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A Survey of Human Factors in Military Night Operations

(With Special Application to Armor)

by

Donald A. Gordon

FC

U.S. Army Armor Human Research Unit
Fort Knox, Kentucky

Under the Technical Supervision of

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

A SURVEY OF HUMAN FACTORS IN MILITARY NIGHT OPERATIONS
(WITH SPECIAL APPLICATION TO ARMOR)

by

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Task ARMORNITE

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

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A SURVEY OF HUMAN FACTORS IN MILITARY NIGHT OPERATIONS

(WITH SPECIAL APPLICATION TO ARMOR)

SUMMARY AND CONCLUSIONS

PROBLEM

It has become increasingly important to know what men can see and do when illumination is imperfect, for more and more military operations are taking place at night. This survey was initiated to provide a comprehensive background for a broad research program,[1] the objectives of which are to identify training problems peculiar to night Armor operations and to develop methods which will train crews to be effective in night combat.

SCOPE OF THE SURVEY

In this survey, the scientific and technical literature on human factors in night military operations has been outlined and the research developments have been considered particularly for their applicability to tank operations. Primarily, the "human" aspects of a topic have been reviewed, with less emphasis on mechanical and engineering problems. The aim has been to review as large a variety of topics as possible, so that problems in training can be seen in relationship to each other and to problems in other Armor areas.

CONCLUSIONS

The most significant conclusions from the study are as follows:

(1) The formulation of research problems in Armor night training progresses with advances in establishment and clear statement of doctrine and concepts of night operations.

(2) There is a pressing need to devise means of measuring the proficiency of Armor units and individuals in performing their night operations duties.

(3) White light sources seem at present to be the best illuminants for general use.

(4) Infrared illumination is presently of restricted value in support of gunnery or as an area illuminant, although fairly suitable for driving when the enemy lacks IR detection devices.

(5) Further information is needed concerning night vision, including studies of the relative effectiveness and appropriate uses of various kinds of illuminants, and of countermeasures against such illuminants.

[1] The research task ARMORNITE was approved in Ltr, Chief R&D to CONARC and Director, HumRRO (CSRD/E) dtd 16 May 55; Subject: HumRRO Work Program, FY 56.

Chapter 1

INTRODUCTION

RECENT RECOGNITION OF THE IMPORTANCE OF NIGHT COMBAT

Military strategists have become increasingly aware of the necessity of understanding and developing the methods of night operation. During World War II, the night fighting tactics of the Japanese were surprisingly effective, particularly at Hong Kong and Singapore, and in Malaya, the Philippines, and Burma. In the European theater, night operations took precedence over day action; ". . . night and other periods of poor visibility, such as fog and snowstorms or rainstorms, gradually came to be considered the ideal time for action. Interference from the air reduced fighting and paralyzed movements in daytime hours, with the result that the space between the front and the most remote corner of the rear areas was often empty and deserted. During the hours of darkness combat movements resumed with new intensity . . ." (2).[1] The U.S. Chief of Army Field Forces recognized the strong necessity for night training; a training directive issued in 1951 states that "a minimum of 33 per cent of individual and team performance of all tactical training . . . be conducted during hours of darkness" (4).

At the beginning of World War II, tanks were "night blind." Up to that time, there had been little emphasis on night fighting by land forces in general, and by tanks in particular. Techniques, training methods, and technical doctrine on the use of tanks at night were therefore not available. The inside of the tank was highly illuminated, making it difficult for crewmen to see outside unless they were dark adapted; at the same time, the tank was an easy target for enemy observers. Such night fighting equipment as sights, blackout lights, and searchlights was not available.

The need for equipping the tank for night fighting was particularly evident in the African campaign. General Robinett found that the men wanted to operate in the cool night but were unable to do so because of a lack of equipment and methodology (3). Subsequent research and development have been aimed at removing this limitation.

PURPOSE AND SCOPE OF THE SURVEY

The purpose of this survey is to outline the scientific and technical literature on human factors in night military operations. The research developments will be considered particularly for their applicability to tank operation.

[1] See page 55 for list of references, by chapters.

Each daytime operational problem has it's nighttime counterpart; in addition, some problems arise at night which are not very significant during the day. In order to whittle the survey to workable proportions, only those problems have been considered which have received particular attention in the scientific and technical literature, and which appear to be applicable to tanks. Lack of time has prevented a review of the extensive literature on night camouflage and night lookout duty. It would also have been interesting to deal with new technical developments, such as infrared homing and detecting devices and other invisible ray applications. So little is known about such devices that one can only speculate about their applicability to tanks.

When possible, topics have been reviewed in their "human" aspects—those involving the behavior and capabilities of the human being in the military situation. Less emphasis has been given to such mechanical and engineering problems as measurement of night illumination, attenuation of illumination by dust and haze, lethality of weapons, and causes of mechanical failure in equipment.

Some of the problems reviewed are somewhat peripheral to the HumRRO interest in training research. The aim has been to review as large a variety of problems as possible, so that problems in training can be seen in relationship to each other and to problems in other areas. Since training usually involves equipment, a training problem may be created or eliminated on the basis of the success of previous engineering solutions. Sometimes a modification of equipment may be more effective than a change in training methods.

VISUAL FUNCTIONING UNDER NIGHT ILLUMINATION

Visibility information is essential for planning over-all tactical methods as well as particular field engagements. This information, in terms of what can be seen at various levels of illumination, indicates the handicap attributable to darkness and reveals the magnitude of the night operational problem.

It is instructive to consider some typical visibility data. The distances at which men, dressed in khaki, may be seen at night when they are standing against various backgrounds are given below (1).

Illumination	Background		
	Snow or Sky	Grass	Ploughed Field
Full moon	300 yards	150 yards	100 yards
Half moon	150	75	50
Starlight	100	30	15

At full-moon or half-moon levels, visibility may be adequate for many military operations; the use of telescopes and binoculars will make it more nearly so. At brightnesses associated with starlight and lower levels, visibility is not satisfactory; rapid and effective shooting, driving, bridge building, evacuation of the wounded, clearing of mine fields, map reading, gun laying, and instrument reading are not to be expected. It is at these brightnesses that an acute night problem exists.

It must be appreciated that the point at which lack of illumination becomes a problem is related to the task at hand and the weapon used. Darkness is much more of a handicap to the tanker with his long-range armament than to the infantryman with his relatively short-range weapons.

FIELD AND LABORATORY RESEARCH

Night (a . . other) military problems are best solved by a combination of field trials, laboratory research, and field experimentation. The distinction between these types of experiments is well worth making; examples can be given of research which was ineffective because the wrong technique was used.

In field trials, new equipment and techniques are tried out under simulated battle conditions. These observations set the stage for research by pointing out problems and by giving a notion of how critical they are. Field trials are also useful in testing the application of principles and techniques developed in the laboratory. In laboratory research, an effort is made to determine the effect of a single independent variable on one or more dependent variables. Because of the sensitivity made possible by precise control, differences in equipment and techniques can be quickly brought out in laboratory research. In field experimentation, control is maintained, and as far as possible the operating conditions found in the field are preserved. Some artificiality is allowed in order to achieve discrimination of scores and accuracy of recording. This type of experimentation is required where laboratory procedures cannot duplicate field conditions. It is the method most frequently applied in training research.

Scientists have at times overlooked the fact that military research must show practical military significance as well as statistical significance. A special night sight may yield an increase of 300 per cent in accuracy of night shooting, an impressive improvement—but if the new sight allows a standing opponent to be shot at six feet instead of four feet, and it requires 10 seconds to take aim, the method is obviously unsuited for military application. The striking power of tanks will be largely wasted if efficiency of night operation is improved only slightly. The researcher's job is not finished when laboratory or field experimentation is completed; the new technique or equipment must also be proved in field trials.

Chapter 2

NIGHT VISION TRAINING FOR ARMOR PERSONNEL[1]

INTRODUCTION

Early in World War II it became evident that scientists had amassed a large body of information applicable to night vision training. This information was gathered and organized into "courses," first in England and later in Canada and the United States. The specific objectives most commonly mentioned in the training manuals of these courses were: First, to give the trainee a body of sound basic information about using the eyes at night—for example, how to develop maximum sensitivity, how to protect the eyes at night; second, to develop actual skill in using the eyes at night—for example, learning to recognize objects under starlight illumination; third, to develop adequate attitudes toward seeing at night—for example, to develop belief that one can see at low levels of illumination and to reduce the fear commonly associated with night operations. Appendix A is an outline of a night vision course given at Fort Knox, Ky. (42). This schedule is a good sample of the content of night vision training programs given in the Navy, Air Force, and Marine Corps.[2]

BASIC PRINCIPLES OF NIGHT VISION TRAINING COURSES

The principles listed below have been selected chiefly on the basis of the frequency of their mention in manuals and lectures (1,7,33,34,35,36, 38). The statement of each principle is an attempt to generalize from several sources. The principles are grouped in arbitrary categories which are not necessarily related to the systematic presentation of the material in a training program.

[1]This chapter is adapted from: Brant Clark, "Night Vision Training: A Summary of Research and Practice," Minutes and Proceedings of the Armed Forces-NRC Vision Committee, 29th Meeting, November 1951 (CONFIDENTIAL), pp. 199-211.

[2]The training at Fort Knox and other installations was intended to improve the effectiveness of the individual soldier. Training in group tactics at night has also been widely given, but no attempt to assess its effectiveness has yet been made. Methodology for evaluating effectiveness of rifle squads in daylight maneuvers may be found in M.D. Havron *et al.*, *The Effectiveness of Small Military Units* (Report 916), Personnel Research Section, The Adjutant General's Office, Washington, April 1951; see also, M.D. Havron *et al.*, *The Effectiveness of Small Military Units*, (Report 980), Personnel Research Section, The Adjutant General's Office, Washington, September 1952.

Basic Anatomy and Physiology of Rod Vision

All training schedules give some statement about the anatomy and physiology of rod vision, although such statements are usually perfunctory and limited to the most elementary facts, such as the following:

(1) There are separate mechanisms for vision in daylight and for vision at night, and each has its separate functions. The "duplicity" theory, which maintains that there are two functional systems in the eye, has been considerably modified by the results of recent researches (32). It is nevertheless a good approximation of visual functioning under bright and dark conditions.

(2) Rod vision is dependent upon a photochemical process in the retina. Wald has recently summarized the chemistry of rod vision in terms of the known reactions (47). The photochemical reactions of the retina are believed to involve light, rhodopsin, vitamin A plus protein, and retinene plus protein.

(3) The rods are sensitive to extremely small amounts of radiant energy. Hecht et al. have found that "the minimum energy required for threshold vision under optimal physiological conditions yield [sic] values between 2.1 and 5.7×10^{-10} ergs at the cornea, which correspond to between 54 and 148 quanta of blue-green light. When losses through the optical mechanisms are taken into account the threshold value absorbed by the retinal rods is reduced to five to fourteen quanta" (21).

Factors Involved in the Development and Maintenance of Dark Adaptation

The principles of dark adaptation make up the major part of discussions of night vision. The most frequently mentioned principles are these:

(1) The eye is adaptable to a wide range of intensities of light. Bartley states that the sensitivity of the eye, from the stimulus threshold to the upper limit of visual tolerance, ranges from .000001 to 16,000 millilamberts (3).

(2) Adaptation depends to some extent on the change in the size of the pupil, but chiefly on the increase in sensitivity of the rods. During exposure to darkness the pupil normally increases in size to a maximum some five times its normal diameter. This dilation, although it permits approximately 25 times as much light to enter the eye, could account for only a small fraction of the over-all increase in sensitivity. Dark adaptation is a function of the chemistry of the retina (46,47,48). Neurological factors are also involved (3).

(3) Thirty minutes in complete darkness are required to dark adapt the eyes. This period of time is suggested almost universally as the minimum time needed to dark adapt the eyes. Although the rate of dark adaptation varies widely for different situations, there is much experimental evidence to support the selection of 30 minutes as a practical minimum period under average situations. It should be pointed out that adaptation proceeds for a long time thereafter (3,18).

(4) Red goggles or red light may be used to achieve adequate dark adaptation and to protect adaptation once it is achieved. This procedure has been widely used. The method most commonly suggested involves wearing red goggles for 20 minutes in moderate illumination and then remaining in darkness for 10 more minutes. The adaptive value of filters is based upon the difference in the luminosity curves for the rods and cones (22). The rods are stimulated by only one per cent of the total flux beyond 600 mμ, whereas the cones are stimulated by approximately 10 per cent. The filter passes enough light to permit a degree of cone vision sufficient to do a variety of tasks. If the glasses are worn for 20 minutes and the observer remains in the dark for 10 more minutes, the rods will in effect be in the dark 30 minutes and the cones, 10 minutes. This procedure achieves a practical level of adaptation. The protective value of red light can be understood on the same basis.

(5) When white light must be used for seeing, minimum interference with adaptation is produced by brief exposure of the lowest intensity possible. Vitiation of dark adaptation by white light is a function of wave length, intensity, and duration (3,22,48). Instrument panels should be illuminated with red light of low intensity to reduce the loss of dark adaptation which results from reading dials. (See preceding paragraph.)

(6) Brief exposures to bright light, such as produced by searchlights and flares, reduce visual efficiency in low illumination but recovery is more rapid than normal dark adaptation is. Data which support this statement are found in experimental investigations (2,18).

(7) An effective method of protecting adaptation during exposure to dazzle is to cover one eye. The independence of adaptation of the two eyes has been frequently demonstrated (47,48).

(8) Individuals who are to make night observations should avoid brilliant sunlight during the day or wear low-transmission glasses. The effect of pre-exposure to very brilliant light in elevating the absolute threshold, delaying adaptation, and causing other ocular changes is well known (3,18,25). It has been shown in several studies that the higher threshold may last for 24 hours or more (8,10,18). The protective value of wearing high-density filters has also been demonstrated (10). The transmission of such filters should be 15 per cent or less for protection against brilliant sunlight and 5 per cent or less for exposure to highly reflecting material such as white sandy beaches.

(9) Constant practice is necessary to maintain a high level of skill at scotopic levels. This statement is commonly made, but there is little supporting experimental evidence. A British paper reports that maximum efficiency was obtained after three days of practice (36). Low states that 25 hours of practice are necessary to bring peripheral acuity to nearly maximum efficiency (27). Studies on the permanence of improvement in seeing would be helpful in evaluating night visual training programs.

(10) Good physical condition is necessary for superior scotopic vision. Several studies have shown that deficiency in vitamin A will reduce scotopic sensitivity (20,23). It has been shown that night

blindness is sometimes alleviated by remedying deficiencies of vitamin A (23). Anoxia also produces marked reduction in brightness discrimination (3,19). Deterioration begins at fairly low altitudes, becoming obvious at 8,000 feet, and marked at 15,000 feet. This effect of altitude on both rod and cone vision is due not to the photochemical process but to the fact that the functioning of the visual pathway is impaired.

(11) Rate of dark adaptation is increased and the threshold lowered by nonvisual stimulation. This "principle" has been widely stated, but has not been incorporated in night vision training programs. To omit it is wise for, according to Chapanis and his co-workers, various forms of exercise and other stimulation do not affect dark adaptation, contrast sensitivity, or form discrimination at low illuminations (8).

Limitations of Vision at Night

All night vision training manuals make a point of stressing the limitations of scotopic vision as well as its extreme sensitivity. The principles most frequently stressed are these:

(1) Color perception is not possible at scotopic levels of illumination. This fact has been frequently verified (3).

(2) The comparative brightness of colors in photopic vision is different from that in scotopic vision. It is known that the visibility curve shifts under dim illumination, because of differences in the sensitivity of the rods and cones to various parts of the spectrum. Reds appear relatively less bright and blues relatively brighter at scotopic intensities (3).

(3) Visual acuity at scotopic levels is far below acuity at photopic levels. Studies have been made using various types of targets to measure visual acuity (3,13). Experiments by Low (26,28) confirm earlier work showing that for peripheral vision the acuity at scotopic levels roughly approximates that found at photopic levels. Rowland and Rowland have found that the greatest scotopic sensitivity for form is to be found between 4 and 12 degrees from the fovea (40). But the greatest sensitivity to light is found 5 to 10 degrees farther into the periphery.

(4) It is possible to construct tables of distances at which objects can be observed at night. Tables and nomographs have been prepared to indicate distances at which detection (12) and identification (35,38) of objects can occur under various conditions of outdoor observation. Attempts have been made to verify visual ranges derived from the results of laboratory experimentation (6). The topic of visibility research will be more thoroughly reviewed in another section of this report.

(5) Depth perception is impaired at night. Results of experimentation suggest that dim illumination affects depth perception substantially as it affects visual acuity.

(6) Exposure to bright light may produce illusory after-effects. The dark-adapted eye is particularly susceptible to negative afterimages. When inadequate framework is present in dim light, the

observer may possibly mistake the after-image for a real object, which appears to move and change distance.

(7) Night vision shows periodic fluctuations in sensitivity. There has been some disagreement among investigators on the extent and significance of threshold fluctuations (5,44).

Recommended Techniques for Effective Seeing at Very Low Brightness Levels

(1) Off-center vision should be used at low intensity levels. At low brightnesses, acuity and brightness discrimination are keener in the para-foveal than in the foveal regions (13,40).

(2) The most sensitive area of the retina varies from person to person. Rowland and Rowland report wide individual differences in the location of the most sensitive area of the retina (40). Their data indicate that the area of greatest sensitivity for form is between 4 and 12 degrees from the fovea. (Optimum viewing angle also becomes more peripheral with decreasing brightness.) The sensitivity to flashes of light parallels more closely the rod distribution curve reported by Osterberg (37).

(3) A systematic scanning pattern is essential to adequate observation at night. This procedure can be supported on purely logical grounds since it is obviously necessary in order to cover the visual field.

(4) Regular rest periods are important in seeing at night. This assumption appears to be at least a reasonable one, and has indirect support from studies reported by Low (28) and Judd (24).

(5) It is important to know how things look at night in order to increase the efficiency of night vision. It has been found that humans (45) and chimpanzees (39) are able to perceive the visual environment only after long periods of learning. A prediction might be made that considerable learning would occur in adjusting to the changed appearance of objects at night. It would be of considerable theoretical and practical interest to determine whether or not perceptual training is effective, and if it is, the extent of improvement made, in terms of increased distance at which objects can be seen.

(6) The use of night binoculars improves the efficiency of seeing at night. Laboratory (31) and field studies (43) have clearly shown that binoculars aid night observation. The effectiveness of night binoculars will be discussed in a separate section of this report.

Physical Factors Affecting Visibility

(1) The brightness of an object depends upon the incident light and the reflectivity of the object. This is a fundamental fact of the physics of light.

(2) Contrast between objects and their backgrounds influences visibility. The functional relationship between brightness contrast and visibility is known (4).

(3) Shadows affect visibility at night. Shadows may change the apparent shape and brightness of objects (14,34). The direction of a light

source, such as the moon, and the position of the observer may completely change the appearance of objects. For example, a plowed field with furrows running across the field of view appears bright when the moon is behind the observer, whereas if the observer is looking toward the moon the shadow of each furrow will make the field appear dark.

(4) When observations are made through glass, it is vital that it be clean. A British manual cites a study by Craik, which found visibility loss up to 67 per cent associated with dirty, scratched plexiglass (36). This loss was found to depend upon the angle of vision through the glass.

Some Special Problems in Visual Perception Under Low Brightness Levels

Reduction in illumination reduces the visibility of objects and partially eliminates the visual framework within which objects are perceived. Accuracy of localization is impaired and illusory effects are facilitated. Illusions mentioned in various night vision training manuals are these:

(1) Autokinetic effect may occur under conditions of low brightness. Graybiel and Clark studied autokinesis, with particular application to aviation (15). The effect occurred uniformly in normal people; it occurred a large part of the time, and was difficult to eliminate when conditions were optimum for its occurrence. Interruption of fixation, and the use of a fixed reference object as a sighting device, tended to reduce the effect.

(2) Oculogyral and oculogravic illusions may be manifested at night. These illusions result from stimulation by radial acceleration and involve displacements of visually perceived targets (16).

(3) Illusions of rotation and tilting may occur in the air at night. After-effects of rotation which result in illusory perceptions of turning are well known (51). These may occur in conjunction with visual cues but are particularly pronounced at night when visual cues are reduced or absent. MacCorquodale (29) has reported prolonged illusions of tilting and turning which occur during flight under simulated night conditions.

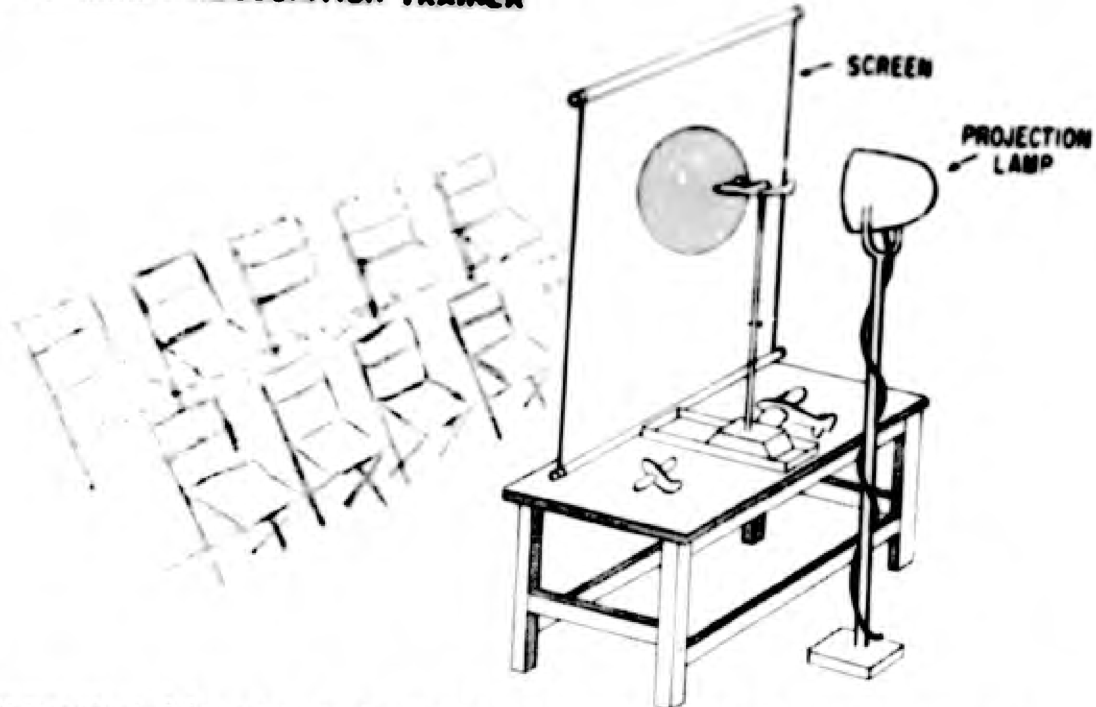
NIGHT VISION TRAINING METHODS

A large number of training aids have been developed for the purpose of showing how military targets appear at night. The British and the Canadians have been particularly active in this field.

Description of Night Vision Training Methods

(1) Projection Trainers. Commonly used techniques involved projecting fixed or movable objects on screens by means of silhouettes or slides (30). A simple device used for group instruction of aircraft recognition appears in Figure 1. An ordinary car head lamp could be used as a projector lamp.

SHADOWGRAPH RECOGNITION TRAINER



The apparatus includes a projection lamp (such as an automobile head lamp), a stand for supporting aircraft models, and a screen suspended in a lecture room. The pupils are seated in front of the screen, with the shadowgraph apparatus behind it. The room need not be totally dark.

Figure 1

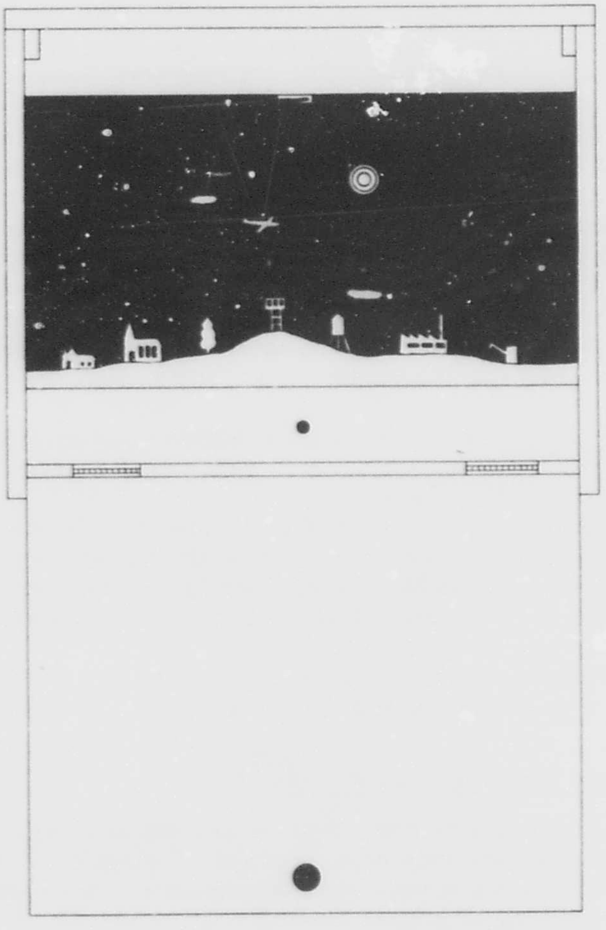
In the more elaborate devices, cloud formations, glare, and certain other meteorological effects could be produced while slides of ships and aircraft were projected on the screen. A lecture on the principles of night vision and recognition training usually accompanied the demonstration.[1] The most widely used projector, which used a pin point source of light to cast sharp shadows of silhouetted objects on a screen, was developed by Dr. K.A. Evelyn for the Royal Canadian Air Force (38). (See Figure 2.) Modifications have been used by the U.S. Air Force (1) and the U.S. Navy (33).

Silhouettes have also been used at the U.S. Navy Submarine School, ship models being silhouetted against a dimly lit seascape background. Portable models, with radium plaque illumination, were also developed (58). Views of Landolt rings, dice, and silhouettes of ships could be inserted in the velvet-covered slot. Work in this area has also been done by British sources (17).

(2) Model Landscapes. Scale models of real or imaginary land areas, developed by the RCAF (38), have been widely used by the U.S. Navy (33). The model is placed on the floor and observed by the trainee from an elevated platform to simulate a particular altitude of observation.

[1]The lecture given to the RAF in connection with the Evelyn Trainer is outlined in Appendix B. This lecture was very effective and was widely used.

EVELYN NIGHT VISION TRAINER



The trainer is housed in a wooden box 31 x 20 x 16 inches, placed 12½ feet from a screen 15 feet square. A pin point source of light casts sharp shadows of the silhouetted objects on the screen. Silhouettes of barrage balloon and aircraft are supported by fine wire loops (upper left) and rotated in front of the light beam by a synchronous motor. A projector lens is located to their right. Cloud effects are obtained by moving irregularly cut pieces of celluloid across the light beam.

Figure 2

The model is ambiently illuminated from above at scotopic levels. Additional illumination may be furnished by a "moon" placed in various directions and at different elevations. The model demonstrates the appearance of such types of objects as water, roads, buildings, beaches, trees, searchlights, and shadows under low illumination.

(3) Physical Activity Under Scotopic Illumination. This technique was originally developed by the RAF but has been used to a limited degree in the United States. In a dimly lighted room, the dark-adapted trainee was put through a series of games designed to develop skill in seeing. The development of morale and appropriate attitudes toward seeing at night were also emphasized. Activities used in this training were squash, walking (and later running an obstacle course), stick-fencing, hockey, shooting clay pigeons, and passing balls. In a variant of this technique, soldiers were trained in a human maze so constructed that with careful use of off-center vision, the normal person could

negotiate it without difficulty. These procedures have been strongly recommended by those who have used them.

(4) Training by Controlled Practice on a Perimeter. This technique has not been used by the military services, but has been developed on an experimental basis by Low (26,27,28). The training was done on a specially designed 25-centimeter perimeter. Subjects worked in pairs under the supervision of an instructor. They alternated between operating the device and being trained by their partners. Thirteen Landolt rings, having breaks which varied in size between one-half and ten millimeters, were presented to the subjects, who were required to identify the position of the break in the ring after a brief exposure. Low reports substantial improvement in peripheral acuity, and transfer to situations outside the laboratory (27). Motion acuity was not improved by practice. According to Low, his data also show that the total process of dark adaptation does not end when the maximum sensitivity to light has been reached.

(5) Films and Film Strips. Films have been widely used as part of night vision training programs to teach (not demonstrate) certain basic principles. Among such films are:

(a) "Presenting: Demon Dazzle in Night Vision." Film strip and lecture prepared by Department of Ophthalmology, AAF School of Aviation Medicine, Randolph Field, Texas.
(b) "Night Vision for Airmen." Navy training film, concerned with night flying.
(c) "Lookout Training—Navy Lookouts." Navy training film, concerned with seeing aboard ship at night.

Evaluation of Night Vision Training Procedures

The evaluation of a training program involves several problems: Are the objectives of the program related to operational requirements? Is the training valid; that is, does it improve performance in the operational situation? Is the training of proper length?

(1) Objectives of Night Vision Training. In determining the objectives of the night vision training program, it would be desirable at the outset to obtain an exact description of the tasks to be performed and the skills to be learned. It would be important to know what illumination levels are to be encountered in the night operations and the types of observations to be made. Certainly the operational situation differs in Armor, the Submarine Service, the Coast Guard, and the Air Corps, and the emphasis and content of night training for these services should, therefore, not be identical. As an obvious example, recognition training should involve targets related to the duty to be undertaken.

In the absence of objectives derived from job description, night vision training has usually involved the aims previously mentioned, that is, teaching the basic principles of night vision, developing skill in seeing at night, and inculcating proper attitudes towards night duty.

(2) Validation of Night Vision Training. Certain aspects of night vision training hardly need experimental validation. The tank driver should be told that he can see better when dark adapted, and he should

be taught how to acquire and retain dark adaptation. He should know about off-center vision and the improvement in seeing that can be obtained with binoculars. He should be told the purpose of red illumination and red goggles. The airman should be told about illusions of movements and loss of horizon which are due to faulty adaptation. He should know about the lowering of visual acuity caused by dirty and cracked windshields. Awareness of any one of these facts might make "all the difference," at some time, for some man on whom other men depend.

The main conclusion which may be drawn from the discussion of "Basic Principles of Night Vision Training" is that these principles are valid in relation to laboratory findings. Their validity in terms of application—that is, the demonstration that knowledge of these principles will make a better soldier—is far less convincing. Experimental evaluations of night vision training have been rare, and have usually involved very indirect criteria. In one experiment, many pretraining misconceptions about night vision were found (11). These tended to disappear after projector and landscape training. The cadets appeared to retain the material presented as long as three months after the training period. Low has reported marked improvement in skill in seeing, after perimetric training (26,27,28). It is not known whether his method of training, which has been previously described, can be applied to groups of men. Only one study of the change in attitude resulting from night vision training has been found. Walker, using a questionnaire technique, found that attitudes toward the hazard of night flying changed little or not at all as a result of training (49). But 65 per cent of the cadets believed that the night vision training increased their ability to do a good job.

In their review of the effects of training on night vision ability, Sharp, Gordon, and Reuder state: "No evidence is available on the effectiveness of a night vision training program as evaluated by performance in an actual field situation. An experimental evaluation of these programs would supply very crucial information which is at present missing. As evaluated by simple testing devices, training is relatively ineffective" (41). It is probably too much to expect that night vision training could be shown to affect the performance of men in battle. Under combat conditions many factors operate in conjunction, and indices of performance are insensitive. It is unlikely that the effects of training can be shown, even with large groups. It is reasonable, however, to expect that night vision training would result in better performance on visual field tests involving targets of military significance, such as tanks, anti-tank guns, personnel, and machine guns. Such field tests should be used in evaluating not only the components of night vision training, but the whole course in night training as well. (See Appendix A.)

In any evaluation of night vision training procedures, however, it is to be remembered that the time, effort, and expense required by the training program may have effects which are no different from the results of devoting equivalent time, effort, and expense to night operations. In other words, each night vision program and technique should be compared with a control situation which involves no night vision training, per se, but practice in night tasks instead. The criterion of the efficiency of night training should be the improved performance on appropriate vision field tests.

(3) The Length of Night Vision Training. The duration of training schedules has been determined largely on arbitrary bases; no controlled studies have been made to determine the optimum period. Wartime courses lasted as long as two weeks. Low suggests 25 hours as the minimum training period (27), while an English source considers three days of training adequate (36). Optimum length of training probably varies with the service. It should be determined by empirical test.

PROBLEMS FOR FUTURE RESEARCH

The foregoing discussion indicates the need for information in a number of areas related to night vision training. The following projects should be undertaken:

(1) A job analysis dealing with the visual tasks required of all members of the tank crew, in a variety of night operations, should be made. This analysis should precede the drafting of a training program. The probable use of artificial illumination, for example, may affect the emphasis on unaided vision in the dark.

(2) An attempt should be made to assess the effectiveness of night perceptual training in enabling the soldier to see farther and better. A field test rather than a laboratory test should be used in making this evaluation.

(3) Other visual skills commonly taught in night vision training programs—systematic search and scanning procedures, use of off-center vision, and dark adaptation procedures—should be evaluated. A field test should be carried out to determine the applicability of these techniques to tank operations.

(4) If night perceptual training and other visual skills are shown to be effective, improved methods of training these skills should be devised and tested. The possibility cannot be excluded that under combat conditions men might acquire many of these skills without formal training.

(5) The time required for formal visual training should be determined.

(6) Assuming that night vision training is effective, the appropriate time in the training cycle in which to conduct night vision training should be determined. The amount of military training which the soldier has had would probably influence the ease with which he acquires night vision skills.

(7) If night vision selection procedures are adopted, as seems likely, the optimum sequence and combination of testing and training should be determined.

(8) A methodology should be developed for evaluating the effectiveness of tank units at night.

Chapter 3

NIGHT SIGHTS AND OPTICAL SYSTEMS

Research on the "eyes" of the tank—the sights, periscopes, and telescopes—is the subject of this chapter. As a result of wartime research by the Air Force, the Navy, the Submarine Service, and the Army, a great deal is now known about effective designs for these systems. It has been found that, for best results, a night sight or telescope must have characteristics somewhat different from those of instruments intended for daytime use.

THE DEVELOPMENT OF NIGHT GUNSIGHTS

Introduction

Most research on the development of gunsights has been conducted in the laboratory where it is possible to control such factors as illumination, dark adaptation, mental concentration, and ocular fatigue. Such research makes it possible to detect small differences between sights which would require years to discover by using other methods.

As a result of research findings, illuminated reticles are almost universally used on night sights. Although such reticles cause some loss of visibility of the target,[1] they are used in night sights for the following reasons (20):

(1) To enable men to aim at night on lights, on machine guns firing tracer, and on other luminous targets which do not silhouette the reticle lines.

(2) To enable the position of the reticle to be checked quickly by a temporary illumination of it.

(3) To enable men to aim at targets large enough to be seen when illumination is such that the unlighted reticle is invisible.

(4) To make it possible to adjust the brightness of the reticle line in such a way that it bears an optimum relation to the brightness of the target over the entire range of daytime and nighttime operating conditions.

[1]The loss of visibility may be a result of physiological reaction to glare, reflection off the lenses, after-images caused by small movements of the eye, or imperfections of engraving which cause haze effects (20).

Factors Affecting the Accuracy of Night Sights

In one of the better-known wartime studies, Lamplough photographed the track of a burst of fire aimed through the gunsight at a slowly falling target (14). In other trials he recorded the proportion of time during which the aim was accurate when the gun was aimed at a target which was in continuous lateral motion. By these techniques he was able to determine the order of importance for the main factors which affect the accuracy of night shooting, as follows:

(1) Dimming. It should be possible to gradually lower the brightness of the sight until it is extinguished. Once an adjustment is made, the level of brightness should remain fixed, even under vibration.

(2) Evenness of Illumination. The sight should be evenly illuminated by means of an opal diffuser or some similar device.

(3) Monocular and Binocular Sighting. It is easier to use binocular sights than monocular sights, for there is greater comfort, less fatigue, and less tendency to "alternation of vision." Serious errors in sighting may occur when airplane sights are used. The target may be seen by both eyes, the reticle by only one; difficulty in fusing the two images may result. In binocular sights "false fusion" must be prevented by the use of such techniques as fore-and-aft marks or unequal spacing of the vertical lines of the pattern (22).

(4) Magnification. Magnification of the image will increase the range of vision under starlight brightness. However, the magnified image is proportionally affected by movement and vibration. (See discussion of night binoculars, page 24.)

(5) Color of Reticle. Individuals differ in their preference for colored reticles. Blue is unsuitable because of the difficulty in accommodating (14). Black lines have been shown to give accuracy equal to that of illuminated white lines (9).

(6) Thickness of Reticle. Although aiming is not affected appreciably by considerable variation in reticle thickness, thin lines give men a feeling of precision when they are aiming. The lines should be .5 minute or more in thickness (9).[1] A British source gives a formula for computing the distance at which a tank target and a given sized reticle line become simultaneously invisible at dusk (20). However, the formula does not check with the example given.

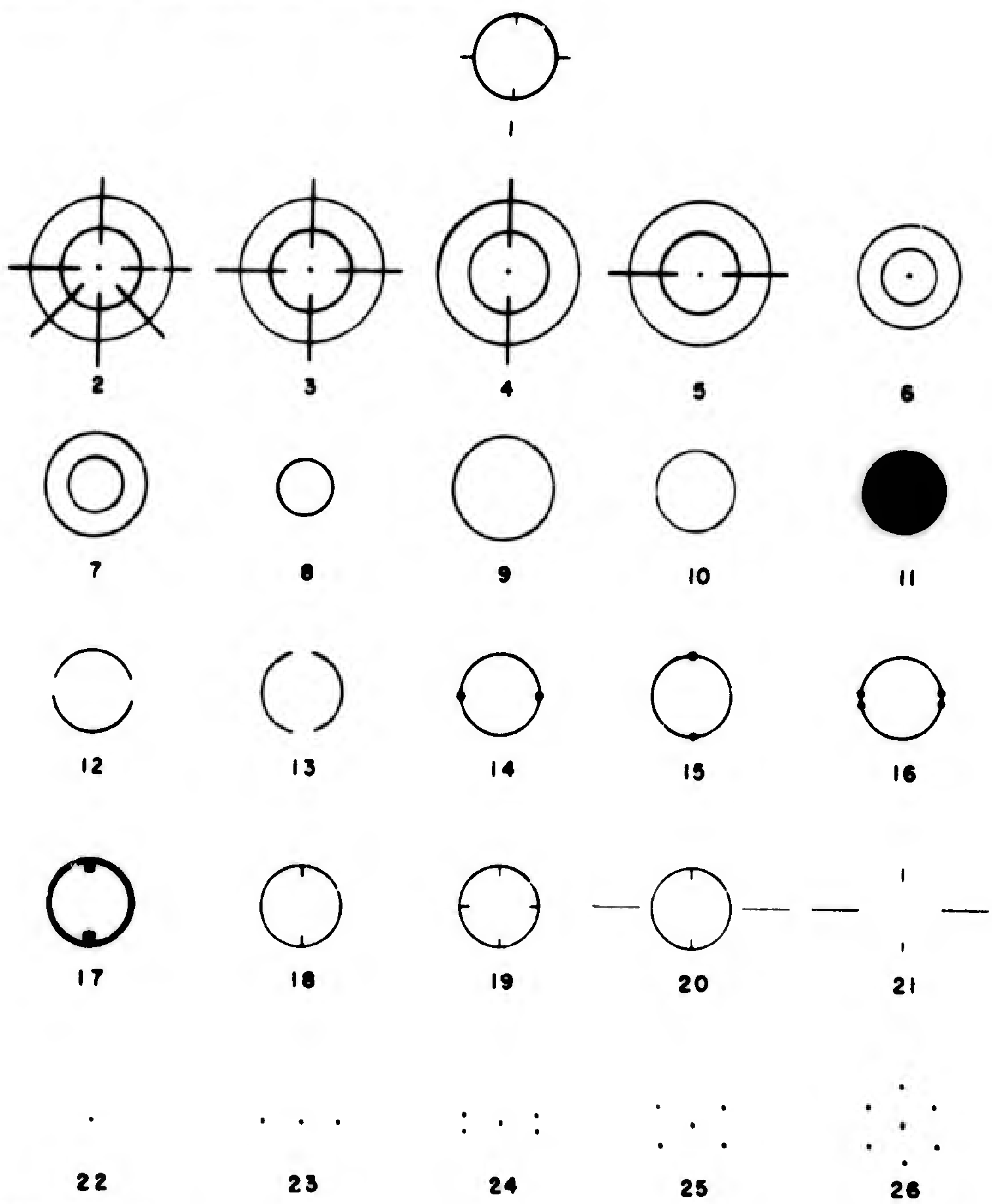
(7) Pattern of Reticle.[2] It is not always possible to predict from the appearance of a reticle pattern how accurately it can be used.

[1]British reticles have fine lines in the center of the field and coarse lines on the outer part. The thick lines do not obscure the aim and, being 1.7 mils thick, indicate the center of the reticle until the tank at 150 yards becomes invisible.

[2]General considerations in designing reticle patterns have been given by Pochin (20). Reticle lines should be thin enough not to cover the target, thick enough to be visible in poor light, frequent enough to give an accurate indication of the point of aim for any range combined with any lay-off, infrequent enough to avoid the obscuration of indistinct targets which occurs near a reticle line (the obscuration factor is extremely important, both by day when the reticle is not illuminated, and at night when it is illuminated), and arranged in a pattern which provides enough "landmarks" to allow any position on the reticle to be identified at a glance.

Reticles containing one, two, or three central spots are not superior to line reticles. Using two vertical spots for any length of time fatigues the aimer, and does not give very accurate results. A single spot is not as good as a 4° ring. Three horizontal spots are not good with lateral target movement. A small cross (+) or very small circle is better than a dot (16). Tousey found that the best pattern for a night sight for planes is a simple circle with tabs added to the sides (24). (See Figure 3.)

RETICLE DESIGNS TESTED BY TOUSEY



From Tousey (24).

Figure 3

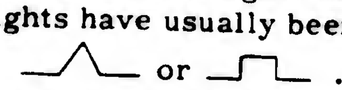
In addition to the factors cited by Lamplough, a number of others may influence the accuracy of a night sight:

(8) Obscuration of Reticle Design. A black reticle line decreases the visibility not only of targets covered or partly covered by the line, but also of those lying near the line (20). This characteristic holds particularly for indistinct, camouflaged, or small targets, or for hazy conditions. The effect may have some influence as far as 2 1/2 mils from the edge of each line. In the area of obscuration, clear targets become less visible, and indistinct targets may become invisible. Obscuration is due to the human eye and not to a defect in telescopes or reticle lines; the amount is equal for photo-etched and lead sulphide lines (20). Obscuration is also caused by glare from illuminated reticle lines (19). A complicated reticle pattern may cause aiming errors as large as 30 mils through interference with a distinct view of the target (24).

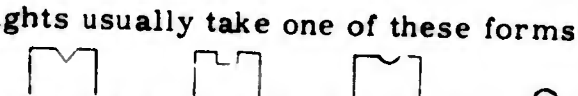
(9) Interference With Habits of Day Sighting. If the patterns of day and night sights differ, the tanker has to learn to use two sights, and interference between competing habits may result. (The same principle holds for differing periscope, telescope, and range finder sights.) The use of a single night and day sight will involve compromises in design. A reticle thickness most suitable for day use may be too thin for night use (20).

The Design of Rifle Sights for Dim Illumination

It is relatively simpler to design a rifle sight than a tank sight for use under dim illumination. There are fewer factors that can be varied; in fact, rifle sights have changed little throughout the centuries. Front sights have usually been points or posts:



Rear sights usually take one of these forms:



Greater accuracy of shooting will result if the rear sight is moved forward, but this change will result in a larger separation between the eye and the rear sight. Increased accuracy would also result from using the sniper's 2 1/2x telescope sight instead of iron sights. However, the service need is for snap shooting rather than long-range or deliberate shooting (5). An improved set of rifle sights for dim illumination had been developed by C.J. Warden (28). It was found that a rear aperture sight 3.5mm in diameter gives much more accurate sighting than either the standard Garand sight (aperture 2.035mm diameter) or a standard Springfield notch sight, at the lowest level of illumination at which sighting was possible. Warden recommended that the front sight be a post or bead sight, with a flat face, about 2.9mm in width, with a white, gold, or other bright surface for high visibility. It was shown in later field trials that this set of sights is significantly more accurate than the standard Garand sights, at brightness levels below one millilambert (23). Above this level, standard sights were superior.

TRAINING THE SOLDIER TO SHOOT AT NIGHT

Only a limited amount of research is available on training the soldier in night shooting. There is considerable experience to show that training is required to correctly use tracer ammunition at night. Some aspects of the use of tracer ammunition are discussed in a British report (7).

A thorough study of training in rifle marksmanship at night was carried out at Human Research Unit Nr 3 (13). One training method was found to be better than the others tested. Under this method, hits on an experimental night firing range increased 60 to 210 per cent (depending on the type of target engaged) over hits made with a standard method of sighting. The new method required 11 hours of training time and 62 rounds of ammunition per man. It consisted of three hours of familiarization firing at night to show the soldier how hard it is to hit targets at night, three hours of corrective firing by daylight with M1 rifles minus sights to show the proper correction,[1] two hours of instruction to explain how to follow targets at night, and three hours of application firing to convince the soldier that he can apply what he has learned.

It was also found:

"(1) That the auxiliary firing aids (flash hider, white string, and the combination of the two) did not increase proficiency in night firing.

"(2) That combat veterans fired no better than did men who had just finished basic training.

"(3) That degree of illumination and range were important determiners of proficiency in firing at dark targets, although not in firing at flashing ones."

The last conclusion warrants further study. It may have been a consequence of the low percentage of hits (approximately 5%) obtained on flashing targets.

[1]The following procedure was used in the Daytime Corrective Firing:

"The infantry soldier is given a weapon with no sights, front or rear. He is instructed to hold at six o'clock on the bull, and to take his sight picture and fire with both eyes open. From the prone position he then fires a 3-round shot group at a B-type target from 50 yards range (the night midrange). When spotted, he will see that his shot group was high and left. At this point the soldier is reminded of his difficulties of the night before. The principal reasons for his difficulties are again pointed out; how the situation he is presently in has been built to simulate certain important nighttime conditions with their attendant difficulties is explained to him; and he is instructed to compensate for the tendency to fire high and left by holding low and right. The soldier then continues to fire 3-round shot groups at the target until he has got one complete shot group inside the bull ring. After his first shot group, the soldier is assisted in adjusting his fire upon the target by a Student Firing Coach who lies directly behind him and observes the strike of his tracer for each round. From this point on, corrections are made from round to round, on the advice of the coach, until the shooter has learned how much low and right that he must hold to compensate for erroneous tendencies present at night and demonstrated in the present situation. After the soldier has got his complete shot group in the bull ring, he is taken off the firing line and admonished to remember his "correction," which, being obtained at the night midrange, becomes his night battle zero."

THE DESIGN OF NIGHT OPTICAL SYSTEMS FOR TANKS

Introduction

Research on binoculars has been carried out to determine the optical characteristics of an effective night instrument. Binoculars are particularly fitted for this type of development work, for they permit ready manipulation of the optical factors (magnification, size of field, size of exit pupil, etc.). Results of these studies are readily applicable to tank periscopes, telescopes, and range finders.[1]

Modern tanks are frequently provided with one- and six-power periscopes. The unit magnification telescope will not give the same impression as viewing the exterior scene, for there is loss of contrast between target and background due to reflection and scatter. Also, the appearance will be of looking at the world at a distance through a long tube. These disadvantages can be overcome to some extent by magnifying the image somewhat; a 1 1/2-power magnification has been found to give a more normal appearance.

Characteristics of Good Night Binoculars

Early experimentation on night binoculars was carried out at Dartmouth College (22) and Brown University (16,17). Later experimentation by Verplanck at New London yielded valuable information on the performance of binoculars under field conditions (8,27). Verplanck compared a large number of different kinds of binocular and monocular telescopes from shipboard. About 200 tests were run in Gardner's Bay, Long Island Sound. These tests were conducted mostly at night. Twelve observers were stationed on board a destroyer escort vessel which made repeated approaches to an island where various types of targets were mounted. Radar ranges were used to determine the distance at which the targets were sighted by the various observers with the various instruments.

Recently, Coleman has prepared an extensive bibliography of over 300 references on the design of binoculars (1). According to the findings of the studies mentioned above and those cited by Coleman, the characteristics of an effective night binocular appear to be the following:

(1) The magnification should be as great as possible until atmospheric conditions (broil) make additional range of no use. With constant pupil size, nighttime detection ranges increase in direct proportion to magnification, up to a limit of 10x or so. If the binocular is mounted rather than hand-held, ranges continue up to at least 20x. In

[1]Tank instruments must also conform to operational requirements; they must function under conditions of vibration, be designed so that they can be used while the driver's hands are otherwise occupied, and be quickly replaceable in case of accident.

the daytime, there is little change in detection range for hand-held binoculars of 6, 7, or 10 power (6).[1]

(2) The exit pupil should be at least 5mm in diameter, larger if possible. If it is 7mm, good; if it is 8 or 9, it is easier to hold the binocular in the right relation (12). The size of the fully dark-adapted natural pupil is about 7mm in diameter; the light-adapted pupil is 2mm in diameter.

(3) The size of field must be adequate. The larger the field, the more can be seen without readjusting the instrument. For optical instruments for tanks, there is a limit to the size of the objective imposed by space and vulnerability.

(4) Transmission should be high at night—over the 80 per cent mark if possible.

(5) Scattering must be low because any reduction in contrast will decrease over-all performance. To reduce scattering, night binoculars are frequently "bloomed."

(6) Binocular viewing gives ranges at least 10 per cent greater than monocular observation; hence, binoculars are preferable to monoculars (6).[2]

(7) Mounts and rests for hand-held instruments increase the range by about 10 per cent. Anti-oscillation mounts increase it even more.

(8) Provision must be made for diopter adjustment for left and right eyes. Accommodation at night involves a shift of as much as minus three diopters (26).[3]

(9) Provision must be made for adjusting the alignment of the binocular pupils with the natural pupils of the eye.[4] The gain made by

[1]If no atmosphere were present, range would be directly proportional to magnification. The effect of the atmosphere is to decrease the apparent contrast of the target as distance increases. The amount by which even perfect binoculars can increase the sighting range depends upon the manner in which the eye of the observer is willing to "trade" the increase in apparent size for a decrease in apparent contrast (11). The reduction of target contrast with distance is described by Koschmieder's law as follows:

$$C_r = C_o \, e - BR,$$

where C_r is the apparent contrast of target,
C_o is the inherent contrast of target,
e is the base of natural logarithms,
B is attenuation of coefficient related to meteorological range, and
R is distance to target.

At night the distances viewed are frequently short; hence, target contrast may not be appreciably attenuated by atmospheric haze.

[2]The range for two-eye (unaided) vision is from 19 to 26% greater than it is for one-eye vision (22). The advantage of binocular observation may be due to the fact that twice as much retinal area is stimulated (15); two-eye vision is more comfortable (2); if the acuity of each eye is fluctuating, the probability of detection will be greater if both eyes are used (18); there may be summation in the higher visual centers (21).

[3]"Night myopia" may be caused by chromatic aberration associated with the Purkinje effect, the Stiles-Crawford effect, and spherical aberration (26). Tousey has shown, in an ingenious series of experiments with a glass lens simulating the eye, that highest target brightness is obtained when the target is slightly out of focus (25).

[4]A loss as great as .15 log unit of range may be attributed to improper alignment of the binocular pupils (22).

the use of binoculars is greater at night than during the day, and greater when the visual task is recognition or identification (rather than detection). There is greater effectiveness if the position of the target is known than there is when the target is in an unknown position and must be searched for (21). The techniques of efficient seeing at night (dark adaptation, off-center vision, and scanning) apply when binoculars are used (6).

CONSIDERATIONS WITH REGARD TO NIGHT OPTICAL DEVICES FOR THE TANK

This chapter has dealt with the design of tank optical instruments—sights, periscopes, and telescopes. It has been indicated that for best results at night, these instruments should be designed to be somewhat different from day instruments. In establishing the need for special night optical devices, several questions of fact must be taken into consideration:

(1) What proportion of time will the tank be operating at night without auxiliary light? (Special night equipment may not be required when searchlights and pyrotechnics are used.)

(2) Under what night conditions (brightness level, targets) are special night optical instruments appreciably more effective than the customary day equipment? It may be that night rifle sights, for example, are more effective than day sights only at levels of illumination so low that shooting is ineffective (the visibility of the object being perhaps the limiting factor). Night scopes may be superior to day scopes only when visibility ranges are so small as to make the advantage of negligible military significance. The rather impressive claims for the effectiveness of night sights and scopes should be critically reviewed (10)

(3) If the field, magnification, and exit pupil of the tank periscope or telescope are increased in size, it may be necessary to enlarge the aperture in the armor. This possibility also holds true for other optical instruments.

If the decision is made to use night sights and night scopes, they may be designed in accordance with the characteristics listed in this chapter. More detailed information on design may be obtained from the scientific and technical articles referred to.

Training problems in the use of tracers and rifle marksmanship at night have been discussed. A considerable amount of research has also been done, particularly by the Navy, on techniques of night lookout duty. This material has been well reviewed by Riggs (22). Additional training problems will emerge when decisions have been made about whether night sights and scopes will be used on tanks, and about how tanks are to be used at night.

Chapter 4

BATTLEFIELD ILLUMINATION

THE OPERATIONAL SETTING (18)

Artificial illuminants are used to offset the limitations usually inherent in night operations. They help the commander maintain control of his men, even in extended engagements, deep in enemy territory. They provide orientation for movement and gun fire, and enable units of battalion size and over to make attacks at night.

Illuminants are also useful in night defense. They are used to disclose the enemy's position and his movements, they make it difficult for him to depend on darkness for secrecy and surprise, and they may be used to facilitate the movement of troops and supplies behind the main line of resistance.

It must not be assumed, however, that illuminants are always useful. Usually all lights should be extinguished in order to avoid revealing one's position. Illuminants do not aid activities which require secrecy and surprise, such as patrolling, forward observing, and skirmishing. But plans which call for complex coordination of large numbers of troops may require illuminants.

The tank should be provided with an independent source of illumination in order to achieve its obvious function in night combat. Being large and noisy, the tank is not a weapon of stealth; rather, it is a mainstay of the assault and a mobile fire support for the infantry. In carrying out such purposes, illumination is essential; otherwise a precise and expensive combat instrument is entrusted to a semi-blind crew, and the tank's inherent characteristics of mobility and accuracy of fire will not be effectively utilized.

Attempts to provide the tank crew with night eyes have taken two main directions. Powerful searchlights provided with shutters which flicker the light have been developed for tank use. Infrared driving and sighting equipment has also been used. This section deals mainly with the problems encountered in using these types of equipment. Very little interest has been shown in adapting pyrotechnics to tank use, although an illuminating shell has been suggested for this purpose (5).

TYPES OF BATTLEFIELD ILLUMINATION

The most generally used types of battlefield illumination are searchlights, pyrotechnics, and invisible ray devices (11,12). Searchlights are usually situated far behind the front, hidden in defilade. They are used to provide continuous illumination for long periods of time. Pyrotechnics are used during local engagements for signalling, or for lighting up wide areas in large-scale maneuvers. Ultraviolet and infrared devices are used to furnish illumination to friendly troops, at the same time denying this advantage to the enemy. Ultraviolet and infrared devices are now undergoing research and development. Radar and sonar devices are also under consideration.[1]

The Tank-Mounted Searchlight

The tank searchlight is an 18-inch commercial searchlight mounted on the gun mantlet and boresighted with the gunner's sights. The regular turret controls are used in aiming the searchlight. The tank has advantages as a searchlight mount because it is mobile, has its own source of power, and has means of communication (necessary for keeping in touch with positions requiring illumination).

The searchlight shutter is activated by a solenoid which makes it possible to vary the light-dark interval and rate of flicker to suit the tactical situation. A flickering beam, said to be very annoying to the enemy observer, may be produced. This beam is difficult to hit, even when tracer ammunition is used.

The development of the tank-mounted searchlight was a British project from its inception in 1939 until its release to the United States in 1942 (9). Ostensibly it was merely a high-powered searchlight intended to be part of the Suez Canal defense. The name CDL (Canal Defense Light) was given it to hide its true purpose. The British had equipped several tanks of the Royal Armored Corps in Egypt with CDL turrets to develop the idea. The project was released to the United States subject to several conditions: The equipment was not to be used in action without previous agreement with the British War Office, the manufacture of CDL equipment in the United States was to be undertaken by several firms, and the final assembly was to be carried out under military supervision. The U.S. phase of development was carefully

[1]*Searchlights* may be used to provide *direct illumination*. The searchlight beam is narrowly focused to give illumination up to distances of 20,000 yards. A beam greater in spread and shorter in effectiveness may also be used. In *illumination by diffusion* (artificial moonlight), the beam is directed at a minimum elevation above the ground. The area beneath and to the flanks of the beam will be illuminated by light which is scattered by atmospheric particles. The light is not as intense as direct illumination but may be effective as far away as 15,000 yards. The searchlight may be directed against low-flying clouds to provide an area with light by *reflection*. Fog, mist, or rain will decrease the area and intensity of illumination.

Pyrotechnics consist of burning chemicals. The most commonly used pyrotechnics are: (a) ground signals, hand-held rockets provided with parachutes; (b) illuminating grenades, grenades which are thrown or launched by rifle, and which burn on the ground; (c) trip flares, rocket parachute devices left in the path of the enemy, and activated by him; (d) illuminating shells (star shells, flare shells), parachute shells fired by artillery or mortar; (e) aircraft flares, parachute flares dropped by airplane.

Invisible ray devices utilize radiations outside the visible band. *Ultraviolet* devices consist of projectors and phosphor screens which utilize radiations between 400 and 130 millimicrons. *Infrared* devices utilize radiations of 760 millimicrons and longer.

kept secret. All manufacture was performed under the nomenclature, "Shop Tractor, T-10."

To implement the American phase of development, a unit known as the Special Training Group was set up at Fort Knox under the command of Col. F.M. Thompson. Observers were sent to the British CDL school to learn the necessary techniques and tactical doctrine. The tank used in the United States was the Grant M3 medium tank. It was equipped with a special turret containing a carbon arc light source.

The CDL units were shifted to England, but did not participate in the invasion crossing. They were sometimes used to provide illumination for bridge construction at night at the Rhine; they were also used to detect and destroy floating mines, barges, and swimmers. Otherwise they were not used in battle action.

Tank-mounted searchlights figured in the Korean fighting. The 1st Marine Tank Battalion used them to escort mechanized flamethrowers during a night attack. An observer states: "When the flamethrowers opened up, complete surprise was obtained; and a well-entrenched superior enemy force withdrew in haste and confusion" (13). Searchlights were also used at White Horse Mountain, Eerie Hill 191, the T, and Bunker Hill. One especially successful action involved a Marine tank battalion equipped with tank-mounted searchlights, which supported a Turkish Brigade. Over 700 attacking enemy troops were killed in several actions ranging from dusk to dawn (13). No positions were lost, and few casualties were suffered by the defending forces.

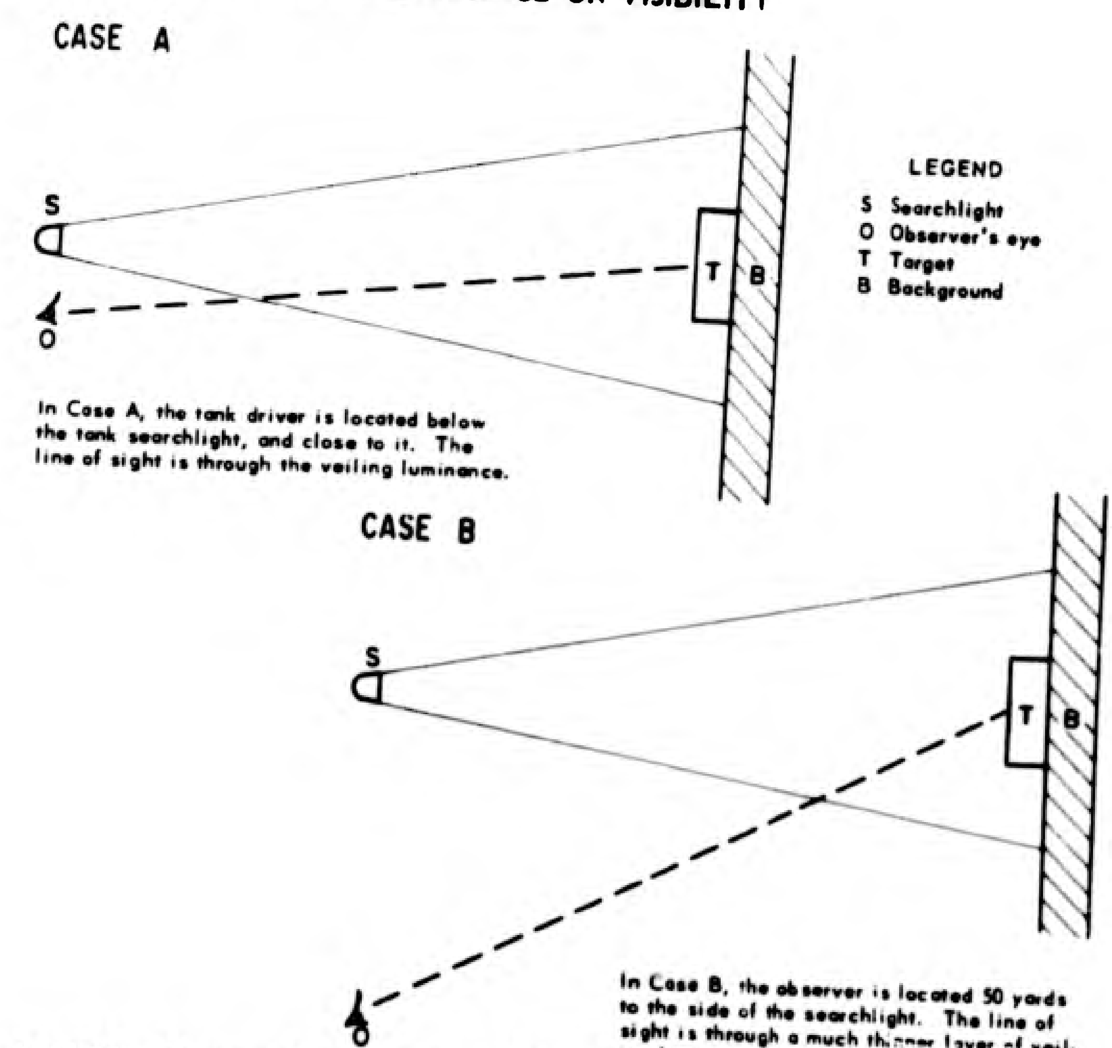
(1) <u>How far can objects be seen under tank searchlight illumination</u>? Visibility information is required in planning tactical methods at night. Ideally, such information should be compiled in tables or nomographs indicating the distances at which such targets as personnel, tanks, and field pieces can be detected and identified. Allowance should be made for such conditions as background contrast, haze, brightness of illumination, and so on. This discussion deals with results on tank searchlight illumination. The detection problem will be fully discussed in Chapter 5.

It is interesting that the only comprehensive data on searchlight visibility have been derived from laboratory experimentation. Blackwell, Duntley, and Kincaid have computed tables to indicate the searchlight illumination which is necessary to make tanks visible at various distances (7). The tables are based on Blackwell's data for contrast thresholds of the human eye (6) and on the candlepower distributions reported by Hulbert (16). The field detection problem was equated with that of detecting a circular disc of tank area (8.72 feet diameter) against backgrounds of terrain and sky reflectances, with 99 per cent accuracy. The effects of beam attenuation and veiling luminance were considered.

The tables indicate the candlepower intensity (center of beam) necessary to allow the target tank to be detected. Data are given for the naked eye and for binocular vision when the target is at the center, the near edge, and the far edge of the beam. Data are also given for various distances, meteorological ranges, and illumination-target-observer orientations.

It was shown that the position of the driver is relatively inefficient for observation by tank searchlight. The driver must observe through a layer of veiling luminance (see Figure 4). Because of the inverse square law, the part of the searchlight beam close to the searchlight contributes a disproportionate amount of veiling luminance. More effective observation would result if the driver were located so that his line of sight entered the beam close to the target area. This fact is supported by the finding made in Korea that fog, smoke, or heavy dust, which increase the veiling luminance, made observation of the target from tanks mounting searchlights very difficult (13).

THE EFFECT OF VEILING LUMINANCE ON VISIBILITY



Adapted from Blackwell, Duntley, and Kincaid (7).

Figure 4

Field trials have also been carried out to determine visibility with tank searchlights (14). It was found that an 18-inch searchlight with a 1000-watt lamp made efficient observation and identification possible at ranges up to approximately 900 yards. The 2,000-watt searchlight made identification possible at 1,200 yards. Though these observations were carefully carried out, it is difficult to generalize from them, for many variables affect visibility. The advantage of deducing visibility ranges from laboratory data is that prediction may be made to the almost infinite number of conditions that may occur in the field. To measure and tabulate these visibility situations separately would be an almost unlimited task. To insure that such tables are valid, they should be checked against field observations under carefully measured conditions. Such checks would bring the theoretical and field results into closer and closer conformity.

Blackwell showed that the candlepower requirements were reduced drastically when 6-power binoculars were used (as compared to observations by the unaided eye). Considerably less additional improvement is obtained as power is increased from 6- to 10-power. These results agree with those of other investigations of binoculars at night. The influence of binoculars on detection range has been reviewed in Chapter 3.

(2) The vulnerability of searchlights. Because tank searchlights are easily spotted, it might be thought that they would be particularly vulnerable to aimed fire, but experience contradicts the supposition. A picturesque historical account of an engagement in the Golopi campaign illustrates the difficulty of hitting searchlights at night ([illegible]). Admiral Keys writes:

> When the *Canopus* got close she opened fire on the lights. They kept on going out, but only for a few minutes, and it seemed impossible to put them out of action, though we often thought we had succeeded. . . . The fire was very wild, and the *Canopus* was not hit, and for all the good we did towards dowsing the searchlights we might as well have been firing at the moon.

Field trials, too, indicate the difficulty of hitting searchlights. In one test, a 1000-watt, tank-mounted searchlight was fired on by five M1 rifles and a .30 caliber light machine gun ([illegible]). The light was alternately kept steady and made to flicker. At 900 to 1,200 yards, no hits were made on the tank. At 500-900 yards, sporadic hits were obtained. Not until the tank stopped 125 yards from the firing line was the light damaged. At all distances, the tank crew could identify the defending weapons at front and side, and could aim the main armament at them. The defenders could not see the front sights of their weapons, and had difficulty in adjusting fire.

In another field trial involving a 60-inch searchlight, HE fire was adjusted by aerial and ground observers (3). The range was about 4,000 yards. With adjustment from the air, the only damage resulting was a flat tire on the generator. Ground observers located outside the direct rays of the searchlight beam could spot the target, but shooting was ineffective. Even when a target area base was established using two aiming circles, and when the position was plotted on a firing chart, aiming was inaccurate. Only stray fragments pierced the drum of the searchlight, which was not put out of action. In trials with direct 75mm tank fire, the only damage sustained by the searchlight was a crack, of undetermined origin, in a section of the front door glass.

It is even difficult to hit a searchlight from the air. Two missions were flown by an F84 type aircraft firing .50 caliber, armor-piercing, incendiary ammunition at an emplaced 60-inch searchlight target (1). On the first mission, 1,085 rounds were expended, 11 of which hit the searchlight. None were effective in putting it out of commission. On the second mission, 1,574 rounds were expended, six of which hit the searchlight. One put it out of commission. It was concluded on the basis of these and more elaborate tests that a B26 strafing has a 28 per cent probability, and an F84 mission a 5.2 per cent probability, of putting an emplaced searchlight out on the first pass. The probability would be less if the searchlight were mounted on a moving tank.

A number of factors contribute to the difficulty of localizing and hitting searchlight targets. In the dark, a searchlight appears as a focal point of light in the blank landscape or sky, as if a "cloak of darkness" were thrown around the light. The surrounding terrain, which normally furnishes cues of distance, is missing (13). If the searchlight is flickered, the dark adaptation of an individual aiming at it is affected. If it is close enough, he may be dazzled.[1] In viewing artificial moonlight, the source of light cannot be seen, and the searchlight is virtually invulnerable to aimed fire (11). In firing on bright sources, the gun sights tend to fade out. All these factors would obviously affect the accuracy of aimed fire.

(3) Countermeasures against tank-mounted searchlights. In British studies of tank-mounted searchlights, it was not possible for observers at 600 yards to obtain accurate range estimation (16). If the light of the tank was exposed for 10 seconds or longer (which would be unrealistic), it could be hit by tracer ammunition. With shorter exposures, practiced gunners had some success in hitting the flickering lights. A fluorescent telescope screen, on which the image of the searchlight illumination persisted, also helped. Another defense was sighting on the guns singly, in depth, with mutually interlocking and supporting arcs of fire.

An exposed 60-inch searchlight can be accurately located by conventional, short-base methods of triangulation, even at long

[1]An interesting tabulation of the subjective effects of a pulsing light has been made by Strughold (17):

Cycles Per Second	Subjective Impression
1	bearable to disagreeable
2	disagreeable
3	very disagreeable
4	very disagreeable
5	very disagreeable to disagreeable
6	disagreeable
7	disagreeable
8	disagreeable
9	disagreeable
10 (and more)	improvingly bearable

It is not known whether these results would hold for a wide range of prevailing illuminations. To be applied to tank-mounted searchlights, the flicker rate should also provide visibility to the friendly side, and deception of the enemy.

ranges (3). Defiladed searchlights are much more difficult to locate. In field trials, when the point of emergence of the searchlight beam from a mask was accurately determined and an estimate made of the azimuth of the beam, a careful map study of the possible searchlight positions behind the mask gave estimates of the location within 100 yards of their actual positions. By crossing the beam of the defiladed searchlight with a searchlight beam under the control of the flash base, a point of intersection on the searchlight beam was determined. The point of intersection with the mask provided an accurate azimuth, and aided in the map study of possible searchlight locations. This method of beam intersection could not be carried out with aiming circles, because of the limited elevation measuring capability of this instrument. It appears that research could profitably be undertaken on the development of methods of locating and hitting searchlight targets.

Infrared Devices

Invisible ray devices consist of projector sources, and receivers which focus the rays on a phosphor screen. These devices enable friendly troops to see at night; enemy troops, without receivers, are "in the dark." Much more work has been done with infrared (IR) than with ultraviolet equipment.

IR has been chiefly applied to tank driving and fire control equipment. Illumination is furnished by a commander's 12-inch light, a gunner's 18-inch light, or both. The commander uses in-line binoculars, while the driver may use an infrared binocular periscope. In fire control applications, an IR periscope is used.

(1) Tank driving with infrared equipment. Field trials were carried out to compare the effectiveness of driving with infrared and with standard equipment (4). Eight tank driving courses, presenting as many normal driving hazards as possible, were used. The drivers had to select proper road forks, turns, and so on. Each important turn was marked with a direction sign (one by two feet), with black or yellow arrows to show direction. White engineer tape was used to indicate extreme hazards and side trails. The courses were usually traversed four times: using infrared, without vision aids, using blackout driving lights, and using infrared. The average speed under infrared conditions was 9.7 mph (2,000 miles of driving); under blackout driving, 8.9 mph (1,385 miles). It was concluded that infrared was of marginal value, if any, for driving on the desert trails. But drivers seemed to favor the equipment: 99 per cent of them said that infrared tank equipment is useful for convoy operations. They felt that the increased visual range allowed safer maneuvering of the tanks but was of less advantage for driving over dusty roads.

A series of studies is now being undertaken at the Armor Human Research Unit to determine the speed of infrared driving under non-desert conditions and under various levels of natural illumination.[1]

[1]C. J. Bailey and Howard C. Olson, "Illumination and Terrain as Factors Affecting the Speed of Tank Travel," HumRRO report under preparation.

The following conclusions seem warranted by what is now known about IR driving equipment: On moonlight nights, when illumination is sufficient for safe driving, IR equipment offers no additional advantages, except in shaded, forested, or mountainous regions. Under starlight and moonless, overcast conditions, IR driving equipment is of value. The exceptions would be on dusty or smoky terrain or in situations involving enemy observers equipped with detecting devices.

(2) Infrared gunnery equipment. The use of IR fire control equipment is accompanied by a number of difficulties. The detection range of IR is affected by smoke, haze, and dust. Enemy camouflage is very effective. A tank, which is black to IR, cannot be seen when it is parked behind a leafless bush, even at close ranges (75 yards). An observer cannot see clearly outside the area illuminated by the IR beam (this area should, therefore, be as large as possible, or projector and viewer may be coupled so that the position viewed is always illuminated). Muzzle flash will momentarily blind a gunner using an IR viewer. The flash, and obscuration due to dust picked up by the muzzle blast, prevent effective adjustment of fire on near targets. Extended use of the equipment causes visual fatigue. In addition to these difficulties, there is the disadvantage that a tank operating with IR gunnery equipment would be vulnerable to an enemy equipped with IR scopes and aiming devices. It may be concluded that the application of IR to fire control equipment, at least at present, is attended with less than complete success.

(3) Training requirements for infrared equipment. Tank and field units equipped with IR fire control equipment might require considerable training. The appearance of military targets is changed when they are viewed under IR; tanks, for example, appear black. Camouflage is effective against IR detection. Smoke, fog, and dust limit visibility. Tactics, countermeasures, and maintenance of IR equipment must all be taught. It has been recommended that three to four months of training be given before men use IR gunnery in offense (4). For defensive use, it is expected that less training is needed. These estimates of training time may be somewhat high; they are specified in a report generally unfavorable to IR fire control equipment.

Estimates on time required for driver training with IR equipment were obtained in the Camp Irwin field trials (4). Although it was claimed that range estimation and depth perception were not accurate, and that terrain slopes appeared exaggerated, the drivers had no difficulty in using the IR equipment. No extensive training was required.

(4) Infrared countermeasures, human engineering. A number of effective countermeasures may be used against troops equipped with IR. An IR source is seen by the unaided eye as a red glow, discernible at a considerable distance. In one field test, the IR source was detected at the following distances (4):

IR Source	Unaided Vision		Night Glasses	
12-inch	382 yards	(300)	602 yards	
18-inch	507	(300)	842	(300)
24-inch	637	(650)	718	(700)
60-inch	661	(300)	1500	(350)

The conditions of the test were as follows: IR sources included the tank commander's 12-inch light, the gunner's 18-inch light, the 24-inch half-track mounted light, and the 60-inch IR searchlight. The observers were dark adapted and were aware of the nature and approximate location of the sources. The night glasses were M17A1 binoculars. (Ranges shown parenthetically were estimates made by the project officer and three assistants who also observed.) The detection ranges for various targets in the same field tests were these:

IR Source	Stationary Targets[1] Detection	Stationary Targets[1] Identification	Moving Targets Detection	Moving Targets Identification
12-inch	371 yards	288 yards	467 yards	329 yards
18-inch	417	338	463	367
24-inch	692	442	767	592
60-inch	892	529	1067	721

These results are interesting because they show that the security range with the naked eye is almost as large as the detection range.

IR can be neutralized by the use of ordinary illuminants. Under adequate illumination, acuity is as good with natural vision as with IR. Likewise, when the moon is out, or where the battlefield is illuminated by searchlights or flares, there is no advantage in using IR.

IR devices now in use are in need of human engineering (4). For example, a more comfortable and efficient driving binocular is required. Sniperscopes are too bulky for field use. Also, projectors are susceptible to fire and are easily put out of adjustment. Almost all IR equipment requires excessive maintenance. If IR equipment were adapted for service use, it is probable that these human engineering shortcomings would eventually be removed.

PROBLEMS OF DAZZLE

A tank crew may be severely dazzled by gun flash at night. The time required for recovery is related to the darkness of the night, the type of gun fired, the direction of the eye in relation to the line of fire, and the criterion of return to normal adaptation. The after-effects of dazzle may last as little as a few seconds, or as long as several minutes. These effects are reduced if flash hiders or flashless powder are used.

The possibility of using dazzle as a weapon to blind the enemy has been considered. In fact, a committee on dazzle held regular meetings in Great Britain during the war. The method did not prove very successful in practice. It was almost as difficult to dazzle the enemy as to hit him. And dazzle may be easily avoided by closing one or both eyes.

In a field trial, assessment was made of dazzle as a weapon against enemy bombardiers (10). Experimentation was carried out using

[1]Detection distance is that at which the observer is aware of a target; identification distance is that at which the target can be named.

photographic bulbs exploded in front of a grounded airplane. The pilot reported a bright dazzle, with an after-image that persisted sometimes as long as three or four minutes. Even with the greatest dazzle produced in this way, he could still read his instruments.

Conditions of the field trials themselves were set up to favor the success of the method. The flashes were supplied by nine pounds of pyrotechnic material similar to the type used in photographic flash bulbs. The target was a concrete structure 50 feet high and 50 feet long, standing toward one side of a horizontal surface 150 yards in diameter. The aircraft made dummy runs up to the target. When it was 2,500 to 700 yards away, the flash was fired. The pilot had no difficulty in bombing the target. The sparks and small stars thrown up in the air after the flash helped to outline the terrain. The pilot stated that he was not bothered by the flash, except in the last run, which was carried out under very dark conditions. These results do not encourage the use of dazzle as an antiaircraft weapon.

THE TANK AS A MEMBER OF THE NIGHT COMBAT TEAM

The tank has acquired night eyes so recently that it is not certain what role it will have in the night combat team. Searchlights and infrared equipment have not yet been subject to battle trial, and their particular capabilities are not yet known. Future experience will dictate whether the tank should precede, accompany, or follow the infantry in the night assault, and how it can best aid the infantry by supporting fire.

There may be important advantages in coordinating illumination and fire between tanks. Acuity of observation is increased if the target is viewed from some other tank besides the one on which the illuminant is located. Tracer ammunition may be better sensed through flash and dust, from a second tank. Deception of position may be accomplished by having first one tank and then another use its light. It might even be possible (by proper coordination of the on and off periods of lights) to create the illusion that the column was moving in a false direction—an illusion like the "moving" figures seen on lighted advertising signs. Coordination of several lights, in terms of the duration of the light and dark phases, could provide constant illumination of a single target or target area without giving the enemy much chance to detect or disable individual sources of light.

Fitting the tank into the night combat team also involves standardization of illuminants. Field trials at Fort Bragg (2) and conferences at Fort Benning (5) have been conducted to select the illuminants which most effectively satisfy operational requirements. The field trials were concerned with troop use of a wide variety of illuminants. The Fort Benning conference recommended that, for defense, each front line unit from platoon to regiment have a means of battlefield illumination. In the attack, powerful illumination over wide areas is required. The need may be partially satisfied by providing the division artillery with an illuminating shell.

Participants at the Fort Benning conference drew up the following simplified list of required illuminants:

Field Piece	Illuminating Shell
155mm Gun	M118
155mm Howitzer	M118
4.2-in. Mortar	E71 (experimental)
105mm Howitzer	M314
81mm Mortar	M301 (limited standard)
76mm Gun	MK 25 Mod 1
76mm Gun	MK 24 Mod 1 (limited standard)
60mm Mortar	M83A1 (limited standard)

The ground signal selected was the white star parachute, M17A1. Two trip flares were approved: the M49 and the parachute M48. It was also recommended that security units and patrols be provided with illuminating devices, and tanks with illuminating shells.

There seems to be particular need at present for improved illuminants to cover large areas. Mortar shells require that a field piece be diverted for a secondary use, and aircraft flares obviously require airplane delivery. Illumination furnished by shells and flares is brief, variable, and somewhat undependable. The development of new methods of illumination may also be desirable.

SOME PROBLEMS FOR FUTURE RESEARCH

It is evident that the development of tank illumination involves a number of problems. Research on those involving human factors may profitably be conducted in the following areas:

(1) Laboratory data on visual detection under the illumination of tank-mounted searchlights should be checked by field observations.

(2) Countermeasures should be developed against searchlights and tank-mounted searchlights. At present, we do not have a fully satisfactory defense.

(3) IR equipment requires improvement from the human engineering point of view.

(4) If searchlights or IR equipment is adopted for service use, training requirements must be determined, and methods of training must be devised, continuously evaluated, and improved.

(5) Research should be done on the development of tactics for tanks equipped with searchlight and IR. Some of the related problems are these:

(a) What is the optimum rate of flicker of searchlights? How may searchlights be coordinated for better mutual support and enemy deception?

(b) Do blue and red filters affect range estimation on tank-mounted searchlights, as British sources mention?

(c) How effective for hiding the movements of tanks and infantry is the veiling luminance of the searchlight—as, for example, when an observer must look across the beam or through a portion of the beam?

Chapter 5

SOME ADDITIONAL PROBLEMS OF NIGHT COMBAT

This material concerns a number of topics—the visibility of objects, the illumination of tank interiors, map reading and orientation, night vision tests, and the morale effects of night operations—which are related to military night operations but do not fall under the general topics already covered.

THE VISIBILITY OF OBJECTS

Early in World War II it was discovered that visibility information was not available for developing day and night methods of land and sea bombing, and methods of detecting hostile submarines. The two-part program to obtain the required visibility data was formulated by A.C. Hardy. It included determining (1) the effect of the atmosphere on the transmission of light and (2) threshold sensitivity of the human eye. These data were to be combined so as to predict how well objects at varying distances can be detected. The program was later implemented with funds from the L.C. Tiffany Foundation.

The research on transmission of light by the atmosphere was directed by S.Q. Duntley; the visual threshold determinations were made under the direction of H. Richard Blackwell (4). The threshold experimentation was based on a modification of a Navy lookout procedure. The observer was required to state in which of eight possible locations a circular target was located. One set of data involved targets brighter than their background; another set involved targets darker than the background; a third set was obtained with the target always in the same position. The judgment required was to state whether the target was on for a long or a short time.

Published monographs based on the Tiffany data suggest the distances at which targets of various sizes, brightnesses, and brightness contrasts can be detected, as a function of meteorological range (12, 13,34). More recently, interest has shifted to the determination of visibility ranges, for moving as well as for stationary objects (11). A start has also been made in checking laboratory-based predictions, and in bringing them into closer conformity with field results (2,5,18).

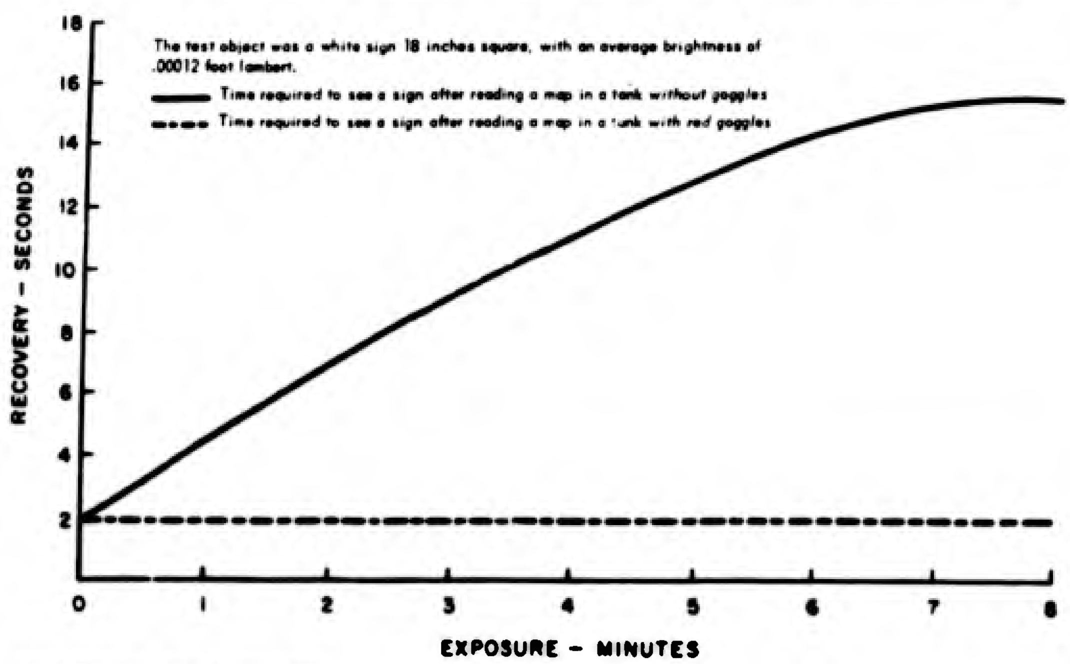
ILLUMINATION OF TANK INTERIORS

Tank interiors were formerly so strongly lighted that the crew could not see outdoors at night and the tank itself could be spotted at a distance.

Research on specifying satisfactory interior lighting has been concerned chiefly with two characteristics, spectral quality and intensity.

The utility of red light for maintaining dark adaptation has been shown by Rowland and Sloan (25). This and other studies have been reviewed by Kappauf (19). The application of the findings to tanks has been shown by Roberts and Eichna (23). In their study, the observer was required to identify a break in a disc or to see a sign after various periods of viewing a map (a typical night tank task). After looking at the map with red goggles, for each period of observation used in the test, every observer could see the sign after two seconds (see Figure 5).

EFFECTIVENESS OF RED GOGGLES FOR PRESERVING DARK ADAPTATION



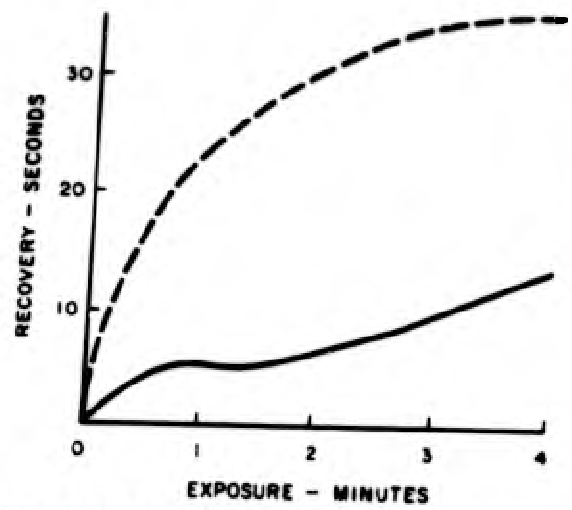
From Roberts and Eichna (23).

Figure 5

The length of time required to see the sign after reading the map for different periods without goggles varied up to about 16 seconds. A reduction in dark adaptation time also occurred when red filters were used over the lights. After two minutes of map reading, the crew exposed to red light identified the break in the disc in an average of six seconds, (Figure 6). The crew with unaltered lighting required 30 seconds, on the average, for equal recovery of adaptation. In other studies it has been shown that red flood lighting is as effective as indirect panel lighting in preserving dark adaptation (35).

The use of white light of low color temperature offers some advantages over red lighting. It facilitates reading of colored maps at night. Installation involves the simple operation of placing a resistance in the illumination wiring system (rather than installing filters, as for

EFFECTIVENESS OF RED LIGHT FOR PRESERVING DARK ADAPTATION



The test object was a blank Landolt ring eight inches in diameter, on a 2½-foot white target. Subjects were required to identify the orientation of the break in the ring after various periods of map reading in a tank:

--- Average recovery time for a crew who read the map *under white light*

—— Average recovery time for a crew who read the map *by red light*

From Roberts and Eichna (23).

Figure 6

red lighting). Brown and Grether found that red light is superior to low temperature white light for preserving dark adaptation (6). The adaptation threshold for white light was as much as .153 micromicrolamberts higher than that for red light of equal intensity. The authors believe, however, that the factor which limits visibility is not the lighting of the instrument panel, but rather reflections on the plane windshield which mask the view of outside objects.

The intensity of tank interior lighting should be low enough to preclude or hinder detection by the enemy, but at the same time high enough to make it possible for the crew to perform tank tasks quickly and accurately. Spragg and Rock investigated the speed and accuracy of dial reading as a function of the quality and quantity of dial illumination (27,28). The brightness range varied from .005 foot lambert (slightly above cone threshold) to 6.0 foot lamberts. The time and accuracy scores obtained suggested that a critical brightness level exists at about <u>.02 foot lambert</u>. Below this level of brightness, performance becomes significantly poorer; above it, performance does not improve significantly with increase in brightness. The recommendation was made that instrument dials be illuminated so that their brightness be just above the .02 foot lambert level, about the same level suggested by the results of studies by Kappauf (19) and Crook (10).

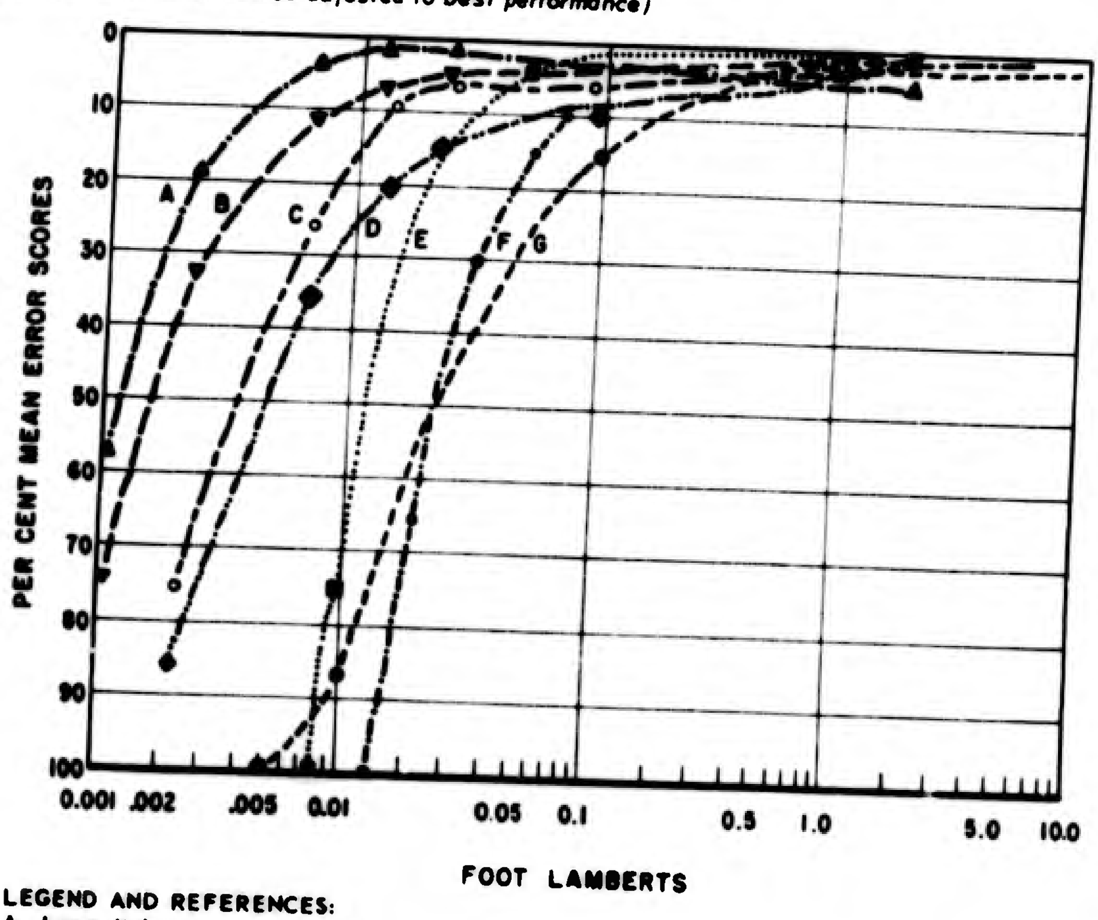
Even if the eye is adapted to higher brightness levels, critical brightness is still at about .02 foot lambert. Spragg had observers view Landolt rings at brightnesses ranging from .035 to 6.0 lamberts, before determining their ability to read instrument dials at other brightness levels (26). Adaptation to the dial task was very rapid, requiring only 10 to 15 seconds, even when the preadapting brightness was two to three log units above that of the task. Optimum illumination of the dials was the same, regardless of the brightness of the preceding ring task. Speed and accuracy of dial reading were again adequate, down to a dial brightness of .02 foot lambert.

Farnsworth has attempted to specify minimum light levels for the interior of the submarine (14). It was agreed that the lower level of illumination must be safely above the minimum level which makes possible easy and reliable performance of visual tasks. The upper limit was considered to be the brightest area which results when the areas or dials which are most difficult to light are illuminated to the minimum specified level. A brightness range of about one to ten was obtained under these conditions.

Farnsworth found, on the basis of a review of studies on dial reading under dim illumination, that the percentage of errors changed markedly between brightnesses of .01 and .1 foot lambert. (See Figure 7.) For work involving such coarse detail as manipulating

VISUAL PERFORMANCE AT LOW BRIGHTNESS LEVELS

(per cent mean error scores adjusted to best performance)



LEGEND AND REFERENCES:

A. Large dials – gross criteria
B. Large dials – fine criteria
C. Small dials – gross criteria
D. Small dials – fine criteria

(A–D: Chalmers, Goldstein, and Koppauf (8).)

E. Addition problems – 20-pt. type. Rock, M.L., *Visual Performance as a Function of Low Photopic Brightness Levels*, Wright-Patterson AFB, Dayton, 1950.
F. Legibility of letters – 20/40 size. Brown, F.E., *A Study of the Legibility of Transilluminated Markings in Aircraft Cockpits*, Aeronautical Medical Equipment Laboratory, Phila., 1949.
G. Depth perception. Rock, M.L. *op. cit.*

From Farnsworth (14).

Figure 7

switches and control knobs and reading standard dials, the change between satisfactory and unsatisfactory performance occurs at .01 foot lambert. For work involving fine detail, such as reading 4-point type, mathematical tables, check-off lists, poor quality mimeographing, slide rules and calculating devices, navigational charts, recording equipment, and engraved name plates, the break occurs at .1 foot lambert. The brightnesses decided on for lighting the submarine compartments ranged from .01 to 2.00 foot lamberts.

Sample specifications adopted for submarine compartments were the following:

Areas	Brightness (foot lamberts)
General Readiness (Crew's mess, officers' wardroom)	.20 - 2.00
Immediate Readiness (Staterooms, chief's quarters)	.00 - 0.10
General Operating (CIC and control room)	.01 - 0.20
Periscope and Pre-Lookout	.01 - 0.05

These specifications may be useful in suggesting dim lighting levels for tank interiors, bivouac areas, evacuation areas, and so on.

MAP READING AND ORIENTATION AT NIGHT

It is difficult to read ordinary colored maps under the dim red illumination of tank, airplane, and submarine instrument panels. The order of luminance of colors changes, contrasts are greatly reduced, and red markings become invisible. Colors which are easily discriminable under daylight conditions may become indistinguishable. A number of suggestions have been made for adapting maps for use under red panel lighting (36):

(1) Charts can be designed primarily for night use. Detail would be eliminated, type size increased. This method would have the disadvantage that the maps would be somewhat less satisfactory for day use.

(2) Day maps could be used, but altered to improve discriminability under night lighting. Letters could be made larger than a certain minimum size, small areas of shaded colors eliminated, and lines rearranged to reduce cluttering.

(3) Day and night aspects of the map may be separated by printing two editions or by colorimetric separation. The latter method involves showing all detail under white light, but only night features under red light. The RAF, for example, uses charts which under red light do not show such details as secondary roads. Tonal keying for red light may be accomplished by eliminating reds and substituting blacks or purples, in this way increasing the blue or green component of yellow and brown (1). Because of their intensified colors, tonal keyed

maps are only a little harder to read than standard maps; the tonal keyed maps which have been developed are also readable under white, amber, red, and ultraviolet light.

The various types of night maps are being evaluated by a subcommittee of the Armed Forces-NRC Vision Committee (6). Besides legibility, such practical considerations as ease of printing will determine which kinds of night maps are most feasible. At present, three or four runs through the printing presses are required to print the 11 colors used in Air Force charts. If special colors are decided on, it may be necessary to adopt more elaborate printing methods.

The problems of night orientation are related to those of map reading because map reading is a method of orientation. Orientation at night is facilitated by reconnaissance of the terrain during the daytime, by the study of maps, by acquaintance with natural landmarks, and by a knowledge of star positions. Orientation is also helped by the use of the prismatic compass and by such techniques as radio beam control, orientation rounds by mortars, light signals, (such as Very lights, parachute flares, and searchlights), fires behind one's own front, artificial or natural sources of illumination in enemy terrain set afire by the artillery, tracer ammunition fired by machine guns, orientation tables for night fire, and firing charts. Guides should be provided whenever possible.

In developing a training program of night orientation, it may be helpful to set up a problem requiring the soldier to find his way from one position to another, both positions being indicated on a map. The performance should be observed and the errors noted. Analysis of these errors will indicate what techniques should be emphasized in the training program.

NIGHT VISION SELECTION TESTS

Probably no phase of night vision research has aroused more discussion and debate than night vision testing. During the war over a hundred studies were carried out on the standardization and validation of these tests.[1] However, no night vision tests have yet been adopted for Armed Services use.

Some of the more widely used of these wartime tests are the following eight (33):

(1) *U.S. Navy Radium Plaque Adaptometer*–adopted as the official Navy device
Test object: rotatable, 3° Snellen T
Visual acuity required: .025
Test field: circular, 5° diameter
Fixation point: red cross, 7° above center of test field
Brightness level of background: practice, 4.5 log micromicrolamberts; test, 3.9 log micromicrolamberts
Source of illumination: radium plaque

[1] An excellent summary of these studies is presented in: W. Berry, *Review of Wartime Studies of Dark Adaptation, Night Vision Tests and Related Topics*, Ann Arbor Army-Navy-NRC Vision Committee Secretariat, December 1949.

(2) *Admiralty Adaptometer*—the official Royal Navy instrument

Test object: a 60° silhouetted wedge which may appear in any one of eight positions

Test field: circular, 4.5° diameter

Fixation point: none

Brightness level: discontinuous control of brightness in .10 log unit steps over a wide range

(3) *Hecht-Schlaer Model III Adaptometer*—the official Royal Canadian Navy instrument

Test stimulus: flash of light .2 second in duration over a circular field, 3° in diameter

Fixation point: red point of light, 7° above test field

Brightness: continuously variable by optical wedge

Source of illumination: incandescent lamp calibrated against internal standard lamp

(4) *NDRC Model III Adaptometer*

Test object: rotatable, 3° Snellen T

Acuity required: .025

Test field: circular, 3° diameter

Fixation point: red cross, 7° above center of field

Brightness: continuously variable by gelatin wedge from 3.0 to 6.0 log micromicrolamberts

(5) *Clockface Adaptometer*

Consists of a black background four feet in diameter on which are four white "hour" markers, approximately 4 by 6 inches, at the 12, 3, 6, and 9 o'clock positions. A single white hand, 14½ by 3 inches, may be set at any of the four positions. The white source is an incandescent lamp which illuminates the face to a level of 4.0 to 5.0 log micromicrolamberts.

(6) *Field Artillery School Night Vision Tester*

Test object: Landolt ring subtending 2°

Test field: circular, 4° diameter, viewed from a distance of 20 feet

Fixation point: none

Brightness: controlled by changing apertures to give five levels: 5.26, 4.96, 4.48, 4.18, and 3.73 log micromicrolamberts

Source of illumination: 3.3 candlepower (Mazda 63) lamps

(7) *British Hexagon*

This test is interesting because it presents the most complex stimulus of any of the night vision tests. The test derives its name from the fact that the apparatus consists of a hollow rectangular hexagonal prism. The source of illumination is inside the prism. Each face of the prism presents several test figures against a background. Some of the figures are simple, like the Snellen T, while others are quite complex. The subject records his answers with a pencil on a notched pad.

The test was not widely used in this country, chiefly because of poor control of illumination, inadequate standardization of directions, and other less important difficulties. However, Evelyn, by developing a calibrated source of illumination, standardizing the administration, and otherwise slightly modifying the test, was able to develop it to the point where it showed a fair reliability.

(8) *Miles Four-Plaque Adaptometer*

The Miles Four-Plaque deserves mention chiefly because of its historical interest. It was one of the first adaptometers, and was also the first to use radium compounds as a source of illumination.

The apparatus consisted of four self-luminous plaques in the form of a T, 3 by 3 inches. The plaques had brightnesses of 4.2, 3.9, 3.6, and 3.3 log microlamberts. They could be presented in varying positions of rotation. The fixation point was a small red cross 7 inches above the center of the plaque. The subject sat 5 feet from the plaques, which then subtended a visual angle of 3°.

The tests were given at various scotopic brightness levels, after half an hour of dark adaptation. As pointed out by Wedell, there were many points of difference (33): "Some used a single level of illumination; others employed several levels. The stimuli varied all the way from the simple flash in the Hecht-Schlaer to the complex forms of the British Hexagon. Fixation distances varied from 15 inches to 20 feet. A carefully planned practice session preceded the testing with some instruments, while with others the practice trials were haphazard or non-existent. More significant, perhaps, are the implicit assumptions underlying the several test situations. For example, whoever puts faith in the Hecht-Schlaer believes that absolute sensitivity is closely related to the complex form perception which must be involved in detecting targets. The proponent of the Navy Radium Plaque Adaptometer takes a similar stand with regard to a simple type of form discrimination. Finally, those who developed the British Hexagon test must have assumed that the best test is a kind of omnibus measure of many different types or levels of form discrimination, even though no one of the types or levels involved was measured very reliably."

Night vision tests have been criticized for low reliability, for low validity, and for being subject to a practice effect. The most telling criticism against them is that of low validity (22,32). In the final analysis, the value of the test is determined by its success in predicting field performance. Acceptable validities have been obtained for some of the tests (24). (See below also.)

Lately a comprehensive program has been carried out at the Personnel Research Branch, The Adjutant General's Office, to standardize a mesopic test of night vision (17). It was considered that the older tests did a technically adequate job of classifying night vision but that they had certain shortcomings from a practical point of view. The viewpoint taken was that the chief difficulties in the older methods of night vision testing were operational in nature. Intermediate brightness tests involve shorter adaptation time (and hence more rapid testing), less dependence on light-tight testing conditions, and fewer testing personnel—factors resulting in a more economical procedure for measuring ability. It was thought that in military situations these advantages might well be critical in determining whether or not a test of night vision could be adopted for extensive use.

The brightness level selected for the mesopic test was 6.67 log micromicrolamberts. This level is approximately in the middle of the mesopic brightness range, where rods and cones may be operating with about equal effectiveness. The validation study was carried out by the author at Fort Benning.

The criterion used to determine visibility ranges under night illumination was constructed by F. Jones of the U.S. Army Infantry Human Research Unit. The criterion test was repeated several times to enable an estimate to be made of its reliability. The validity of the night vision tests, corrected for unreliability of the criterion, was found to be between .50 and .60.

The value of night vision selection and classification will depend upon the amount and importance of the duty carried out under mesopic or scotopic conditions, and on the effectiveness of the test as a selection measure. It is possible to compute from the Fort Benning data, for example, what the improvement in night vision will be (in terms of yards) if any given proportion of the population is rejected. The test may be adopted if the improvement is worth the effort of giving the test and if enough men are available to make possible a selection (or rejection) ratio.

Night vision tests may be used to equate groups for night training problems. If the research is at scotopic levels, the older scotopic tests would probably be most suitable; mesopic tests would probably be best for testing acuity at the higher levels of night illumination. But the PRB research has shown that there is a considerable relationship between acuity at different levels, and that a single test may serve fairly well for all dim levels (31).

NIGHT OPERATION AND MORALE

It has frequently been observed that fear is easily aroused at night, and that the morale of an enemy may be shattered by a successful night attack (28). Night tank attacks have been successful on some occasions (15,16,20), but not on all (30).

The subjective aspects of night combat have been vividly described in a Japanese manual (7). The views of these masters of night combat are particularly worthy of consideration: ". . . at night time a person is not able to see his surroundings; accordingly it is only natural that there should be uncertainty. One cannot know when there will be danger in the darkness just a little ways ahead. In such cases there is a feeling of apprehension, of doubt and uncertainty—and finally there is extremely cautious watchfulness and fear. In short, at night-time the mind is agitated and excited. . . . As a result of too much care and concentration, what has hitherto been imagination almost ceases to be such and approaches reality . . . illusions very often arise. For example, white clothes hanging on willow trees, or white flags in a cemetery, become ghosts; an old rope in the grass becomes a snake; tall pillars, or bundles of Manchurian millet, an enemy. . . . On account of such suggestions, confusion, mistakes, false reports, etc. in one detachment, will extend quickly to the entire body. . . . During the Japanese-Russian War, a detachment of the Russian Army in a seacoast fortification was thrown into disorder on account of one or two men in the front crying out that there was a night attack. . . ." Measures which were recommended in this manual to avoid panic at night included discipline to repress weaknesses of individual soldiers, silence to provide calm and coolness, use of massed formations to give the feeling of collective strength, and thorough previous reconnaissance to avoid uncertainty of command.

The disorganizing effects of night combat may possibly be attributed to the same causes that produce fear and anxiety during daytime combat—the existence of a situation with which the individual cannot cope. According to this notion, night warfare, or tank night warfare, is not inevitably terrifying, but only so when the enemy does not expect it, and has no countermeasures to deal with it. It may be somewhat easier to achieve the unexpected at night, when vision is limited. And, other things being equal, a night attack should be more terrifying if it involves tanks.

It would be helpful if some definite statement could be made on the optimum size of a group for night combat. It is known that unilluminated night attacks should not be made with units of over battalion size, because of the difficulties in communication and control (29). The optimum size of a group is particularly a function of its purpose, and of previous team training. For example, if a squad has been trained to work together, it would not be reasonable to use half a squad at night.

PROBLEMS FOR FUTURE RESEARCH

(1) Prediction of visibility, derived from laboratory data, should be checked against actual field data. Distances at which military targets can be identified should be determined, when these targets and the observers are moving at various speeds.

(2) A type of map should be devised which is easy to print and which would present the necessary information clearly in daylight and under dim red lighting.

(3) There is a need to clearly outline the problems of night orientation by exploratory studies which make use of realistic field problems.

(4) It should be determined what equipment constitutes the most effective aids to orientation.

(5) In the area of night vision testing, definite standards of what the tests are to accomplish should be specified; present tests should be evaluated by these standards.

(6) The principal conditions of fear and anxiety in night combat should be determined (through interview, or review of the literature), and methods of minimizing or exploiting these conditions (whichever the situation requires) should be developed.

Chapter 6

APPLICATION OF RESEARCH TO NIGHT OPERATIONS

SUMMARY OF THE SURVEY

The discussion in Chapters 2 to 4 may now be related to the problem of specifying how the tank may best be equipped for night combat. It has been pointed out that the need to adapt the tank for night operations was clearly shown in the African campaign of World War II, when soldiers who wanted to operate in the cool evening were unable to do so because the proper equipment and techniques were not available. Since then, certain obvious changes have been made to correct this deficiency. Red panel-lighting of low intensity allows the tanker to retain his dark adaptation. Blackout lights have been adopted for night driving. Tracer ammunition and illuminated sights allow more accurate shooting at night. Flash suppressors help prevent dazzle. All these and other well-proved aids have prepared the tank for use at night.

But the role of the tank in night warfare is still not established. Doctrine on tactics, strategy, and methods of coordination between tanks at night is still in an early stage of development. The difficulty may be that even though the results of field trials and scientific research related to night fighting are known, insufficient night combat experience is available to indicate the precise role of the tank.

Some of the technical resources and methods which may help define this role have been reviewed here. Training methods enable the tanker to make more efficient use of his eyes. He may be told of the importance of dark adaptation and how to preserve it. He may be informed of the advantage of using peripheral vision at night, and he may be trained in systematic scanning procedures. Special viewing devices and night sights will enable him to see farther and better, and to shoot more accurately at night. Such methods of illumination as tank searchlights and IR equipment are also available. With proper use, the searchlight will provide effective illumination, and it is almost invulnerable to enemy fire. IR lighting which provides "secrecy" has been adapted to driving and sighting equipment. The methods are available; the problem is, how shall they be used?

In assessing the usefulness of these methods, it is helpful at the start to state what they are expected to accomplish. The requirement is simply to overcome the handicap of darkness—in other words, to enable the tank to operate with daytime effectiveness. It should be able to hit a target at extended ranges;[1] to attain speeds of 30 mph and more with full daytime mobility, and to make full use of range finder and sighting devices. If anything less than these requirements is accepted, the tank will be operating at less than full efficiency. It may, in effect, be serving only as a place of shelter for a crew of men. If so, the job it is performing may be done as well by other less precise and costly weapons.

The requirement dictates that the tank have a source of illumination. Training in the use of the eyes will enable the tanker to see at perhaps 50 instead of 30 yards under starlight illumination. Methods of testing serve mainly to eliminate personnel who are night blind. Night sights will enable the tanker to shoot under conditions of dusk and darkness but do not offer a solution for "You can't hit what you can't see." Night scopes are valuable in enabling the tanker to see farther, but the improvement still falls far short of daytime effectiveness. The "logic of the situation" demands that some form of battlefield illumination be adopted. This is not to say that training and testing methods, night sights, and optical systems should be discarded. There may be occasions when any or all of these methods may play a useful part. They do not, however, give a satisfactory general solution to the night problems of Armor (whatever their applicability to other services may be.)

Of the forms of illumination available, searchlights and IR have been used most with tanks. The advantages of searchlight illumination over IR can be supported. The two types of illumination work similarly, except that IR is presumed to combine visibility with secrecy. This advantage is probably more apparent than real. If IR were adopted for general use, the enemy would be forced to standardize the equipment used in countermeasures. This equipment is simple and effective. Even without special snooperscopes and metascopes, the security range of IR (directly viewed) is comparable to the visibility range which it affords.

If the special claim of IR to affording secrecy be disallowed, the advantage lies clearly with white light. For a given amount of power, much more illumination is afforded by white light equipment. (All but a small portion of invisible rays are filtered out in IR equipment.) Visible light integrates with the system of pyrotechnics, mortar shells, flares, and searchlights used by the Infantry and other arms. IR is not a "compatible system"; if the battlefield is otherwise illuminated by shells or searchlights, the tanker may as well stow his IR equipment, for it will be of no use. Equipped with IR alone, the tanker cannot provide support for friendly troops who are not so equipped. In its present state of development, IR sighting equipment is so full of "bugs" that it demands an excessive amount of maintenance; IR driving equipment is somewhat more satisfactory.

It may be that these various difficulties will eventually be overcome. But even so, IR equipment would always be more unreliable and subject to breakdown than simple visible light illuminating devices.

[1]The daytime requirement is for 80% first round hits on a panel 7½ feet square at 2,000 yards, in 8 seconds.

"Passive" IR detection devices—IR viewers which pick up the natural radiation of target objects without their first having to be illuminated by the viewer—are in a comparatively primitive stage of development; even workable prototypes will not be available for several years.

It must not be concluded that IR devices have no value (even if they have none for general battlefield illumination). IR is effective against an opponent who does not have detecting devices, or who does not expect that those he has will be needed. (Unfortunately, it is difficult to guarantee that the enemy would be so disposed.) IR may also be useful in forcing the enemy to devote time and effort to taking countermeasure precautions. Sporadic use of IR may keep the enemy prepared for an IR attack that never occurs.

There may be certain advantages in attempting to develop a source of visible light illumination separate from the tank itself. Such a source could give stronger illumination than could a tank-mounted searchlight (the tank generator is already burdened with other requirements). A separate source would allow more effective observation; the tanker would not have to view through the layer of veiling luminance. With the beam stationed on the side, the tank would be provided with a protective "cloak of darkness." Even if such methods of battlefield lighting were developed, however, the tank still should be provided with its own source of illumination since extra-illumination sometimes would not be available.

The requirements for training and testing methods, for night sights and optical devices, may be more clearly established when a basic policy on illumination has been set. If adequate illumination were by some unusual circumstances always supplied, there would be no need for any of these methods. If lighting is used only part of the time, however, a judgment must be made as to the value of using these methods to combat the handicap of darkness.

GENERAL CONSIDERATIONS FOR FUTURE ACTION

The general goal of Armor is that it be able to move, shoot, and communicate effectively during the night—if possible, as effectively as during the daytime. In any event, night performance must be equal or superior to that of a probable enemy. If this goal is to be achieved, we must know what is required of each crewman during his job duties at night. We must develop our equipment to the limit of our present engineering knowledge. And we must, as well, determine means of motivating our soldiers so that they can accomplish, within the limits of human capabilities, all the things which the current state of development of doctrine and equipment will allow. Formulation of research problems is crucially dependent on clearly enunciated doctrine and concepts of night operations.

What, then, needs to be done? The research considerations suggested at the end of Chapters 2 to 5 need not be restated here, but may be summarized as follows:

(1) The present capability of Armor units to satisfy current and intended night operations doctrine needs to be determined, but such

a task will be difficult to carry out until troops have had the required training and experience in night duty. Adequate training may resolve or mitigate many of the research problems suggested in Chapters 2 to 5.

(2) Assuming that the development of new and improved techniques is always desirable, an aggressive effort in this direction should be instituted, and promising techniques should be thoroughly evaluated in relation to our present level of night operations capabilities.

(3) Efforts should be made to develop methods and techniques which will utilize all the human capabilities of our troops. This consideration suggests that we must not only make maximum use of vision skills, but also give attention to such sensory endowments as hearing, and possibly even smell and touch. (A program of research dealing with the effective utilization of hearing is now being developed by the Armor Human Research Unit in cooperation with the Combat Developments Group, The Armor School.) It must be realized that no equipment which requires a human operator can ever be effective beyond his sensory capabilities; early in the equipment development program, caution needs to be exercised to insure that the performance requirements are capable of being met by the operator.

(4) There is a most pressing need to devise means of measuring the proficiency of Armor units and individuals in performing their night operations duties. It might be assumed that criteria of performance for daytime activities will be sufficient to measure night performance, but any such theory needs to be verified; it probably is not true.

Darkness should be an ally instead of an enemy. Every possibility should be exhausted in the effort to train our troops so well that they are able and willing to conduct themselves effectively at night.

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Appendix A

OUTLINE OF COURSE IN NIGHT VISION GIVEN FOR ARMOR INSTRUCTORS

(First week of a two-week course, Fort Knox, Kentucky)

<u>Monday</u>: Orientation, Mission of the Service School, Night Vision Testing and Demonstration Teams, and General Scope of Night Vision Instructors' Courses 2 and 3.

History and Background of Night Vision in Relation to Military Training and Operations.
Light Principles of Practical Importance in Night Vision.
Theory and Principles of Night Vision, Elementary Anatomy of the Eye.
(Lunch)
Exercise in Night Vision, Shadowgraph, Autokinetic Illusion.
Administration of ANVT-1 Test to Students.

<u>Tuesday</u>: Instructor Training.

Binoculars and Optical Aids to Night Vision.
Use of Shadowgraph for Training.
Description of Test and Classification Based on Scores.
Night Vision Testers in Current Use.
(Lunch)
Light Principles of Practical Importance in Night Vision.
Demonstration and Practice in Operation and Construction of ANVT-1.
(Supper)
Field Demonstration of Night Binoculars, Principles of Night Vision Recognition, Black-out Driving, Practice in Recognition of GI Vehicles.

<u>Wednesday</u>: Instructor Training.

(Lunch)
Measurement of Light, Intensity and Brightness Instrument and Procedure.
Description and Demonstration of Taylor Low Brightness Meter.
Calibration of ANVT-1.
Use of Electronic Aids, Description of First Echelon Maintenance.
(Supper)
Outdoor Night Observation Test, and Transition and Binocular Training.

<u>Thursday</u>: Instructor Training.

(Lunch)
Critique of Night Vision Outdoor Test, and Open Forum and Question Period.
Calibration of ANVT-1.
Use of Searchlight as Artificial Moonlight.

Friday: Instructor Training.

Psychology of Night Combat.
Night Vision Training Games, Film: "Night Vision."
(Lunch)
Combat Lessons of Night Operations.
Construction of ANVT-1 Alignment to Practice Terms.
Assembling and Maintenance of ANVT-1.
(Supper)
Night Observation and Movement.

Saturday: Instructor Training.

Examination.
(Lunch)
Study Period: Preparation and Selection of Material for Instructor Training.

Appendix B

OUTLINE OF RAF LECTURE ACCOMPANYING NIGHT VISION DEMONSTRATION[1]

1. The number of pupils should be about 12 but should not exceed 20.

2. The pupils should be placed on each side of the trainer, the first row being level with it.

3. The trainer is prepared . . . and the blackout is drawn. The pupils are not dark adapted and as a result can see nothing. If it is desired, the pupils may stare at a lamp while the blackout is being drawn and then can experience "after effect" when the light is put out.

4. It must be explained to them that the trainer is switched on and that silhouettes are appearing on the screen at starlight visibility. The first pupil to see anything must tell the instructor. The instructor then can give a general introductory talk on night vision and the R.C.A.F. (Evelyn) night vision trainer. It won't be many minutes before first one and then another pupil will claim he can see something. This is a useful demonstration that while full dark adaptation takes anywhere from half-an-hour upward, a certain amount is acquired in quite a short time.

5. Seven pupils are then numbered from 1-7 and are asked in turn to describe as fully as possible one of the objects.

6. The effect of scanning can then be demonstrated and each individual pupil can find out for himself at what angle he must offset his eyes. This position varies with the individual.

7. The aircraft continue to move across the screen; if they are not seen by any of the pupils, they must be drawn to their attention. The cloud effect can be used in conjunction with the aircraft and also in conjunction with the fighter aircraft.

8. The pupils can try scanning for the aircraft, either by sweeping the skies or by 10-degree jumps, and each can decide for himself which is the more successful method.

9. The fog effect lamp can now be used and the different intensities illustrated. The background light can also be reduced and the falling off of identification demonstrated.

10. The dive bomber and balloon can be used and scanning practiced.

11. It can now be demonstrated that a red torch of low illumination does not destroy night vision. With the small square maps it can be shown that all colour values are destroyed by the red light. A normal white light can now be switched on for two or three seconds. This will

[1]See Figure 2.

serve to illustrate that damage to night vision depends not only on the intensity of the light, but what is more important, on the duration of the exposure.

12. All this time the pupils' night vision has been improving and the same seven pupils can be asked again to describe the object they described before. This is a very useful demonstration of how night vision definitely does improve with time.

13. All this time the silhouettes of vehicles and men have been passing across the screen. If the pupils have not yet seen them, they must be told where to look to expect to see something. This is quite a good demonstration of how incomplete scanning can be. The silhouettes are not very large and it is quite likely that some of the pupils will not be able to see them, particularly that of the "one man" even when it is pointed out to them.

14. As a matter of interest, each pupil can now find, by covering up first one eye and then the other, which is the master eye.

15. Before finishing the period, each pupil, by keeping one eye closed and his hand over it, will have his other eye exposed to a bright light for some minutes. The lights will then be switched off and the eyes winked alternately to show the difference in vision. This demonstration also shows that by covering one eye up when exposed to searchlights, night vision can be very quickly recovered in both eyes by winking them.

16. The lecture lasts about an hour.

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