C-G	5253		
A-100	10450	C-100	4223		
A-PI	6833	C-PI	2917		
6-G	12643	D-G	4733		
6-100	14337	D-100	4227		
6-PI	11820	D-PI	3800		
9-G	13217	10-G	12937		
9-100	12550	10-100	12650		
9-PI	11077	10-PI	11093		
B-G	9750	F-G	3177		
B-100	9370	F-100	2843		
B-PI	5850	F-PI	1450		

DATA ON RUNS FOR SET cG

SUMMARY OF INSTRUMENTS

	Instruments	Position	90% RRP	50% RRP
1.	7x50x7 HH	10	77.0	100.0
2.	7x50x7 Mon.	12	81.0	92.0
3.	Naked Eye	11	72.0	84.0
4.				
5.				
6.				

RANGES

Runs	Simult. Set	Date	No. on Date	Course	Wind	Observer Sect. g'	Target 3-100 Range (yds)	Search Target	Search Range (yds)
10		12-15	1		-	Anderson	9200		
11		12-13	2		-	Hughs	14000		
12		12-13	3		-	Staton	12700		

SUMMARY OF OCCURRENCE OF SIGNIFICANT "F" VALUES ON DISCRIMINATIONS

	Runs			Observers			Instruments		
	Not Sig.	5%	1%	Not Sig.	5%	1%	Not Sig.	5%	1%
Target 1G and 100	2			2			2		
Other Discriminations	23	5	2	29	1	1	29		2
Total Discriminations Calculable	32			33			33		
Total Discriminations Observed	36			36			36		

Closest Discrimination Calculable: 10-PI

ARITHMETIC MEANS 7 x 50 x 7 HH BY DISCRIMINATION

Discrimination	Mean Range (yds)	Discrimination	Mean Range (yds)	Discrimination	Mean Range (yds)
1-G	12650	6-G	13223	C-G	6233
1-100	11800	6-100	12583	C-100	4893
1-PI	11167	6-PI	10267	C-PI	3700
3-G	13517	7-G	9683	D-G	6433
3-100	12460	7-100	8333	D-100	5143
3-PI	10600	7-PI	6317	D-PI	3150
4-G	13777	9-G	10983	10-G	12900
4-100	13150	9-100	9483	10-100	11967
4-PI	11167	9-PI	8033	10-PI	9933
A-G	9783	B-G	9006		
A-100	8017	B-100	6867		
A-PI	5583	B-PI	3833		

DATA ON RUNS FOR SET cQ

SUMMARY OF INSTRUMENTS

	Instruments	Position	90% RRP	50% RRP
1.	7x50x7 HH	10	78.0	100.0
2.	7x50x7 Mon.	12	90.0	100.0
3.	Naked Eye	11	62.0	84.0
4.				
5.				
6.				

RANGES

Runs	Simult. Set	Date	No. on Date	Course	Wind	Observer Sect. q'	Target 3-100 Range (yds)	Search Target	Search Range (yds)
1		11-21	1		W	Bridges	13700		
2		11-21	2		W	Phillips	13100		
3		11-21	3		W	Klooz	12730		

SUMMARY OF OCCURRENCE OF SIGNIFICANT "F" VALUES ON DISCRIMINATIONS

	Runs			Observers			Instruments		
	Not Sig.	5%	1%	Not Sig.	5%	1%	Not Sig.	5%	1%
Target 1G and 100		2		1	1		2		
Other Discriminations	33	3		36			32	4	
Total Discriminations Calculable	38			38			38		
Total Discriminations Observed	44			44			44		

Closest Discrimination Calculable: E-PI

ARITHMETIC MEANS 7 x 50 x 7 HH BY DISCRIMINATION

Discrimination	Mean Range (yds)	Discrimination	Mean Range (yds)	Discrimination	Mean Range (yds)
1-G	17627	6-G	16803	C-G	12217
1-100	17110	6-100	16803	C-100	12153
1-PI	14283	6-PI	11300	C-PI	5350
3-G	17087	7-G	11333	D-G	9817
3-100	16920	7-100	11267	D-100	6177
3-PI	13267	7-PI	9433	D-PI	3367
4-G	17087	9-G	15427	10-G	14700
4-100	16920	9-100	13687	10-100	13177
4-PI	18827	9-PI	9837	10-PI	7950
5-G	17087	B-G	13033	E-G	8310
5-100	16920	B-100	12950	E-100	7750
5-PI	13143	B-PI	4650	E-PI	2250
A-G	16860				
A-100	16860				
A-PI	7033				

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DATA ON RUNS FOR SET kD

SUMMARY OF INSTRUMENTS

	Instruments	Position	90% RRP	50% RRP
1.	7x50x7 HH	7	85.0	100.0
2.	7x50x7 Mon.	9	84.0	96.0
3.	10x50x7 HH	8	81.0	95.0
4.				
5.				
6.				

RANGES

Runs	Simult. Set	Date	No. on Date	Course	Wind	Observer Sect. d'	Target 3-100 Range(yds)	Search Target	Search Range (yds)
7		12-8	2		W	Roark	16650		
8		12-8	3		W	Nauman	10000		
9		12-13	4		-	Vedovato	13220		

SUMMARY OF OCCURRENCE OF SIGNIFICANT "F" VALUES ON DISCRIMINATIONS

	Runs			Observers			Instruments		
	Not Sig.	5%	1%	Not Sig.	5%	1%	Not Sig.	5%	1%
Target 1G and 100		2		1	1		2		
Other Discriminations	15	12	4	26	4	1	29	2	
Total Discriminations Calculable	33			33			33		
Total Discriminations Observed	36			36			36		

Closest Discrimination Calculable: F-PI

ARITHMETIC MEANS 7 x 50 x 7 HH BY DISCRIMINATION

Discrimination	Mean Range(yds)	Discrimination	Mean Range(yds)	Discrimination	Mean Range(yds)
1-G	16150	6-G	16060	D-G	4483
1-100	15767	6-100	15827	D-100	4443
1-PI	14667	6-PI	13377	D-PI	2833
3-G	16060	9-G	13877	10-G	13483
3-100	15827	9-100	13373	10-100	13290
3-PI	12453	9-PI	10500	10-PI	11150
4-G	16060	B-G	9600	F-G	2900
4-100	15827	B-100	9600	F-100	2697
4-PI	13610	B-PI	6983	F-PI	2360
A-G	12560	C-G	5367		
A-100	12360	C-100	5367		
A-PI	8427	C-PI	3803		

DATA ON RUNS FOR SET k(1)G

SUMMARY OF INSTRUMENTS

	Instruments	Position	90% RRP	50% RRP
1.	7x50x7 HH	1	78.0	100.0
2.	7x50x7 Mtd.	2	94.0	113.0
3.	10x50x7 Mtd.	3	99.0	118.0
4.				
5.				
6.				

RANGES

Runs	Simult. Set	Date	No. on Date	Course	Wind	Observer Sect. g'	Target 3-100 Range(yds)	Search Target	Search Range (yds)
7		12-8	2		W	Staton	13880		
8		12-13	4		W	Anderson	13880		
9		12-8	3		-	Hughs	10250		

SUMMARY OF OCCURRENCE OF SIGNIFICANT "F" VALUES ON DISCRIMINATIONS

	Runs			Observers			Instruments		
	Not Sig.	5%	1%	Not Sig.	5%	1%	Not Sig.	5%	1%
Target 1G and 100		2		2			2		
Other Discriminations	25	5	1	31			29	1	1
Total Discriminations Calculable	33			33			33		
Total Discriminations Observed	36			36			36		

Closest Discrimination Calculable: F-PI

ARITHMETIC MEANS 7 x 50 x 7 HH BY DISCRIMINATION

Discrimination	Mean Range(yds)	Discrimination	Mean Range(yds)	Discrimination	Mean Range(yds)
1-G	17343	6-G	17177	D-G	3350
1-100	16070	6-100	16393	D-100	2633
1-PI	14283	6-PI	11423	D-PI	2223
3-G	17287	9-G	12600	10-G	14267
3-100	16593	9-100	10877	10-100	12670
3-PI	12083	9-PI	9583	10-PI	11727
4-G	17287	B-G	8493	F-G	2733
4-100	16593	B-100	7927	F-100	2260
4-PI	12050	B-PI	6070	F-PI	1583
A-G	11993	C-G	3817		
A-100	9160	C-100	3167		
A-PI	8093	C-PI	2667		

DATA ON RUNS FOR SET mE

SUMMARY OF INSTRUMENTS

	Instruments	Position	90% RRP	50% RRP
1.	7x50x7 HH	4	79.0	100.0
2.	6x33x8 Mon. Mtd.	6	103.0	112.0
3.	4x28x10 Mtd.	5	95.0	104.0
4.				
5.				
6.				

RANGES

Runs	Simult. Set	Date	No. on Date	Course	Wind	Observer Sect. e'	Target 3-100 Range(yds)	Search Target	Search Range (yds)
4		11-23	1		W	Anderson	8350		
5		11-23	2		W	Barberio	11650		
6		11-23	3		W	Brau	9200		

SUMMARY OF OCCURRENCE OF SIGNIFICANT "F" VALUES ON DISCRIMINATIONS

	Runs			Observers			Instruments		
	Not Sig.	5%	1%	Not Sig.	5%	1%	Not Sig.	5%	1%
Target 1G and 100	2			2			2		
Other Discriminations	35	5	2	36	6		39	3	
Total Discriminations Calculable	44			44			44		
Total Discriminations Observed	45			45			45		

Closest Discrimination Calculable: G-100

ARITHMETIC MEANS 7 x 50 x 7 HH BY DISCRIMINATION

Discrimination	Mean Range(yds)	Discrimination	Mean Range(yds)	Discrimination	Mean Range(yds)
1-G	13400	9-G	11183	E-G	6216
1-100	13317	9-100	10043	E-100	4117
1-PI	12543	9-PI	7917	E-PI	2167
3-G	13937	C-G	4817	F-G	3020
3-100	13417	C-100	3517	F-100	2650
3-PI	10593	C-PI	2817	F-PI	1643
4-G	13450	D-G	3210		
4-100	13333	D-100	2783		
4-PI	10417	D-PI	2250		
A-G	13250	10-G	10777		
A-100	13133	10-100	9733		
A-PI	4143	10-PI	7927		

DATA ON RUNS FOR SET mJ

SUMMARY OF INSTRUMENTS

	Instruments	Position	90% RRP	50% RRP
1.	7x50x7 HH	4	82.0	100.0
2.	6x33x8 Mon. Mtd.	6	84.0	93.0
3.	4x28x10 Mtd.	5	84.0	93.0
4.				
5.				
6.				

RANGES

Runs	Simult. Set	Date	No. on Date	Course	Wind	Observer Sect. j'	Target 3-100 Range(yds)	Search Target	Search Range (yds)
10		12-15	1		-	Parker	8700		
11		12-13	2		-	Pauli	16900		
12		12-13	3		-	Meadnis	15450		

SUMMARY OF OCCURRENCE OF SIGNIFICANT "F" VALUES ON DISCRIMINATIONS

	Runs			Observers			Instruments		
	Not Sig.	5%	1%	Not Sig.	5%	1%	Not Sig.	5%	1%
Target 1G and 100		2		2			2		
Other Discriminations	13	11	7	26	5		28	3	
Total Discriminations Calculable	33			33			33		
Total Discriminations Observed	36			36			36		

Closest Discrimination Calculable: 10-PI

ARITHMETIC MEANS 7 x 50 x 7 HH BY DISCRIMINATION

Discrimination	Mean Range(yds)	Discrimination	Mean Range(yds)	Discrimination	Mean Range(yds)
1-G	15767	6-G	15067	C-G	6560
1-100	14850	6-100	14733	C-100	6000
1-PI	12827	6-PI	10700	C-PI	4333
3-G	15367	7-G	10967	D-G	6393
3-100	14800	7-100	10083	D-100	6000
3-PI	10467	7-FI	7367	D-PI	3017
4-G	14867	9-G	13177	10-G	14567
4-100	14633	9-100	13963	10-100	13683
4-PI	10900	9-PI	10910	10-PI	10783
A-G	8400	B-G	7433		
A-100	8300	B-100	6933		
A-PI	5317	B-PI	4093		

DATA ON RUNS FOR SET oH

SUMMARY OF INSTRUMENTS

	Instruments			Position	90% RRP	50% RRP
1.	7x50x7	HH	-	1	75.0	100.0
2.	10x80x7	Mtd.	00325	2	98.0	108.0
3.	6x50x7	Mtd.	A1012	3	82.0	90.0
4.						
5.						
6.						

RANGES

Runs	Simult. Set	Date	No. on Date	Course	Wind	Observer Sect. h'	Target 3-100 Range(yds)	Search Target	Search Range (yds)
10		12-15	1		-	Bombard	7800		
11		12-13	2		-	Farone	15800		
12		12-13	3		-	Calloway	16500		

SUMMARY OF OCCURRENCE OF SIGNIFICANT "F" VALUES ON DISCRIMINATIONS

	Runs			Observers			Instrumsnts		
	Not Sig.	5%	1%	Not Sig.	5%	1%	Not Sig.	5%	1%
Target 1G and 100		1	1	1	1		1	1	
Other Discriminations	17	7	7	23	6	1	26	3	1
Total Discriminations Calculable	33			32			32		
Total Discriminations Observed	39			39			39		

Closest Discrimination Calculable: F-PI

ARITHMETIC MEANS 7 x 50 x 7 HH BY DISCRIMINATION

Discrimination	Mean Range(yds)	Discrimination	Mean Range(yds)	Discrimination	Mean Range(yds)
1-G	15333	7-G	8567	D-G	6760
1-100	15633	7-100	8217	D-100	7183
1-PI	12117	7-PI	6333	D-PI	4933
3-G	15260	9-G	13167	10-G	13883
3-100	14567	9-100	12400	10-100	13367
3-PI	11210	9-PI	10917	10-PI	10350
4-G	14900	B-G	8750	F-G	5397
4-100	13767	B-100	8600	F-100	5070
4-PI	10583	B-PI	6167	F-PI	3500
A-G	8767	C-G	8567		
A-100	10067	C-100	7800		
A-PI	8233	C-PI	4983		

DATA ON RUNS FOR SET oL

SUMMARY OF INSTRUMENTS

	Instruments			Position	90% RRP	50% RRP
1.	7x50x7	HH	-	1	82.0	100.0
2.	10x80x7	Mtd.	-	2	108.0	125.0
3.	6x50x7	Mtd.	A1012	3	84.0	104.0
4.						
5.						
6.						

RANGES

Runs	Simult. Set	Date	No. on Date	Course	Wind	Observer Sect. l'	Target 3-100 Range(yds)	Search Target	Search Range (yds)
4		11-23	1		W	Jagelewski	11700		
5		11-23	2		W	Atchison	11400		
6		11-23	3		W	Hughs	11500		

SUMMARY OF OCCURRENCE OF SIGNIFICANT "F" VALUES ON DISCRIMINATIONS

	Runs			Observers			Instruments		
	Not Sig.	5%	1%	Not Sig.	5%	1%	Not Sig.	5%	1%
Target 1G and 100	2			2			2		
Other Discriminations	27	3		26	4		27	3	
Total Discriminations Calculable	32			32			32		
Total Discriminations Observed	32			32			32		

Closest Discrimination Calculable: G-100

ARITHMETIC MEANS 7 x 50 x 7 HH BY DISCRIMINATION

Discrimination	Mean Range(yds)	Discrimination	Mean Range(yds)	Discrimination	Mean Range(yds)
1-G	13633	9-G	11450	E-G	7983
1-100	13350	9-100	11167	E-100	6660
1-PI	12127	9-PI	8267	E-PI	2617
3-G	14317	C-G	5900	F-G	3233
3-100	13850	C-100	5077	F-100	2983
3-PI	10983	C-PI	3233	F-PI	1717
4-G	14233	D-G	4560	G-G	1980
4-100	13700	D-100	3683	G-100	1513
4-PI	10467	D-PI	2583	G-PI	-
A-G	13350	10-G	12383		
A-100	12700	10-100	11533		
A-PI	5783	10-PI	10417		

DATA ON RUNS FOR SET o(1)L

SUMMARY OF INSTRUMENTS

Instruments				Position	90% RRP	50% RRP
1.	7x50x7	HH	-	1	78.0	100.0
2.	21x76x2.8	Mtd.	-	2	84.0	94.0
3.	6x50x7	Mtd.	A-1012	3	87.0	96.0
4.						
5.						
6.						

RANGES

Runs	Simult. Set	Date	No. on Date	Course	Wind	Observer Sect. 1'	Target 3-100 Range(yds)	Search Target	Search Range (yds)
1		11-21	1		W	Atchison	17600		
2		11-21	2		W	Jagelewski	16800		
3		11-21	3		W	Hughs	20030		

SUMMARY OF OCCURRENCE OF SIGNIFICANT "F" VALUES ON DISCRIMINATIONS

	Runs			Observers			Instruments		
	Not Sig.	5%	1%	Not Sig.	5%	1%	Not Sig.	5%	1%
Target 1G and 100	1	1		1	1		2		
Other Discriminations	21	3	1	25			24	1	
Total Discriminations Calculable	27			27			27		
Total Discriminations Observed	45			45			45		

Closest Discrimination Calculable: F-PI

ARITHMETIC MEANS 7 x 50 x 7 HH BY DISCRIMINATION

Discrimination	Mean Range (yds)	Discrimination	Mean Range (yds)	Discrimination	Mean Range (yds)
1-G	20050	6-G	20017	10-G	18767
1-100	19617	6-100	18810	10-100	18143
1-PI	16233	6-PI	15343	10-PI	16417
3-G	20417	7-G	12043	E-G	11660
3-100	19650	7-100	11417	E-100	10417
3-PI	15577	7-PI	8610	E-PI	2993
4-G	20383	9-G	17567	F-G	7867
4-100	19650	9-100	16217	F-100	7360
4-PI	14977	9-PI	12093	F-PI	3083
5-G	20380	B-G	15743	G-G	6227
5-100	19333	B-100	11617	G-100	6033
5-PI	14017	B-PI	4727	G-PI	-
A-G	19533	D-G	10477		
A-100	18160	D-100	10050		
A-PI	7750	D-PI	4300		

DATA ON RUNS FOR SET pF

SUMMARY OF INSTRUMENTS

Instruments			Position	90% RRP	50% RRP
1.	7x50x7	HH	6	74.0	100.0
2.	20x120x3	Mtd.	4	106.0	134.0
3.	25x100x3.6	Mtd.	5	106.0	133.0
4.					
5.					
6.					

RANGES

Runs	Simult. Set	Date	No. on Date	Course	Wind	Observer Sect. f'	Target 3-100 Range(yds)	Search Target	Search Range (yds)
7		12-8	2		W	Saidikowski	14330		
8		12-8	3		W	Parker	9900		
9		12-13	4		-	Tucker	15600		

SUMMARY OF OCCURRENCE OF SIGNIFICANT "F" VALUES ON DISCRIMINATIONS

	Runs			Observers			Instruments		
	Not Sig.	5%	1%	Not Sig.	5%	1%	Not Sig.	5%	1%
Target 1G and 100									
Other Discriminations	20	2.	2	22	1	1	22	2	
Total Discriminations Calculable	24			24			24		
Total Discriminations Observed	33			33			33		

Closest Discrimination Calculable: F-PI

ARITHMETIC MEANS 7 x 50 x 7 HH BY DISCRIMINATION

Discrimination	Mean Range (yds)	Discrimination	Mean Range (yds)	Discrimination	Mean Range (yds)
A-G	10800	B-G	9850	10-G	13887
A-100	10027	B-100	9427	10-100	13277
A-PI	6947	B-PI	5183	10-PI	12037
6-G	16817	C-G	5127	F-G	3067
6-100	15550	C-100	4333	F-100	2817
6-PI	12700	C-PI	3867	F-PI	2227
9-G	14167	D-G	4250		
9-100	13150	D-100	3633		
9-PI	11387	D-PI	3210		

DATA ON RUNS FOR SET pE

SUMMARY OF INSTRUMENTS

	Instruments			Position	90% RRP	50% RRP
1.	7x50x7	HH	-	6	78.0	100.0
2.	20x120x3	Mtd.	-	4	143.0	193.0
3.	25x100x3.6	Mtd.	-	5	134.0	174.0
4.						
5.						
6.						

RANGES

Runs	Simult. Set	Date	No. on Date	Course	Wind	Observer Sect. e'	Target 3-100 Range(yds)	Search Target	Search Range (yds)
4		11-23	1		W	Anderson	13800		
5		11-23	2		W	Barberio	18930		
6		11-23	3		W	Brau	4300		

SUMMARY OF OCCURRENCE OF SIGNIFICANT "F" VALUES ON DISCRIMINATIONS

	Runs			Observers			Instruments		
	Not Sig.	5%	1%	Not Sig.	5%	1%	Not Sig.	5%	1%
Target 1G and 100	2			2			2		
Other Discriminations	28	8	2	38			34	2	2
Total Discriminations Calculable		40			40			40	
Total Discriminations Observed		43			43			43	

Closest Discrimination Calculable: F-PI

ARITHMETIC MEANS 7 x 50 x 7 HH BY DISCRIMINATION

Discrimination	Mean Range(yds)	Discrimination	Mean Range(yds)	Discrimination	Mean Range(yds)
1-G	20593	6-G	18910	D-G	7767
1-100	19033	6-100	18450	D-100	7200
1-PI	17717	6-PI	16810	D-PI	3233
3-G	19793	7-G	11277	10-G	13550
3-100	19710	7-100	10617	10-100	12343
3-PI	17443	7-PI	8560	10-PI	9000
4-G	19660	9-G	18527	E-G	8283
4-100	19560	9-100	17377	E-100	6683
4-PI	17343	9-PI	12467	E-PI	2533
5-G	19710	B-G	12917	F-G	3507
5-100	19370	B-100	11633	F-100	4103
5-PI	16943	B-PI	4217	F-PI	2687
A-G	19560	C-G	10127		
A-100	18443	C-100	8583		
A-PI	7050	C-PI	5777		

DATA ON RUNS FOR SET wC

SUMMARY OF INSTRUMENTS

	Instruments		Position	90% RRP	50% RRP
1.	7x50x7	HH	7	83.0	100.0
2.	7x50x10	HH	8	92.0	101.0
3.	6x42x12	HH	9	94.0	100.0
4.					
5.					
6.					

RANGES

Runs	Simult. Set	Date	No. on Date	Course	Wind	Observer Sect. c'	Target 3-100 Range(yds)	Search Target	Search Range (yds)
1		11-21	3		W	Hambrick	10350		
2		11-21	2		W	Zachman	17950		
3		11-21	1		W	Myers	16750		

SUMMARY OF OCCURRENCE OF SIGNIFICANT "F" VALUES ON DISCRIMINATIONS

	Runs			Observers			Instruments		
	Not Sig.	5%	1%	Not Sig.	5%	1%	Not Sig.	5%	1%
Target 1G and 100			2	2			2		
Other Discriminations	15	14	11	39	1		39	1	
Total Discriminations Calculable		42			42			42	
Total Discriminations Observed		45			45			45	

Closest Discrimination Calculable: G-PI

ARITHMETIC MEANS 7 x 50 x 7 HH BY DISCRIMINATION

Discrimination	Mean Range(yds)	Discrimination	Mean Range(yds)	Discrimination	Mean Range(yds)
1-G	16400	6-G	19200	D-G	7483
1-100	16400	6-100	19017	D-100	6243
1-PI	16000	6-PI	15133	D-PI	3710
3-G	19200	7-G	12293	10-G	15017
3-100	19017	7-100	11883	10-100	15017
3-PI	16160	7-PI	8893	10-PI	10760
4-G	19200	9-G	16917	E-G	5300
4-100	19017	9-100	16683	E-100	4793
4-PI	15720	9-PI	14743	E-PI	2360
5-G	18860	B-G	12000	G-G	13233
5-100	18860	B-100	9243	G-100	13133
5-PI	14743	B-PI	4717	G-PI	8050
A-G	18876	C-G	10833		
A-100	18693	C-100	10533		
A-PI	7027	C-PI	6317		

DATA ON RUNS FOR SET wB

SUMMARY OF INSTRUMENTS

	Instruments	Position	90% RRP	50% RRP
1.	7x50x7 HH	8	81.0	100.0
2.	7x50x10 HH	9	91.0	98.6
3.	6x42x12 HH	7	92.0	100.0
4.				
5.				
6.				

RANGES

Runs	Simult. Set	Date	No. on Date	Course	Wind	Observer Sect. b'	Target 3-100 Range(yds)	Search Target	Search Range (yds)
10		12-15	1		-	Roark	7700		
11		12-13	2		-	Naumann	16400		
12		12-13	3		-	Filissey	15600		

SUMMARY OF OCCURRENCE OF SIGNIFICANT "F" VALUES ON DISCRIMINATIONS

	Runs			Observers			Instruments		
	Not Sig.	5%	1%	Not Sig.	5%	1%	Not Sig.	5%	1%
Target 1G and 100	2			2			2		
Other Discriminations	20	8	6	29	3	2	32	1	1
Total Discriminations Calculable	36			36			36		
Total Discriminations Observed	36			36			36		
Closest Discrimination Calculable: F-PI									

ARITHMETIC MEANS 7 x 50 x 7 HH BY DISCRIMINATION

Discrimination	Mean Range (yds)	Discrimination	Mean Range(yds)	Discrimination	Mean Range (yds)
1-G	15233	6-G	14733	C-G	6760
1-100	13593	6-100	14360	C-100	6093
1-PI	11150	6-PI	10333	C-PI	4677
3-G	14667	7-G	10500	D-G	6143
3-100	14360	7-100	9867	D-100	6060
3-PI	10350	7-PI	6417	D-PI	3410
4-G	14783	9-G	13227	10-G	13550
4-100	14360	9-100	10150	10-100	13233
4-PI	10333	9-PI	9500	10-PI	9967
A-G	10833	B-G	12610	F-G	2950
A-100	9567	B-100	9917	F-100	2950
A-PI	6283	B-PI	5733	F-PI	2033

APPENDIX D

APPENDIX D

LIST OF PERSONNEL

O - Observer
s - Statistics Crew
fc - Fort Crew (care of targets, etc.)
bc - Bridge Crew

os - Office Staff
st - Stores
so - Staff Officer
lo - Line Officer

Anderson, F. E.	SM2/C	USN	0	s
Atchison, G. B.	QM1/C	USN	0	s
Bamford, T. E.	MoMM3/C	USNR	0	
Barberio, F. G.	S1/C	USNR	0	s
Barger, P. K.	MoMM1/C	USNR	0	
Bergen, R.H.	EM1/C	USNR	0	
Bombard, J. J.	RM2/C	USNR	0	
Brau, L. C.	S1/C	USNR	0	s
Brazil, J.	MoMM2/C	USNR	0	
Bridges, J. K.	TM1/C	USN	0	
Brown, S. W.	EM1/C	USNR	0	
Calloway, [illegible] C.	MoMM3/C	USNR	0	
Carter, L. H.	TM2/C	USNR	0	fc
Casper, G. H.	FC1/C	USN	0	
Cole, L. C.	MoMM1/C	USNR	0	
Coleman, C. A.	QM2/C	USNR	0	
Cook, E.. B.	Lt.H(S)	USNR	so	
Cook, Mrs. N.	Civil Service		os	
Courtney, J. A.	TME3/C	USNR	0	
Curtis, J. F.	Ens.(S)	USNR	so	
Day, G. C.	CSM	USN	bc	s
DeGood, H.D.	EM2/C	USNR	fc	
DeWitt, R. B.	GM2/C	USNR	0	fc
Dobbins, F. G.	QM2/C	USN	bc	
Dunham, T., Jr.	Sect. 16-1 NDRC		0	
Eastin, J. D.	QM2/C	USNR	fc	
Ebben, J. J.	QM2/C	USNR	bc	
Edwards, C. E.	HA1/C	USNR(W)	os	
Ellis, M. E.	QM2/C	USNR	s	st
Elsholz, F.	MoMM3/C	USNR	fc	
Faraone, F. A.	TM2/C	USNR	0	
Fillissey, F.	EM3/C	USNR	0	
Foley, J. J.	MoMM2/C	USNR	0	
Garroway, A. M.	PhM3/C	USNR(W)	s	
Ferguson, R. L.	CBM	USN	bc	
Gargano, M. R.	SM2/C	USNR	bc	
Gassert, C. A.	Lt.(jg) S(O)	USNR	lo	
Graham, D. D.	RM2/C	USNR	bc	
Greiner, C. L.	S1/C	USNR	bc	
Griffin, T. W.	Biological Laboratories, Harvard University		0	
Hale, B. T.	QM2/C	USNR	bc	
Hambrick, C. N.	QM3/C	USNR	0	
Harris, R. C.	SM2/C	USNR	fc	
Haskins, R. L.	GM2/C	USN	fc	
Hendley, Chas. W.	Dept. Of Biophysics Columbia University		0	
Hughs, J. C.	SM1/C	USN	0	
Isselhardt, F. X.	CSM(AA)	USN	s	
Jackson, T. A.	QM1/C	USN	fc	
Jagelewski, R. C.	QM3/C	USNR	0	
Johnson, G. R.	RM3/C	USNR	s	
Joy, L. W.	QM2/C	USNR	bc	
Kern, F. G.	QM1/C	USNR	bc	
Kirk, J. S.	RM3/C	USN	0	
Klooz, R. L.	QM2/C	USNR	0	
Kozlowski, A. F.	CMoMM	USN	s	
Kramer, G. W.	S1/C	USN	0	s
Kuehner, J. T.	TM2/C	USN	fc	
LaMontagne, L.	SM2/C	USNR	bc	
Lamoureux, R. M.	CMoMM	USN	s	
Larson, L. P.	CTM	USN	s	
Lamar, E. L.	Operations Evaluation Group, Cominch		0	
Lee, R. H.	Cmdr. H(S)	USNR	0	

Le Fevre , C. M.	S1/C	USNR	s	
Lemaster, O. M.	EM3/C	USNR	0	
Louderback, W. B.	TM3/C	USN	0	
Luce, O. H., Jr.	S1/C	USNR	0	
Mearig, H. C.	Lt.(D)	USNR	lo	
Mikolay, J. R.	MoMM3/C	USN	0	
Meadnis, D. M.	MoMM3/C	USNR	0	
Miller, L. R.	MoMM2/C	USNR	0	
Milling R. W.	SM1/C	USNR	0	
Mills, G. W.	EM3/C	USNR	0	
Mourton, H. J.	QM2/C	USN	fc	
Myers, C., Jr.	MoMM2/C	USNR	0	
McCarthy, E. V.	S1/C	USNR	st	
McLarney, H. R.	RM2/C	USNR	bc	
Miles, W. L.	Dept. of Psychology, Yale University		0	
Mueller, C.	Lt.(jg)H(S)	USNR	0	
Naumann, W.	TM2/C	USNR	0	
Nichols, W. R.	FC2/C	USN	fc	
Nixon, W. M.	EM1/C	USNR	0	
Oberer, F.	PhM3/C	USNR(W)	s	
Olson, A. G.	RM3/C	USNR	bc	
Osgood, C. E.	Dept. of Psychology, Yale University		in C of s	
Overmier, B. R.	RM2/C	USNR	bc	
Parker, H. R.	TM3/C	USNR	0	
Parker, R. L.	Lt.(E)	USNR	os	
Pauli, J. L.	TM2/C	USNR	0	
Pedersen, L. W.	TM2/C	USN	0	
Phillips, C. A.	SM2/C	USNR	0	
Purington, K. L.	MoMM2/C	USNR	bc	
Pusateri, O. M.	QM2/C	USNR	0	
Reed, J. D.	PhM1/C	USNR	0	os
Rice, B. B.	QM3/C	USNR	0	
Ritter, A. G.	RM2/C	USNR	0	
Roark, R. B.	F1/C	USNR	0	
Robertson, J.	PhM3/C	USNR(W)	s	
Ross, S.	Ens.H(S)	USNR	0	
Sagaser, W. D.	ETM1/C	USNR	0	
Saidikowski, H. J.	RM2/C	USNR	0	
Scott, D., Jr.	Johnson Foundation of Medical Physics, Univ. of Pennsylvania		0	
Shlaer, S.	Dept. Of Biophysics Columbia University		0	
Shook, R. D.	QM2/C	USNR	0	
Shoemaker, J. D.	MoMM3/C	USNR	0	
Smith, J. T	CMoMM	USN	s	
Snyder, H. F.	FC3/C	USNR	fc	
Stanley, H. P.	FC3/C	USNR	0	
Staton, S. H.	RM2/C	USNR	0	s
Strickland, S. E.	TM2/C	USNR	0	
Stroud, D. A.	MoMM1/C	USNR	0	
Tucker, G. W.	EM3/C	USNR	0	
Usher, H. G.	MoMM1/C	USN	s	
Vedovato, J.	EM3/C	USNR	0	
Ventgen, F. J.	RM2/C	USN	bc	
Verplanck, W. S.	Lt. (jg) H(S)	USNR	OinC	
Vickers, C. S.	QM2/C	USN	fc	
Webb, R. L.	EM2/C	USNR	0	
Webster, C. A.	SM1/C	USNR	0	
Walker, J. C.	QM1/C	USNR	bc	
Williams, S. B.	Lt. (jg) H(S)	USNR	0	
Zachmann, G. H.	QM3/C	USNR	0	
Zink, C. E.	TM2/C	USNR	0	