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INFRARED FOR ARMOR

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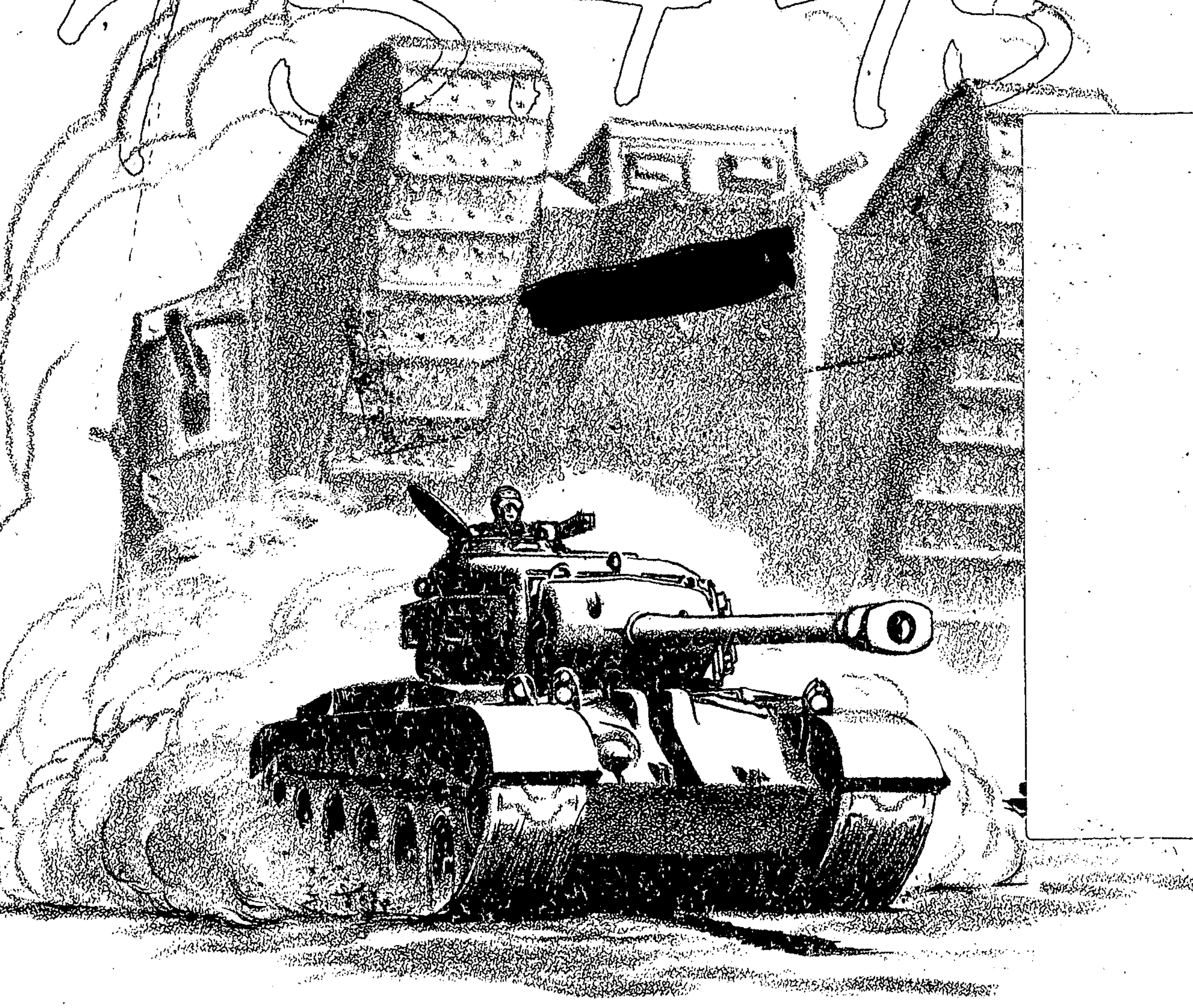

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A RESEARCH REPORT

UNCLASSIFIED

Prepared at
THE ARMORED SCHOOL
Fort Knox, Kentucky
1952-1953

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INFRARED FOR ARMOR

A RESEARCH REPORT PREPARED

BY

COMMITTEE 15, ARMOR OFFICER ADVANCED COURSE

THE ARMORED SCHOOL

1952 - 1953

MAJOR ROY R. MAY

MAJOR JOHN L. CLARK JR.

MAJOR JOSEPH G. CARRAWAY JR.

CAPTAIN DONALD E. BARNARD

CAPTAIN ROBERT E. GOOD

Fort Knox, Kentucky

April 1953

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PREFACE

INFRARED FOR ARMOR is presented in the hope that it will prove of benefit to the reader who may possibly be as uninformed on the subject of infrared, as was this committee when it set about its task. Although the primary aim has been to present a study of infrared and its applications to Armor, a secondary objective has been to bind together in a single document, all of the pertinent considerations on infrared. The latter accomplishment is valuable when it is considered that infrared is still in its infancy and, thus, there has been wide speculation as to its ultimate potential value to Armor.

During the conduct of this research, the committee has entertained the expressed opinions of those who have been directly concerned with the development of a means which would permit Armor to operate as effectively at night as it does in the daytime. An extensive investigation was made of all of the known and available references on the subject. There were, however, a few limitations placed on the committee which have handicapped this effort. Probably the most significant of these is the fact that Army Field Forces Board No. 2 had completed the bulk of its infrared tests prior to the time that this committee became interested in the subject. This, of course, was unavoidable although it did preclude the committee from actually participating in any of the tests. Several inquiries to responsible agencies for the very latest "Ivory Tower" concepts of infrared have gone unheeded or have not been answered as of this writing. We feel that such information would have contributed only to what may be expected in the future and would not have thrown additional light on that infrared equipment that presently exists.

The committee desires to express its gratitude to Colonel William P. Withers, President, Army Field Forces Board No. 2 for making available the facilities of the Board to this committee during the preparation of this research report.

The aid provided by Captain Spencer R. Baen, Combat Vehicle Section, AFF Board No. 2, is particularly appreciated. Without his cooperation, it is doubtful that this report could have been satisfactorily completed.

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CHAPTER 1

INTRODUCTION

The purpose of this committee's research of INFRARED FOR ARMOR was to examine all known information concerning infrared and the equipment used to apply it militarily. It is proposed to analyze its wartime history, its post-war developments and its future trends as might be indicated in light of its most recent tests. Consideration will be given to a general survey of the status of infrared in the Soviet Armed Forces.

Because of each committee member's lack of prior association with infrared other than a brief acquaintance achieved through a cursory exposure to its generalities sometime during his career, it was at first necessary to become familiar with the basic concepts of infrared and its military applications.

Though not involved technically beyond the comprehension of most laymen, certain ramifications of the problem do require technical explanation and technical understanding. Throughout this report, however, an attempt has been made to adhere to simplicities and to avoid weighty masses of detail.

With due respect and great regard for the official position and experience of some persons available for comment as concerns infrared for armored units, a general attitude of negation was apparent in some quarters. Such expressions as the following are indicative comments. "Infrared costs too much." "Use of infrared creates excessive maintenance and training problems." "The equipment is awkward, fragil and excessively complicated." "Infrared is no better than direct white light." "Favorable results of tests were achieved under optimum conditions and not under average or less hopeful combat circumstance." These comments are not presented as verbatim quotes and specific persons are not accredited. However, they are offered a fairly representative thoughts from the more pessimistic.

On the other hand infrared has its share of ardent supporters. Official publications generally indicated a most optimistic future for infrared and its prospects for military application.

The examination and evaluation of such divergent opinions as they affect INFRARED FOR ARMOR was a major committee problem.

In commencing research of INFRARED FOR ARMOR an exhaustive search for material was made in The Armored School Library, The Armored School Document Section and the library at Army Field Forces

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Board No. 2. This labor produced voluminous information of varying value.

In addition to the examination of documents found in the facilities mentioned, personal interviews were conducted with individuals participating in infrared equipment tests; with those concerned with the review and processing of field reports; and with those concerned in any other official manner with the project.

Though a general basis of research study was reached from information derived from these sources it soon became apparent that some answers were unavailable locally. Agencies on Department of Defense and Department of the Army level were querried in order to determine the origin and history of present interest in the military aspects of infrared; to ascertain responsibilities for its development; to secure results and official reaction to infrared's most recent tests; and to be advised of the latest known status of infrared in the Soviet Union. At the time of this writing, it is considered that all known sources of information concerning infrared as it pertains to Armor have been contacted and exhausted insofar as possible.

Infrared Defined

To establish a foundation for future explanation and comment, it is considered appropriate to offer a brief discussion of some of the physical attributes of infrared.

First of all, what is infrared?

Infrared is energy in the form of light or radiation. Like ordinary light infrared is reflected from some objects which it strikes and likewise it may be largely absorbed by others. Infrared may be projected in a narrow beam or it may be emitted without particular regard for direction. Infrared light differs from ordinary light in that it is invisible to the unaided human eye.

A beam of ordinary light in passing through a prism is broken up into a series of merging colors, red to violet. These colors are called the visible spectrum. The most familiar example of this separation of light into its various colors is the natural phenomenon of the rainbow. Beyond the ends of this visible spectrum the colors red and violet merge into blackness. But by using a photographic or other means of detection, the existence of light or energy extending for relatively great distances on both sides of the visible spectrum can be demonstrated. Radiation continuing from the red end of the spectrum out to blackness is infrared.[1]

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All sources which emit visible radiation also emit infrared. Usable infrared then is obtained by filtering out the visible portion of light from a given source.

As a matter of convenience most forms of radiation have been classified according to the length of their impulse or wave. The unit of measure applied in such instances is the micron. A micron is one thousandth of a millimeter. The region of radiation for infrared lies between approximately one milimeter and less than one thousandth of a milimeter or one micron.

The measured wavelength intervals of radiation in the infrared region are relatively unimportant in this discussion except as they effect our understanding of the many ramifications of applying infrared in modern war. Therefore it is appropriate to note that the human eye perceives light in a wavelength interval from about 0.4 micron to about 0.76 micron. This limit of vision is not established at a well defined cutoff of all visual sensitivity but rather as a decreasing perception of light. It is apparent then that an intense source beyond 0.76 micron might be seen by some persons. Because of this the lower limit of the infrared spectrum is established as 0.8 micron.[2] Wavelength intervals to approximately 1,000 micron may be set as the upper limit of the infrared region. While these limits and boundaries are not defined sharply it is sufficient for our purposes to accept them as the general area of wavelength interval with which we will be concerned.

Infrared Regions

Within the infrared spectrum just described, four subdivisions have been established arbitrarily. These divisions are called the near, intermediate, far and very far regions. Each division or region has been named because of the position within which its wavelength interval falls in the scale of the infrared spectrum. Thus, near infrared includes those radiations whose wavelength intervals most closely approach those of visible light. For the same reason the very far region, extending from wavelength intervals of 40 to 1,000 microns, is on the end of the infrared spectrum most removed from visible light.

Beyond a few laboratory investigations little exploration has been accomplished in the very far region.[3] Obviously then we shall be most concerned with the examination and application of near, intermediate and far infrared.

Near infrared is the kind used to illuminate objects or areas by directing a beam of light from which the visible radiations have been filtered. Reflected radiations are then captured on a sensitive screen which forms an image of the object or area receiving the infrared beam. Near infrared is most applicable to night driving, night firing of weapons and night observation.

Intermediate infrared, because of its differences in wavelength radiations as opposed to those of near and far infrared permits certain advantages with respect to distances at which objects may be detected and with respect to its capability to penetrate fog, haze and smoke.

Let's consider briefly the aspects of the far infrared region which is also called the thermal region.

Far infrared can best be explained and understood by imagining a cold block of iron or any other metal in a darkened room. Imagine also that it is possible to heat this piece of metal to any desired temperature. As heat is applied no visible change in the appearance of the object is observed. However, the emission of warmth can be felt. This warmth is experienced because energy in the form of waves of radiation is being emitted by the heating block. When these waves attain a certain length interval it would be possible to observe their physical presence through the means of some viewing device even though it was still impossible to see them with the unaided human eye. As the temperature of the metal is increased a gradual change in the color of the object would become apparent. This would occur because the wave lengths of its radiations would become shorter. At first the object would appear a dull red. The more heated it became the more bright red it would become. As the heat became greater the appearance of the metal would change from an unobservable black through the shades of red into orange then into yellow and finally into incandesent whiteness. The relation between temperature and color is an interesting one but a discussion of that facet of the problem is not considered appropriate here. It is sufficient to be aware of the possibilities this phenomenon presents with regard to detecting the presence and observing the movement of objects not otherwise visible. This is possible, of course, by being able to pick up contrasting radiations emitted by objects by virtue of their being warmer than their surroundings.

It is not intended that the example just used should cause confusion with regard to the difference between heat and infrared. It should be understood that heat is a property of material substances, that is, heat may be transferred to other bodies by conduction, convection or radiation each of which occurs at relatively slow velocities. Infrared, on the other hand, travels through space at tremendous speeds. Further, infrared does not require the presence of material substances such as solids, liquids or gases to enable it

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to get from one place to another. -It is noteworthy to observe, however, that the nature of infrared radiation does agitate the molecules of a body and thereby cause heat.[4]

In addition to the characteristics of infrared and its regions there is another matter of discussion which indicates explanation.

While possibly infringing on a discussion of infrared equipment, which attempt has been made to avoid in this chapter, a distinction between image forming and non-imaging forming infrared should be made. As a matter of reference to the sensitive elements of the infrared pick up devices infrared has been classified as being either image forming or non-image forming. Stated simply these terms mean that image forming infrared receivers pick up not only differences in radiation but also project the outline of the target thereby permitting its recognition. Non-image forming infrared receivers merely indicate the presence of objects because of the differences in the intensity of their infrared radiations. For example, when an infrared detection device is pointed at a building in front of which a tank is parked, non-image forming receivers would indicate the presence of the two distinctly different objects but would not identify them. An image forming device would permit this identification.

Briefly then, infrared possesses much the same characteristics of ordinary light with the significant exception that it is invisible to the unaided human eye. It may be projected in a narrow beam. It is reflected from objects which it strikes thereby illuminating them when viewed through a device sensitive to infrared radiations. Infrared radiations are emitted from objects both animate and inanimate. The presence of these objects may be detected by reason of the difference in infrared radiations caused by their temperatures.

Military Uses

Understanding these things, let's now consider the military potential of infrared and its possible uses to armor in modern war.

Our interest in infrared arises, naturally, from the several possibilities of utilizing its characteristics as aids to success in combat. These applications include: Illumination and identification of targets upon which it is desired to bring aimed fire during darkness. This requirement contemplates night firing of tank guns as well as the aiming and firing of small arms. Night illumination of areas over which it is desired to travel either by vehicle or by foot.

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Night observation of areas without the detection associated with visible light.

These requirements can be achieved without detection by the enemy provided he is not equipped with infrared detection devices. Of course, if hostile forces do possess a means of detection, our efforts at secrecy and surprise become more worthless than if infrared was not used at all. On the other hand utmost secrecy is obtained through the use of infrared as a passive means of detection. That is, the presence of an enemy can be detected by picking up his or his equipments emission of infrared radiations due to contrasts in temperatures.

The major significance of these two systems is in the observation that in one, the active system, targets or areas are subjected to infrared radiations which are in turn reflected and captured on a pick up screen thus producing an image of the illuminated object. This system is effective only if the enemy does not have or does not use means of detecting infrared sources.

In the passive system the enemy is at present incapable of a countermeasure for the means utilized to detect the source of infrared radiations is not in itself detectable. A second advantage to the passive system is apparent when it is acknowledged that: "Radiation intensity coming directly from the target decreases proportionally to the square of the distance only, whereas a system that depends on reflection from a target normally suffers an intensity decrease proportional to the fourth power of the distance."[5] In other words it is possible to detect the presence of targets at far greater distances because of their natural radiations than it is to illuminate and view them by a directed beam of infrared light.

It is hoped that this introductory chapter to INFRARED FOR ARMOR has established some degree of familiarity with this committee's problems and limiting factors. More important, it is hoped that a measure of acquaintance has been achieved in introducing infrared and some of its characteristics.

Having presented these basic thoughts Chapter II will offer a discussion of how infrared is made to comply with some of the requirements of military usage in its early development.

NOTES FOR CHAPTER 1

[1]Background Manual of Information on Infrared, (Washington: Central Intelligence Agency, 23 November 1949) p 1.

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[2] An Introduction to Military Infrared Techniques, prepared by The Panel on Infrared, Committee on Electronics (Washington: Department of Defense, 1 March 1952), p 1.

[3] *Ibid*, p 2.

[4] *Ibid*, p 6.

[5] *Ibid*, p 7.

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CHAPTER 2

WORLD WAR II DEVELOPMENT

SECTION I

INTRODUCTION

During the period between World War I and World War II much basic research was conducted on devices for viewing a field exposed to radiation of wave lengths invisible to the naked eye. Scientists in several countries worked on this project along parallel lines.

In the course of World War II important military applications for infrared were developed. Infrared radiation is not visible to the naked eye and can be made difficult to detect by other means. Thus, its military significance lies in the fact that it can be used in doing many things for which visible light is required.

Infrared equipment usually consists of the following: (1) a source of infrared light, such as a tungsten filament or arc, (2) an infrared filter, necessary since strong sources of infrared light also emit visible light, and (3) a received which may take a variety of forms depending on the use of the apparatus. Devices capable of making visible the reflected infrared image has been developed prior to the outbreak of World War II.

Early Use by Germany

As early as 1940 and 1941 German image forming receivers were a part of the standard equipment of naval vessels. Ships, equipped with these devices, could illuminate other vessels with searchlights using infrared filters and detect enemy vessels with image forming receivers. The effective range was several thousands yards.

Later in the war, German army units were equipped with a complex system of night viewing equipment for aiming in the dark and for night driving. Tanks were equipped with infrared telescopes that permitted the tank commander to view scenes several hundred yards ahead of the tank and to direct fire against unsuspecting targets.[1]

Another application to which the Germans put infrared was for barrier equipment to protect harbor entries. A transmitter would be placed on one side of the entrance and the receiver on the other. Any interruption of the light indicated the presence of an object in the path of the barrier equipment.[2]

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In 1942 when operations of Russian tanks were becoming more effective on the eastern front, the procurement program was accelerated. By 1944 the Germans had put their devices to test in combat. An unconfirmed report stated that two German units using infrared equipment knocked out 67 Soviet tanks in one night. However, the report adds that the German units were captured by the advancing Red Army on the following day.

The German equipment was not used against American and British troops because the use of "artificial moonlight" made it unnecessary. The Germans knew of similar devices which could be used to counter their use of infrared equipment. There is reason to believe that the Russians, using German technicians and equipment are conducting intensive development in the field of infrared.[3]

Section II. INFRARED DRIVING EQUIPMENT

Early Development

Early in 1941, the Engineer Board, Fort Belvoir, Virginia investigated possible means of facilitating the movement of military traffic under blackout conditions. As a result of these investigations it was suggested that the use of infrared radiation could provide for safety and ease of movement at night with maximum freedom from enemy detection.

The first experimental viewer, designed for use in driving vehicles, was developed by the Radio Corporation of America Engineering Laboratory, Camden, New Jersey. This equipment was placed on a contract to RCA by the National Defense Research Committee hereinafter referred to as NDRC. This instrument, designated the NYCTOSCOPE "figure 1," was a special, large size telescope providing non-stereoscopic viewing. It employed an objective lens to pick up the reflected infrared rays and to focus them onto a photo-sensitive element of an electronic image tube. The Nyctoscope could be mounted on a vehicle in such a manner that the driver could place his eye to the eyepiece but it could be turned only through a small angle.[4]

This equipment was first tested by representatives of the Engineer Board, in conjunction with the Infantry Board, at Fort Benning, Georgia in August of 1941. The viewer was found to be unsatisfactory, in many respects, in these tests and the NDRC was asked to make further improvements and to return it to the Engineer Board for further testing.

The improved viewer was returned to the Engineer Board in December of 1941 and more detailed tests were conducted over various

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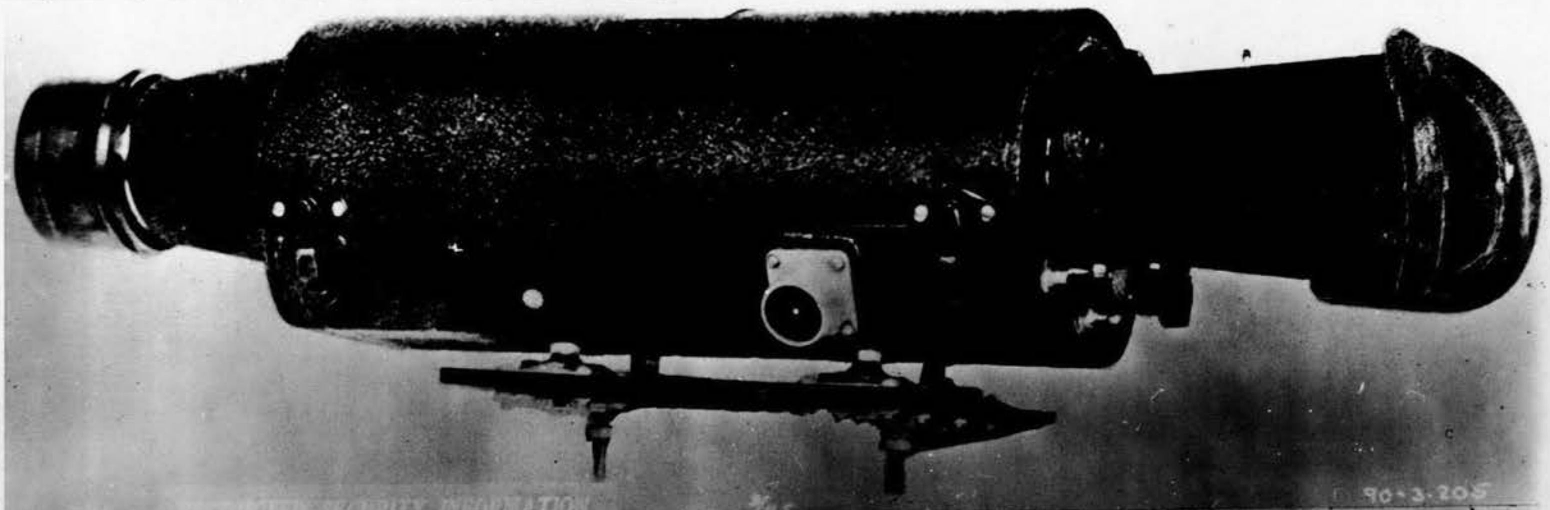

Figure 1

NYCTOSCOPE

The first experimental infrared viewer for vehicle driving.

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types of roads and terrain. The Board has this to say about the equipment:

> The principal functional limitations of the infrared driving equipment tested were inability to negotiate sharp curves, inacurracy of distance estimation and inaccuracy of lateral placement indication; that infrared driving equipment was not effective in fog or rain; that the improvised source of infrared light was too bulky and consumed far too much power to have much practical utility in the field; but that in spite of all its limitations infrared driving equipment did perform a unique function--that is, it permitted driving at relatively high rates of speed without being visible to observers at a distance of 200 feet, even when they looked directly at the light source.[5]

The Engineer Board recommended that six to twelve infrared telescopes with latest optical improvements be manufactured and that an equal number of infrared headlights with power supply be engineered to meet the peculiar requirements of this application. It was further recommended that the resulting apparatus be tested by a tactical engineer unit during maneuvers.

The Chief of Engineers in 1942 concluded that infrared driving equipment was inherently unsatisfactory for facilitating blackout driving. It was recommended that its development, so far as it pertained to the Corps of Engineers, be closed. However, in submitting this recommendation, due consideration was given to the fact that the equipment tested was essentially a laboratory model which could be revised and improved in the future. It was further pointed out that the conclusions drawn by the Engineers should not be construed as indicating that the equipment did not have potential value for other military purposes.

The Ordnance Department was becoming interested in the possibility of utilizing the equipment with tanks. In March of 1942 closure of the development by the Corps of Engineers was approved and assigned to the Ordnance Department in August of the same year.

Development by Ordnance

By the fall of 1942, electronic image tubes--the essential element of all infrared viewers--had been improved to the point where it became practical to build small size binocular telescopes.

The first binocular of this type was a periscopic unit using two 6-inch image tubes "figure 2." The next step in the development

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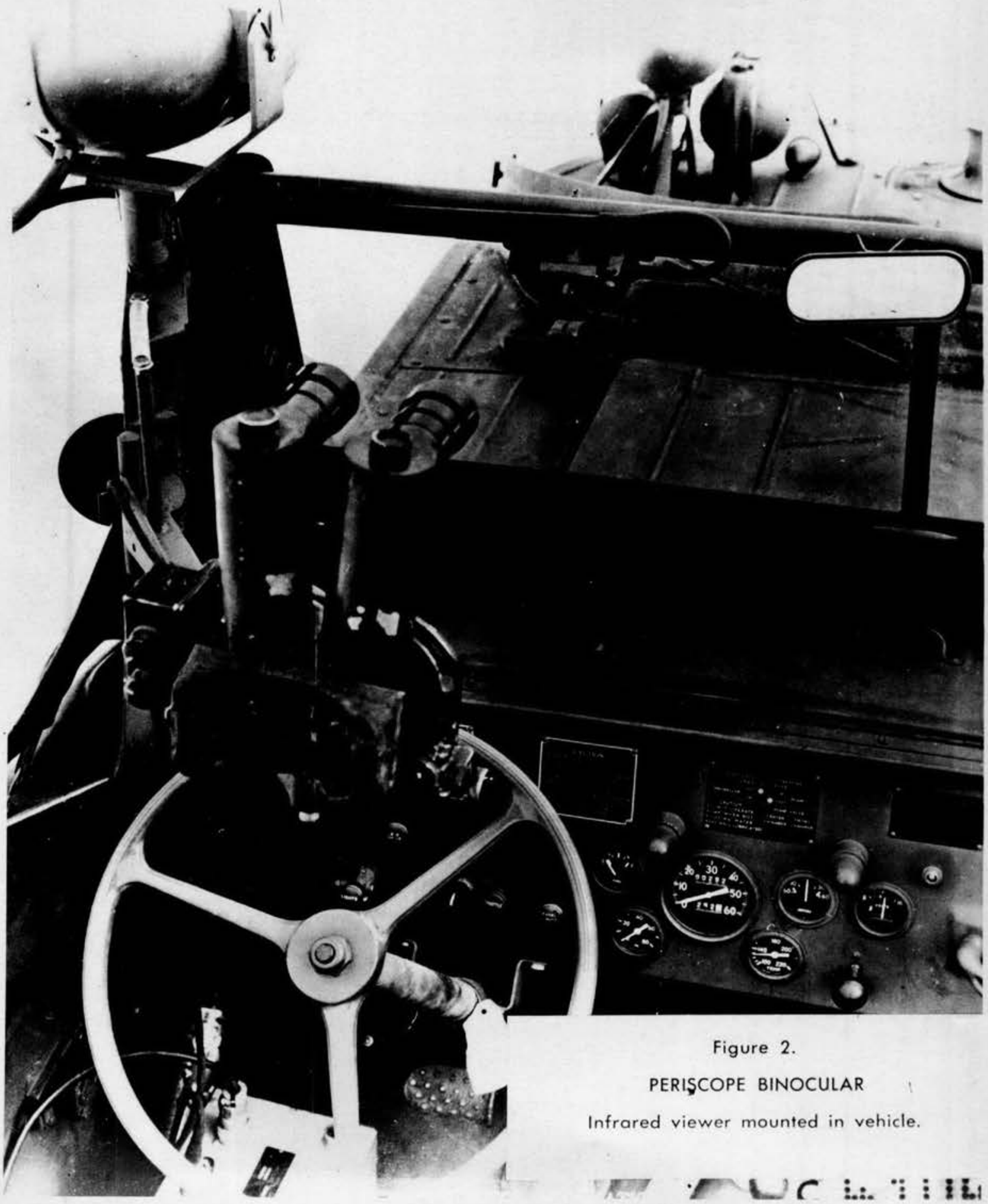

Figure 2.

PERISCOPE BINOCULAR

Infrared viewer mounted in vehicle.

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was the construction of an "inline binocular" "figure 3." This equipment was mounted on a medium tank which employed four filtered 450-watt headlamps as the infrared source. A searchlight was also mounted on the left side of the tank. Electrical power supply was provided by a 2-1/2 kw engine-generator set. Tests were conducted at Aberdeen Proving Grounds and later by the Armored Force Board at Fort Knox, Ky. The Armored Force Board conducted concurrent tests of this equipment on a Dukw (amphibious vehicle) and on a 1/2 ton truck.

Tests by Armored Force Board

The results of the Armored Force Board were set forth in Report on Project 288, Test of Medium Tank, M4AE2, dated 6 May 1943. This report stated that the useful illumination, with the infrared equipment, was 50 yards in front of the tank; 30 yards in front of the dukw and 25 yards in front of the 1/4 ton. However, different wattage sources were employed for the different type vehicle.

The Armored Force Board concluded that:

> ...the results obtainable with the infrared headlight driving equipment in its present state of development precludes its application in the Armored Force as an aid to night driving of combat vehicles[6]...

And recommended that the infrared driving equipment be considered unsuitable for use in the Armored Force.

The Chief of Ordnance referred the Armored Force Board report to a subcommittee for consideration. The subcommittee recommended in July of 1943 that the development of infrared driving equipment be continued towards improvement of equipment and that complete kits be furnished to the Armored Force Board for further testing. It was at this time that the Army Service Forces charged Corps of Engineers with the development, procurement, storage and issue of items of infrared equipment. This, the Chief of Ordnance suggested that the matter be referred to the Corps of Engineers Technical Committee for appropriate action.

Later Development by the Corps of Engineers

The Chief of Engineers, in October 1943, referred the entire file on infrared driving equipment to the President of the Engineer Board for remarks and recommendations. The Board stated in December of 1943 that no additional progress had been made since the tests

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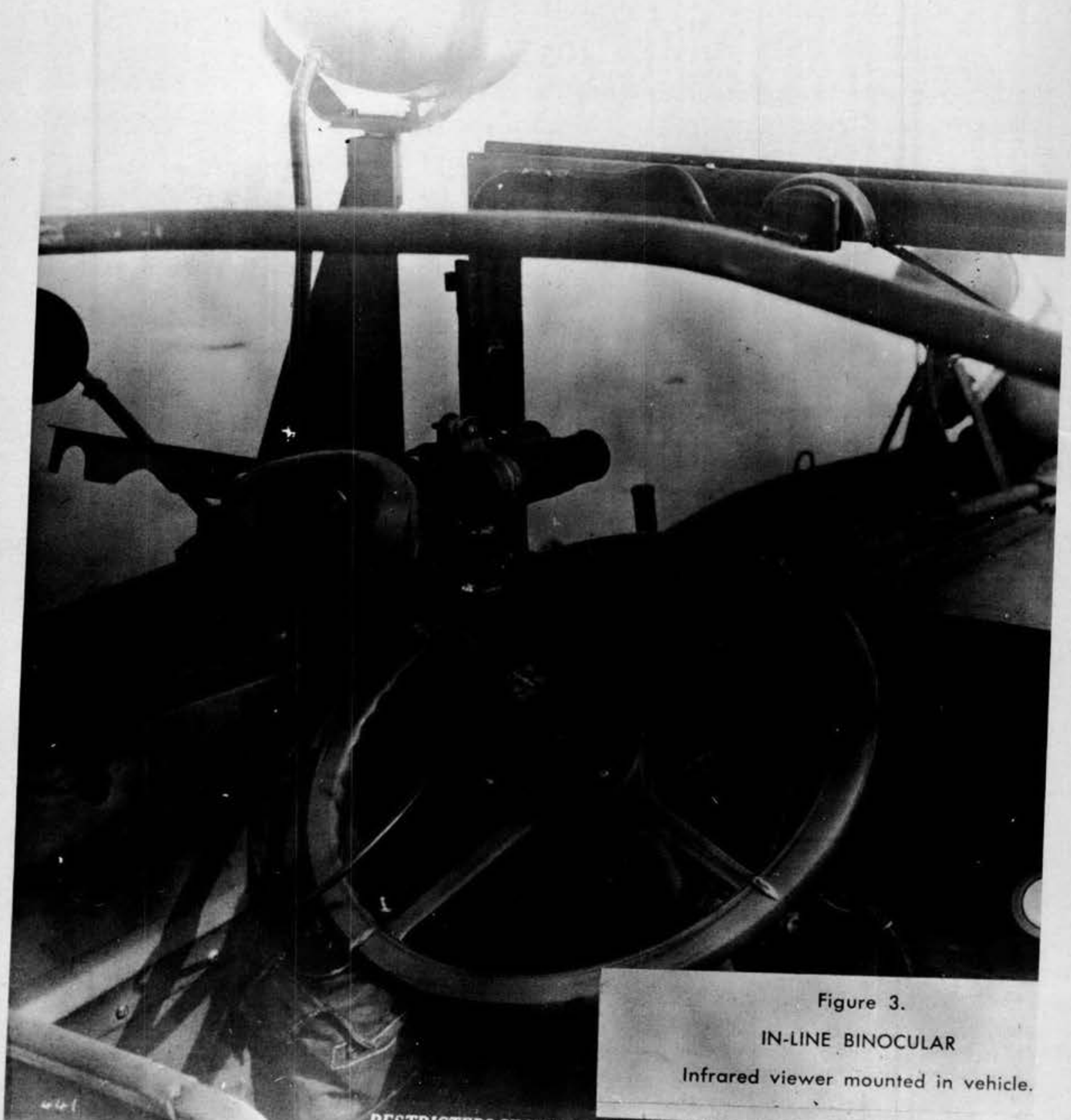

Figure 3.

IN-LINE BINOCULAR

Infrared viewer mounted in vehicle.

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conducted by the Armored Force Board. It was recommended that no further equipment be furnished for service tests until improvements assuring optimum performance and methods of facilitating actual employment could be obtained.

The Armored Force Board had pointed out that:

> ...on the basis of the driving tests, the ideal unit viewer for driving is considered to be one which would be sufficiently small and light in weight to permit wearing on the head in the manner of a pair of binoculars[7]...

Thus, when the development was again taken up by the Engineer Board, the NDRC was requested to direct attention to such an application. The problem was referred to the Johnson Research Foundation, University of Pennsylvania. To this institution belongs the credit for the solution to the problem.[8]

In the interest of reducing weight, attention was first directed towards a periscopic monocular unit designed for mounting on the head. The first trials, using this unit, were rather discouraging. It was clumsy, uncomfortable and it provided no depth perception or sense of natural vision. It was evident that a binocular unit would have to be tried.

The small "in-line" binocular unit was first mounted on a football helmet. This was adequate for preliminary tests, but was uncomfortable when worn for more than a few minutes because the center of gravity was in front of the head. The unit was then mounted on a standard steel combat helmet to which a chin-cup was added. A counter weight was employed, and so adjusted that the center of gravity was approximately at the center of the support "figure 4." This unit was tested in December 1943 and was found to be highly satisfactory. It also permitted the driver to look sharply to one side or the other. This had not been possible with the previous types of equipment as they were mounted on the vehicle in a fixed position.

The need for developing a more compact unit was evident as a result of the tests conducted by the Johnson Research Foundation. The minimum size to which the viewer could be reduced was dictated by the size and nature of the electronics image tube. The tube selected on the basis for this design was the 1P25 image tube. This tube was 4-1/2 inches in overall length and approximately 1-1/2 inches in diameter. It is evident that a reduction in the size of the tube would result in a similar reduction in the viewer and thus in weight.

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Figure 4.

HELMET MOUNTED BINOCULAR

Infrared viewer, first counterweighted model.

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The final design of the helmet mounted binocular was known as Type Z. This unit employed the IP25 image tube and each viewer was made in the form of a Z, thus its designation. The Z design permitted the binocular to fit as close as possible to the head and minimized the counterweight required. The development of a compact power supply by the Radio Corporation of America permitted its placement on the back of the helmet where it acted as a counter-weight for the unit "figure 5." The power supply used a 2-volt, rechargable flashlight cell with provisions for connection to a vehicle power supply for recharging.

The National Defense Research Committee equipped two 1/4-ton trucks with two 150-watt sealed beam auxiliary headlamps and two 80-watt spotlights each and supplied them to the Engineer Board for tests and demonstration. Two of the helmet mounted Type Z viewers were made available for use in these tests. The equipment was tested at Fort Belvoir at intervals between September and December 1944.

Tests were conducted over all types of roads and terrain to determine the capabilities of the new equipment. Report 915, The Engineer Board, 28 February 1945, had this to say:

> The new source of light provided for illumination, suitable for driving, for 200 feet in front of the vehicle. Vehicles could be driven over all roads and terrain that could normally be traversed under normal lighting conditions. Driving speeds were limited only by terrain features and were about equal to those obtainable with the low beam of ordinary headlights. Driving in rain, with the aid of the infrared radiation and viewers was practical. The equipment was not effective in fog since fog scatters near-infrared radiation in a manner similar to its affect on visible light. The drivers reported no fatigue or eyestrain after periods of use of as much as three continuous hours of operation.[9]

The Engineer Board conducted demonstrations for interested agencies and possible using services in December 1944 and in January of 1945. All who witnessed the demonstrations were impressed with the performance of the infrared driving equipment and expressed the opinion that driving by the aid of infrared was certainly feasible.

The Table below shows rather clearly a comparison of the initial infrared driving equipment and the equipment that had been developed by 1945.[10]

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Item	Equipment tested in 1941 at Fort Benning and the Engineer Board	Equipment tested in 1943 by Armored Force Board	Equipment tested early in 1945
Infrared Viewer	Minocular (Nyctoscope) which permitted use of eyes, mounted on the vehicle.	In line and periscope binoculars mounted to the vehicle.	Type Z binocular helmet-mounted.
Infrared Source	2 100-watt lamps and 1 500-watt lamp covered with Corning 2540 glass, 6-mm thick.	For M4 Tank: 4 450-watt lamps and one 600-watt lamp. For Dukw: 2 450-watt lamps and 1 600-watt lamp. For 1/4-ton truck: 3 450-watt lamps. All of the above lamps were covered with Corning 2540 glass, 6-mm thick.	2 150-watt auxiliary head lamps covered with 3 layers of Poloroid film XR7X25.
Range of Infrared Radiation Effective for Driving.	90 Ft	M4 Tank: 150 Ft Dukw: 90 Ft 1/4-Ton: 75 Ft	200 Ft
Visual range of infrared source	Over 600 Ft	Over 600 Ft	250 Ft
Power source for infrared lamp.	2-1/2 kw gasoline engine-generator set.	For M4 Tank: 2-1/2 gasoline engine-generator set. For Dukw and 1/4 ton truck: 1-1/2 kw gasoline engine generator set.	14-volt 55 amp, generator attached to vehicle drive shaft

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HELMET MOUNTED BINOCULAR "TYPE Z." Infrared viewer.

Figure 5

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An analysis of the above table indicates the following:

a. Reduction in the electrical power requirements and in size of necessary power plants.

b. An increase in effective range for driving from an initial distance of 90 ft up to 200 ft or over 100 percent increase.

c. A reduction in visual range of infrared source by individuals viewing the source. This was effected by the use of polaroid filters.

d. A decided improvement in the viewer from a fixed vehicle mounted unit to the helmet mounted viewers. This new type viewer permitted the user to look to one side or the other and was particularly helpful on curves and turns.

Thus by 1945 the United States had a practical infrared driving device that had been tested and proved to be satisfactory. It was determined to provide some equipment to the Service Test Boards for study of its applications and determinations of requirements. Subsequent developments will be discussed in the following chapters.

Section III. SNIPERSCOPE AND SNOOPERSCOPE

As a result of the research on the infrared driving viewers, the Technical Staff of the Engineer Board came up with the idea of developing a small, light weight, self-contained infrared illuminating and viewing device for the individual soldier. With this equipment the soldier would be able to "see" in the dark while he remained in darkness. The Engineer Board requested the Radio Corporation of America to build such a unit and the resulting apparatus was called the Snooperscope.[11]

Later it was decided to mount the components of the snooperscope on a carbine to facilitate the delivery of fire. This was done and this apparatus was designated the Sniperscope.

Experimental Models

The original sniperscope and snooperscope produced by RCA were laboratory models built to test the general principle of using radiation to detect enemy activity at night and to deliver effective fire while our troops remained in darkness. The experimental models weighed about 20 pounds each. Engineering tests revealed that the effective range for viewing and delivery of aimed fire was optimum up to 35 yards. However, objects could be seen less clearly at ranges up to 100 yards.[12]

A survey was conducted in the summer of 1943 in a response from the Pacific theatre. This survey was conducted by the Special Committee on Jungle Warfare to determine suitable items of equipment for use under jungle conditions. The snooperscope and sniperscope were suggested for use in moving through the jungle at night, in placing demolition charges under cover of darkness and in counteraction against enemy night infiltration. The experimental equipment was demonstrated to the committee in September of 1943. As a result of the demonstrations, the committee directed the procurement of both devices for delivery to the Pacific theater and for testing by the Army Ground Force agencies in the United States.

Development

The development of the snooperscope and the sniperscope, subsequent to the engineering tests, was directed towards overcoming the deficiencies that are inherent in all new models. Development was towards increasing the effective range by the use of improved sources and filters, waterproofing and tropicalizing and a general improvement in design.

Demonstration of the production model indicated that performance was satisfactory and that the deficiencies encountered with the experimental models were successfully overcome. Objects the size of a man could be seen at a distance up to 100 yards, but could not be readily identified at the extreme ranges because of non-stereoscopic vision. The effective range for viewing and delivery of aimed fire was not increased beyond the 35 yards obtained with the experimental models. However, the increase in infrared radiations, provided by the improved light source and infrared filter, made the performance more efficient at that range.[13]

The Infantry Board at Fort Benning conducted tests in February and March of 1944 and concluded that a military requirement did exist for devices that would enable troops to detect and observe objects and personnel without themselves being seen. The Board further indicated that of the two types of equipment, the sniperscope was of greater value and recommended that it be adopted as standard articles for issue to infantry troops on the basis of one for each rifle platoon. The Infantry Board also recommended that no further consideration be given to the snooperscope for infantry use.

Section IV. METASCOPE

The need for a small, self contained viewer had been expressed to the NDRC by the Army and the Navy. Basic research was centered at the Institute of Optics, University of Rochester. A device known as the Metascope was developed and demonstrated at the Engineer Board in March of 1943. This device was recognized as having properties desired for such Army use as detection of enemy use of infrared, signalling, and recognition.

Description

The metascope was an infrared viewing device which received infrared radiation and released visible light. The instrument made use of an optical system to focus the incoming radiation on a special infrared sensitive phosphor surface. This then gave off a visible green light which could be viewed through an eyepiece. The instrument was charged by short wave length radiation from a radium compound contained in the instrument. The metascope weighed 14 ounces and was approximately 3x3x3-1/2 inches in size.[14]

Capabilities

Tests conducted by the Infantry Board and the Engineer Board indicated that the effective range of the Metascope for detecting and locating sources of direct infrared radiation were:[15]

From Flashlight TL-122P	1.5 miles
From Signal Lamp SE-11	3 miles
From 30-watt Sniperscope Lamp	5 miles
From 450-watt lamp	5 miles
From Beacon, Airborne, M1	2 miles

Limitations

Unlike radio waves, infrared follows very closely the behavior of visible light. For example, it is effected by dust and fog as is visible light. Similarly, infrared is blocked from view by trees or jungle growth. In this manner the use of the metascope was limited by terrain and visibility.

Tactical Use by Airborne

In the development of tactical doctrine by the First Allied Airborne Army, in the European Theater of Operations, means were sought for rapid assembly of airborne troops on the ground. It was desired to do this without indicating the location of our forces to the enemy. It was suggested that employment of infrared viewing devices by friendly troops might be a solution to the problem. Based on this suggestion, Supreme Headquarters, Allied Expeditionary Forces, requested that suitable design of infrared equipment be undertaken.

As a result of this request, the New Developments Division WD Special Staff, early in August of 1944 established requirements for infrared beacons and viewers as aids in airborne operations. Metascopes were supplied by the Engineer Board and beacons were provided by the Office of Scientific Research and Development, to the European theater for testing.

Airborne Tests

In the tests conducted in Europe, each stick of men (one planeload, approximately 12 to 18) was equipped with a handy talkie radio and two flashlights equipped with infrared filters. Each man carried a Metascope, Type US/F. Assembly on the ground was first accomplished by sticks with the infrared flashlight indicating the assembly point. This point was located by each man by means of the metascope. Next, each stick located the battalion assembly point which was designated by a transmitter and an infrared coded beacon. Each stick, using the metascope and the infrared beacon as a visual guide, proceeded to the battalion assembly point. In this manner the two aids, radio and metascope supplemented each other.

The metascope proved satisfactory and a team was sent from SHAEF to the US in November of 1944. This team was to detail the theater requirements, guide design and to obtain immediate production of the equipment to the extent required for large scale field tests.

Personnel Protection

The problem of protecting personnel from radium eminations was considered by NDRC during the original design and development of the Metascope. Measurements of gamma ray intensity were made at the US Bureau of Standards and the results forwarded to the Surgeon General for comments and recommendations regarding safe use periods.

Based on findings by the Surgeon General, instructions were issued for protection of users. The instruments were to be issued just prior to an operation and turned in for storage as soon as the operation was completed. Personnel carrying the equipment were to be rotated on an equal basis and no one individual for a period greater than one week.

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Section V. SUMMARY

The infrared art expanded rapidly during World War II. At the onset of the war, research was being conducted but much of this work was done in the field of electronic optics without consideration of the possible military applications.

This early research provided a springboard for the development of infrared devices for use by the military. Initial consideration was toward the development of infrared for an aid in blackout driving of vehicles at night. As a result of the initial development and tests, attention was focused on the possibility of the use of infrared to aid in detecting an enemy, in signalling and in directing aimed fire on the enemy while the friendly troops remained in darkness. The most publicized infrared night viewing device was the sniperscope that was used with some success in the Pacific theater. Infrared had been considered and tested by the Armored Force and The Ordnance Department as an aid in driving tanks but was not deemed acceptable at the time. Infrared development had not yet been directed towards its application for tank gunnery.

By the end of World War II all nations had become cognizant of the potential usefulness of infrared for night combat. Research and development were at work to improve infrared techniques and to apply them to military weapons. Infrared was not considered a cure-all but only another aid to take its place with other methods to achieve success in combat.

NOTES FOR CHAPTER 2

[1]An Introduction to Military Infrared Techniques, prepared by the Panel on Infrared, Committee on Electronics (Washington: Dept of Defense, 1 March 1952), p 44.

[2]Ibid, p 55.

[3]Test of Near Infrared Gunnery Equipment, Final Report of Project 1534 (Fort Knox: AFF Board No. 2, 15 Feb 1952), p 3.

[4]Infrared Vehicle Driving Equipment, Report on Project 915 (Fort Belvoir: The Engineer Board, 28 February 1945) p 2.

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[5] _Ibid_, p 5.

[6] _Ibid_, p 6.

[7] _Ibid_, p 11.

[8] _Ibid_, p 11.

[9] _Ibid_, p 25.

[10] _Ibid_, p 29, 30.

[11] _Snooperscope and Sniperscope_, Report on Project 908 (Fort Belvoir: The Engineer Board, 30 January 1945), p 3.

[12] _Ibid_, p 13.

[13] _Ibid_, p 28.

[14] _Metascope, Type US/F_, Report on Project 923 (Fort Belvoir: The Engineer Board, 13 April 1945) p 7.

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CHAPTER 3

POSTWAR DEVELOPMENT

SECTION I

INTRODUCTION

At the end of the war infrared development continued, but at a reduced pace. The advantages of devices which would facilitate night operations were too obvious to be completely disregarded, and as infrared seemed to offer great possibilities in that direction it naturally came in for its share of attention and appropriations. After Soviet Russia began to show signs of belligerency, the technical knowledge and infrared equipment which it inherited from her occupation of Eastern Europe became of paramount importance to us in determining Russian military capabilities. This resulted in acceleration of the entire infrared program.

The purpose of this chapter is to familiarize the reader with the general trend in infrared developments for armor during the post-war period. It will describe in some detail the development and tests leading to the adoption of infrared driving equipment. Infrared fire control and tank commander's equipment will be traced from their inception to the tests conducted by Army Field Forces. The conduct of these tests will be discussed in the next chapter.

Insofar as armor is concerned, practically all postwar development was toward adequate driving and gunnery aids. There were, however, several developments and trends which may bear upon the future of infrared in armor and these will be discussed toward the end of the chapter.

Section II. DRIVING EQUIPMENT

During World War II most of the infrared effort was directed toward perfecting infrared engineering techniques and basic research studies. Several items of equipment were developed, notably the sniperscope and night driving binoculars. The latter, however, were considered to be unsatisfactory in performance, weight, and physical dimension.

Between 1941 and 1943 severals tests of infrared viewers for night driving were tested. The first of these was a large vehicular mounted telescope. Joint tests by the Engineer and Infantry Boards found this instrument to be unsatisfactory.[1] By the fall of 1942 knowledge of image tube construction had advanced to the stage wherein small sized binoculars could be produced.[2] Tests of this equipment by the Armored Force Board resulted in the recommendation that binoculars be sufficiently small and light to enable the operator to wear them on his head somewhat like a pair of goggles.[3] In compliance with this recommendation, the Type "Z" Helmet Mounted Binocular was developed.

In April 1945 two tests of the Type "Z" Binocular were conducted. The first at Fort Riley,[4] Kansas, and the other at Camp Hood,[5] Texas. The Armored Board had representatives at both of these trials and they decided that the results warranted further tests. On the basis of this decision, the Armored Board recommended to Army Ground Forces that tests be undertaken by the Armored Medical Research Laboratory to determine the psychological aspects of infrared night driving equipment upon the operators. This was thought advisable in view of the finding at Camp Hood test that drivers developed headaches after using the devices about 30 minutes.[6]

Investigation of the same equipment was carried out by the Cavalry, Tank Destroyer and Infantry Boards, and although they suggested certain modifications, all boards recommended that development be continued.[7] Shortly after these reports were submitted the service boards were reorganized and the forerunner of the present Army Field Forces Board No. 2 has directed to conduct further tests of the early Type "Z" Binocular and the accessory equipment. The purpose was to determine suitability of the devices as then available and a recommended basis of issue.[8]

Project 1105

In compliance with the above mentioned directive, Project 1105 was begun in the summer of 1945 at Ft. Knox, Kentucky, by Army Ground Forces Board No. 2. The equipment used in this test consisted of Type "Z" Helmet Mounted Binocular with component parts, filters with headlight adapters and a vehicle battery adapter to reduce the battery voltage to 2 volts. There was also a battery charger used to charge the 2 volt wet cell battery in the helmet mounted power supply unit.[9]

The Type "Z" Binocular is mounted directly on a standard US Army MIC Helmet modified by cutting down the front projection to allow the eyepieces of the binoculars to fit more closely to the eyes. The power supply unit was mounted on the back of the helmet to provide a counter balance. It consisted of a 2 volt storage cell and vibrator that converts the 2 volts DC to 4250 volts AC. The binoculars consist of 3 main parts: an objective lens, an electronic image tube which acts to convert infrared light into visible light, and an ocular lens.

The total weight, including the cables, was 8 pounds 7 ounces "figures 6 and 7."

The filters were mounted directly to the vehicle headlights by means of adapters "figures 8 and 9." These filters absorb practically all of the visible light, while permitting the infrared light to pass through.

The tests were of three general types: mechanical tests to determine ease of adjustment and installation; observation tests to determine width of vision, range, depth perception characteristics and the security of each type of filter; and lastly, driving tests to determine the capabilities of the infrared equipment over standard blackout driving equipment, psychological effects on the driver and extent of interference with normal duties imposed by the devices.[10]

The results of the tests are as follows:

1. Mechanical tests:

   a. Installation and adjustment proved to be satisfactory. For example, complete installation of the equipment on a truck, 2-1/2 ton, 6x6, took an average of 28.5 minutes, and required 15 minutes to be removed. Installation time on a Medium Tank M-26 was 19.5 minutes.[11] Adjustment of the same equipment required an average of 4.5 minutes.[12]

   b. The equipment was not readily adaptable to standard vehicles.[13] This could be corrected by certain modifications and posed no serious limitation.

   c. Stowage was a major problem and another study would benecessary before it could be satisfactorily solved[14] "figures 10 and 11."

2. ...rving tests:

   a. The seeing range was found to be satisfactory.[15] Objects were sighted at an average distance of 195 feet and identified at 157 feet. Width of vision which averaged about 55 feet at 100 feet distance was also considered satisfactory.[16]

   b. Depth perception characteristics were determined to be insufficient. The tests were conducted under ideal conditions and with the operator in a stationary position, but the estimations were at great variance with actual distances.[17]

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ARMY GROUND FORCES BOARD No. 2 18067	P#1105	FORT KNOX, KENTUCKY
Truck, 1/4-Ton, 4x4, equipped with Infra-Red Vehicle Driving Equipment. Driver is wearing the Helmet-Mounted, Type "Z", Viewing Device.		

Figure 6.

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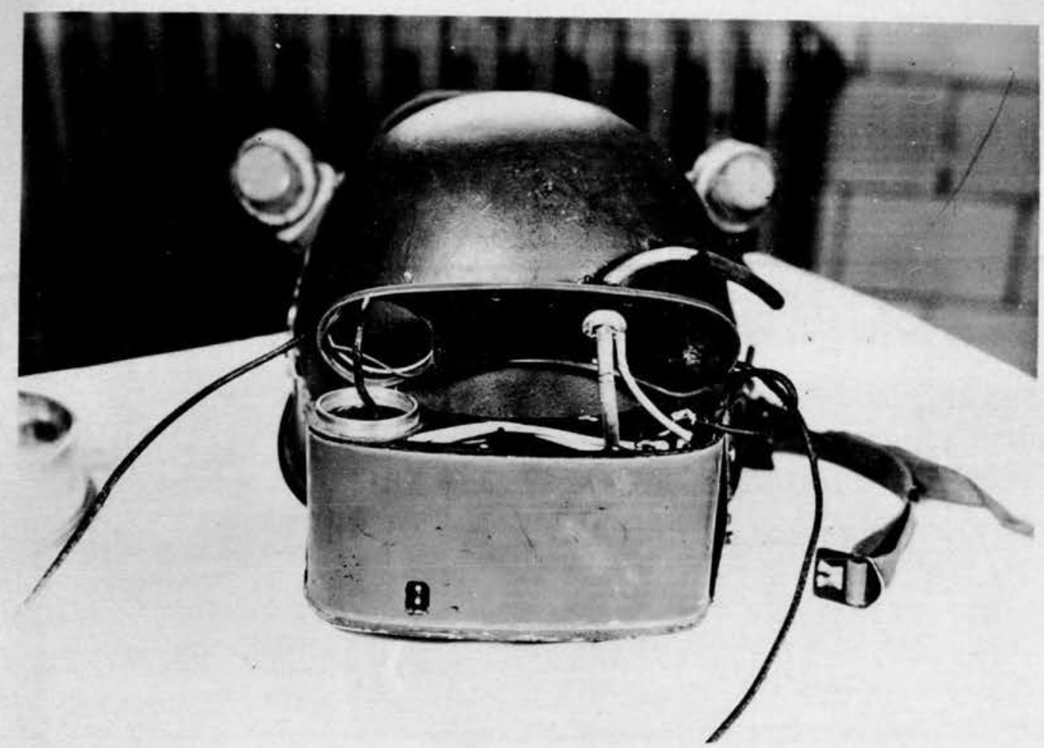

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ARMY GROUND FORCES BOARD No. 2 17879	7#1105	FORT KNOX, KENTUCKY
Power supply unit wired to bypass battery adapter and 2-volt battery. Note cracked insulation.		

Figure 7.

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ARMY GROUND FORCES BOARD No. 2 17375 P#1105 FORT KNOX, KENTUCKY

Filter mounted on tank headlight, and filter equipment required for installation. Note improvised rubber gasket at right.

Figure 8.

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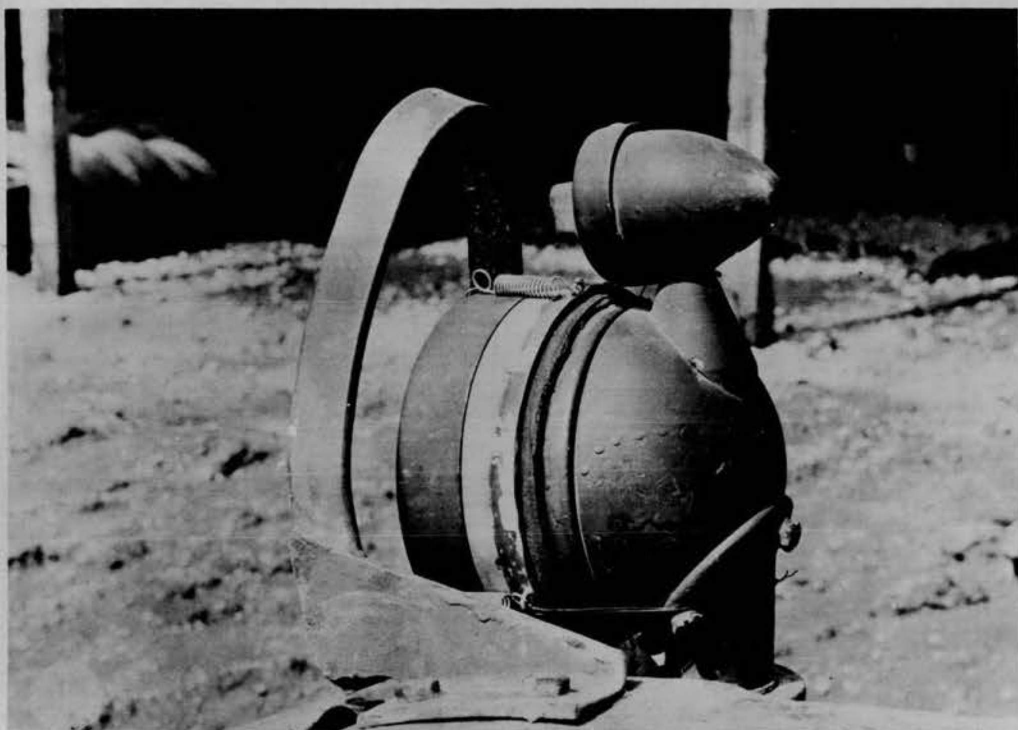

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ARMY GROUND FORCES BOARD No. 2 17376	P#1105	FORT KNOX, KENTUCKY
Filter equipment mounted on standard tank headlight. Note wire around blackout light and headlight bracket.		

Figure 9.

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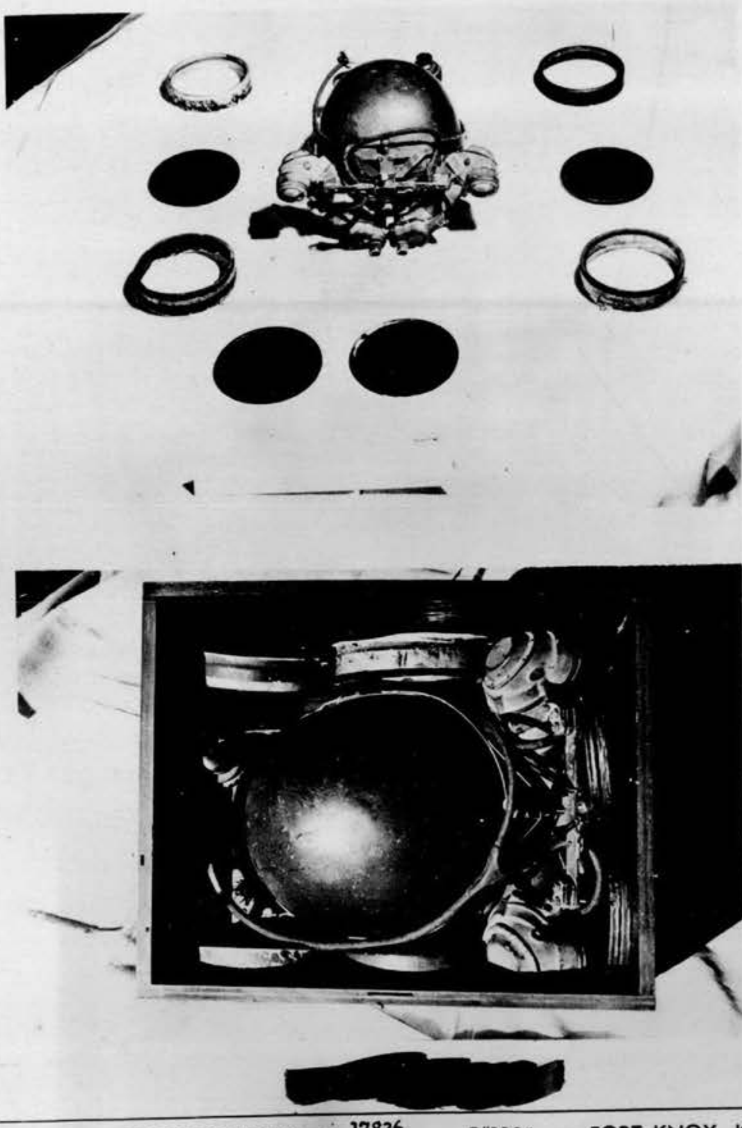

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ARMY GROUND FORCES BOARD No. 2 17836 17834 P#1105 FORT KNOX, KENTUCKY

Upper: Helmet mounted binocular, 2 filter adapters, 4 filters.
Lower: Box for stowage of equipment shown in upper photo.

Figure 10.

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ARMY GROUND FORCES BOARD No. 2 17833	P#1105	FORT KNOX, KENTUCKY
Possible stowage space for equipment in Truck, 6-Ton, 6x6.		

Figure 11.

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c. The headlamps proved to be secure from dark adapted observers using only their naked eyes. The average distance at which an observer walking away from the vehicle could no longer see the light was 28.4 feet.[18] The overall security characteristics were considered unsatisfactory because the greenish glow of the filtered headlamps was immediately discernible to observers equipped with viewers at a range of 4250 yards.[19]

3. Driving tests.

a. The weight of the complete unit (8 pounds, 7 ounces) was excessive. It not only caused fatigue, but the operators frequently suffered headaches.[20]

b. The size of the helmet mounted binoculars presented a very definite problem in that its use in certain vehicles was greatly restricted.[21]

c. The following analysis concerning the advantages of infrared devices over standard blackout equipment is quoted directly from the project report.

> ...Driving at night with infrared equipment showed no great advantage over driving with standard blackout equipment. After sufficient driving practice, drivers using the infrared equipment were able to make slightly better time over a course than those operators using the standard blackout equipment...[22]

Based upon these findings Army Ground Forces Board No. 2 concluding that infrared night driving equipment was unsuitable in the form tested. They recommended that development be continued to improve security and weight characteristics and to increase vision.[23]

Although the test just described took place in the summer and autumn of 1946, it must be remembered that this equipment was practically the same as that tested by the various service boards in 1945. With that in mind, it is not surprising that the conclusions reached and recommendations made as a result of this test do not vary considerably from those made by the service boards in 1945. However, responsibility for field testing and determination of requirements had been centralized and affixed. This gave the program a definite meaning and direction which culminated in the adoption of the equipment five years later.

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Progress from 1946 to 1950

In June 1946 the Engineer Research and Development Laboratory (ERDL) had been requested to develop tank driving and fire control equipment. The scope of the tank driving project was to provide devices that would enable "the driver and assistant driver to see the terrain in their immediate front with sufficient definition to enable them to pick routes, avoid obstacles and judge short distances." Among the military characteristics ERDL established a minimum acceptable range for the driver and assistant driver's image tube of 50 yards with no magnification.[24]

As of January 1947 the Type "Z" Binocular was still being improved. This work was concerned primarily with the development of a more efficient power supply with reduced weight and better magnifiers to increase the field of view. Laboratory tests indicated that the 57.7 degree angle forming the "Z" of the binoculars would have to be increased to 73 degrees to achieve an increase in brightness. In addition, it needed a more adequate internocular adjustment. The target date for completion of the program for the new binocular incorporating these features was 30 June 1949.[25]

By the summer of 1947 a contract had been negotiated with the University of Rochester for the manufacture of fifty units of a new design. In this new model the power pack was carried off the head and it had a shutter for focusing at short distances. The most important feature, however, was the incorporation of the new RCA image tube Type C-7128 operating at 20,000 volts. This new tube was ten to twenty-five times brighter than the tube in the original Type "Z" Binocular.[26] This project had to be terminated when the manufacturer was unable to produce binoculars of a design light enough to permit mounting on the head.[27]

In December 1949 the latest infrared driving and fire control devices were demonstrated. An "in-line" binocular and tank driver's periscope were shown to the group. The in-line binocular incorporated a new type (unipotential) image tube called the IC-6 which had been designed and constructed at ERDL. The power pack was not mounted on the headgear. The total weight of headgear and binoculars was only two pounds. These in-line binoculars used in conjunction with two 150 watt filtered headlamps proved to be a considerable improvement over the Type "Z". The headgear was uncomfortable and at the conference held subsequent to the demonstrations an improved headgear was suggested.[28]

The tank driver's periscope seemed quite promising. The conference suggested certain modifications to increase the field of view and to aid the driver in steadying his head against the viewer.[29] The

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members of the conference recommended that five sets of tank driving periscopes and headlamps be sent to Army Field Forces for testing. Also, that several sets of infrared binoculars should be provided for testing as soon as they became available.[30]

However the contract to produce an improved version of the in-line binocular was not initiated until May 1950. The first engineering models were received in March 1941 for engineering tests and evaluation but were found to be unsatisfactory. A model produced by another firm was also rejected. Following this, a contract was made with the American Optical Company to conduct further binocular design studies. This company determined that a binocular weighing about 1 pound and possessing a greatly increased field of view in addition to simplified maintenance could be produced. They agree to manufacture 125 pairsof this new design.[31]

Project 1490

On 26 January 1950, just a little more than a month after the above mentioned conference, Office, Chief of Army Field Forces directed that a service test of infrared tank driving equipment be conducted"... to determine the suitability and adequacy of Near Infrared Driving equipment for tanks for issue to Army Field Forces Units," and to recommend a basis for issue if the equipment proved to be satisfactory for tank operation.[32]

The various boards concerned realized that the tank driving equipment was not completely perfected, but felt that development had reached a stage sufficient for the determination of the capabilities of such blackout driving aids. No gunnary or tank commanders equipment was available for field test as yet.

The following description of materiel lists the components making up "one unit of driving equipment," which constituted the night driving equipment required for one tank "figures 12 to 14."

a. Two tank driver's periscopes (viewers). The maximum dimensions of each viewer are 14-1/2 x 7-1/2 x 7 inches, and the weight is 13 pounds 7 ounces. Each viewer utilizes two image tubes, type IP25Gl, which operate at approximately 16,000 volts. The unit is a binocular periscope with 16° field of view and unity magnification.

b. One high voltage power supply. This unit supplies 16,000 volts to the image tubes of both driving viewers. The maximum dimensions are 12-1/2 x 5-1/2 x 4 inches and the weight is approximately 13-1/2 pounds.

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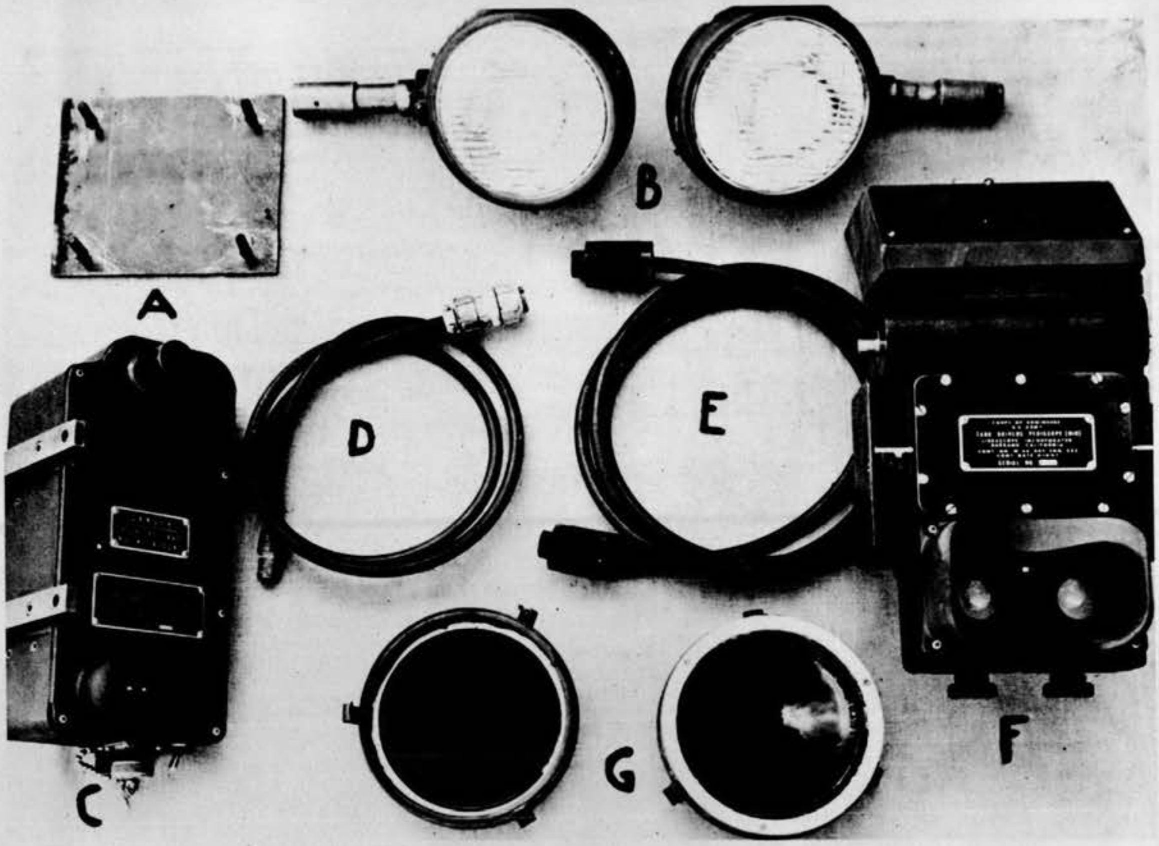

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ARMY FIELD FORCES BOARD No. 2 P-1490 #50-1753 FORT KNOX, KENTUCKY

One unit of IR driving equipment consists of the following:

A. Expedient mounting plate for power pack.
B. Accessory 150-watt head lamps.
C. High voltage power pack.
D. Low voltage (24-volt) cable.
E. High voltage (16,000-volt) cable.
F. IR driver's periscope.
G. Corning glass filters for head lamps.

Figure 12.

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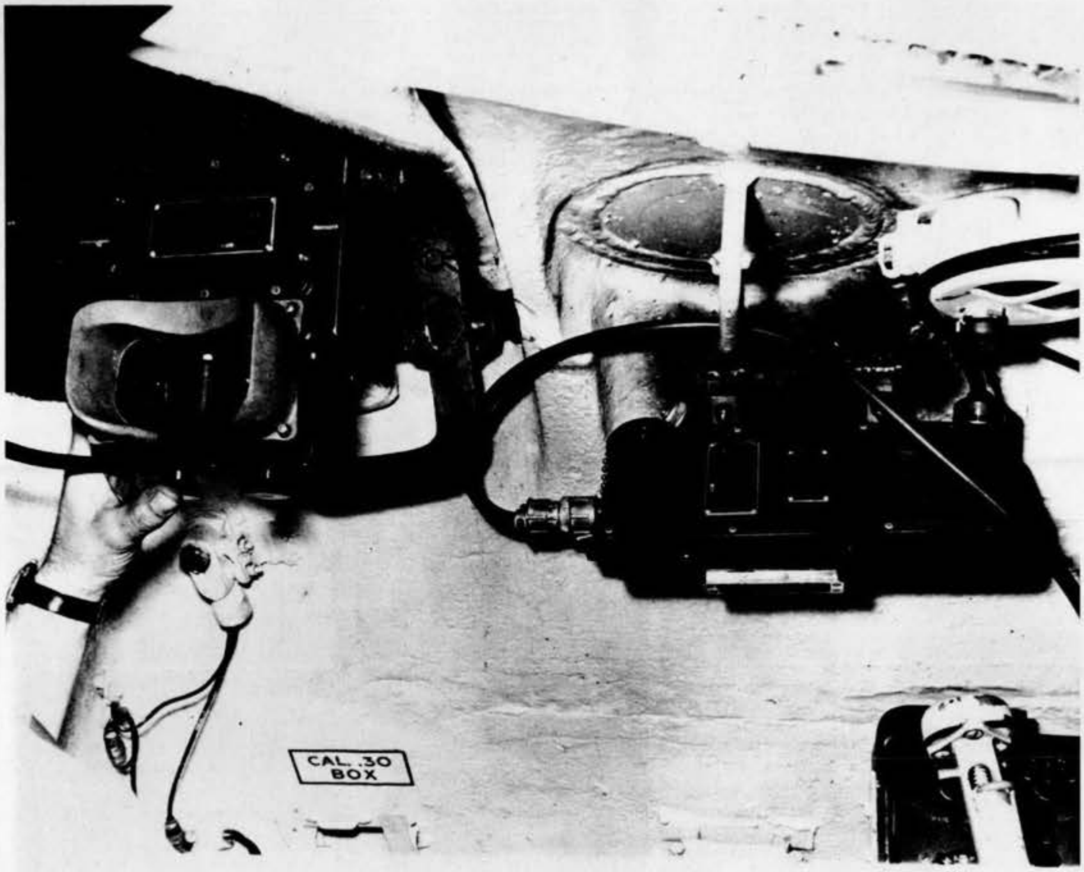

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ARMY FIELD FORCES BOARD No. 2 P-1490 #50-1748 FORT KNOX, KENTUCKY

IR driver's periscope and power pack mounted, equipment ready for use.

Figure 13.

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ARMY FIELD FORCES BOARD No. 2	P - 1490	# 50-1749	FORT KNOX, KENTUCKY
M6 scope has been removed. Near infrared scope being inserted.			

Figure 14.

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c. Two infrared projectors. Each projector consists of one 150-watt, PAR 46 sealed-beam lamp and one Corning glass 2563 infrared filter mounted in a housing designed to fit into receptacles provided for the standard headlights.

d. Three interconnecting cables. One high-voltage cable is provided to connect each viewer to the power supply, and one low-voltage cable is provided to connect the high-voltage power supply unit to the low-voltage power system of the tank.[33]

The test was designated Project 1490 and given an "A" priority. Limited field testing was begun at Fort Knox in the summer of 1950.[34] Limitations in the availability of personnel and equipment limited the scope of this preliminary test. However, the Board thought they had been able "...to obtain an excellent overall indication of the value of this equipment by conducting such portions of the test as time, personnel, and vehicles permitted." The trial was not considered complete, and a more comprehensive test was planned for a later date.[35]

The Board concluding, on the basis of the preliminary test, that "the use of IR (sic) driving devices on tanks increases mobility to a degree comparable to that obtained with full standard headlights," and recommended that the development of infrared equipment for the tank gunner and tank commander be accelerated so that a battalion sized test might be conducted as soon as possible.[36]

On 30 March 1950 in a letter to the Assistant Chief of Staff, G-4, Logistics, Office, Chief of Army Field Forces, requested that studies be initiated to determine the requirements and methods of installing infrared equipment on the new family of tanks. OCAFF also recommended that a program be established to provide close co-ordination between the various technical services involved to facilitate modification of either the tanks or the equipment as found necessary.[37]

In the late summer of 1950 the second part of Project 1490, "Test of Infrared Tank Driving Equipment" was begun under the same directive dated 26 January 1950. There was no change in equipment. The second series of tests were also carried out at Fort Knox, Kentucky.

The specific factors to be determined included the training required for personnel to install and operate the equipment, mechanical and electrical reliability, and the security and mobility achieved through the use of this equipment.[38]

Surprisingly little training or experience is necessary to order to become proficient in the operation of the tank driving aids. The only item the driver is required to install is the periscope, and this operation differs very little from that of mounting the standard tank periscope. During the tests the longest time required for any driver to become proficient in the operation of the vehicle was 2 hours. Most drivers were proficient in less time than 2 hours.[39] members of this research committee drove an infrared equipped M-47 tank over exceedingly difficult terrain without prior practice, and experienced no difficulty. With the exception of restricted visibility to the sides, the degree of vision, and the picture seen, are about the same as that obtained with ordinary automobile headlights.

Selection of personnel will pose no problem, for no special mental or physical aptitude was found to be required of the driver other than that necessary to properly operate a tank under normal visual conditions. Drivers who wear glasses will not be subject to any greater difficulty than they encounter with other vision devices.[40]

The equipment tested was for the most part reliable. Most failures occured in the electrical system. These could usually be corrected by minor adjustments and the use of dielectric grease at points where arcing occurred. The Board recommended that certain items such as resistors be replaced by others designed to operate under greater voltage.

The driver's periscope proved to be very reliable, requiring only minor electrical adjustments. In this model of the periscope, the head was not removable which meant, of course, that damage to this part rendered the entire unit unserviceable. Also, the unit had to be disassembled in order to make an interocular adjustment. Because each driver will have to adjust the distance between the eyepieces to conform to his own eyes, it was felt the means of adjustment should be external for easy access. Both of these changes were included in the Board's recommendations.[41]

The enemy may detect infrared lamps or searchlights with either the unaided eye or by using infrared devices. Detection with the unaided eye is possible because as yet no filter has been produced which filters out all of the visual light. An observer standing directly in the beam and within a limited distance can, if he looks very carefully, see a dull reddish glow. He must, however, look directly at the headlight and even then he will only see a round, dull reddish spot. Under these conditions the greatest distance at which the lights were detected by a dark adapted observer was 50 yards.[42] These observers were completely familiar with the test and the equipment and knew exactly for what they were looking. Very seldom would battlefield conditions permit an observer these advantages.

The radiation from the headlamps can also be detected by infrared viewing devices such as the driver's periscope or the US/F metascope. When using these instruments the observer is not required to stand directly in the beam of the headlamps for the terrain illuminated by the headlamps becomes visible to the observer just as the area illuminated by visible light headlamps is apparent to a person looking in that direction. However, because of the limited field of view of infrared devices, an observer will have considerable difficulty initially locating the infrared light. During these tests the headlamps were observed at ranges up to 1500 yards with driver's viewers, the M2 sniperscope, and the US/F metascope. The results of this test indicate that the infrared equipped vehicle is more secure than one using standard headlights against an observer possessing infrared devices, primarily because he must be looking at exactly the right place at the right time in order to initially locate the illumination.[43] Against an observer so equipped, the standard blackout lights would be much more secure. But when the observer possesses no devices for near infrared detection, the infrared driving devices are more secure than the cats' eyes on vehicles. For example, the maximum range that infrared headlamps could be detected was, as stated above, 50 yards. But these same tests demonstrated that the cats' eyes could be seen at ranges of 300 to 400 yards.[44] In summary, an infrared equipped tank is not secure against observers with infrared viewing or detecting devices, but is secure against an observer not so equipped.

The mobility of tanks equipped with infrared devices was compared to that of standard visible light driving equipment. Two courses were chosen, both of which provided a variety of terrain conditions. These routes were traversed by drivers using standard headlights, infrared equipment, and no artificial illumination at all.[45] It was found that the visibility obtained with infrared equipment permitted the driver to operate a tank at night with about the same capabilities as with ordinary vesible headlamps. The range of vision was about 100 yards. The darker the night the more apparent are the advantages of infrared over standard blackout driving equipment.[46] Thorough brush or overgrown trails, infrared is definitely superior to standard blackout equipment and on a par with visible headlamps. The field of view of 32° was rather restrictive and an increase was recommended if this could be accomplished without a major modification of the equipment.

A total of 210 miles was driven in convoy to compare infrared driving aids to standard equipment. The route was approximately 10 miles in length and including stretches of various road classifications. Here again the results indicated that the infrared equipment provided a degree of mobility comparable to that of standard headlamps. The only serious limitation was that because dust particles in the air will reflect infrared radiation, "cloudiness" occurred under extremely dusty conditions.[47] However, this limitation also occurs with full standard headlights.

AFF Board No. 2 thought that these results warranted the standardization of the infrared tank driving equipment and recommended the basis of issue be one set per tank.[48] OCAFF increased this unit of issue by adding "one extra IR driver's periscope head per tank."[49]

This completed the field testing of infrared tank driving equipment. Continued improvement in equipment, especially the image tube, will increase the capabilities of the tank driving equipment. The tube IP25G used in Project 1490 was superceded by a new tube developed by the Capehart-Farnsworth Corporation designated the IC16. The latter image tube has less image brightness but higher magnification and central resolution than the earlier tube. The Ordnance Department has adopted this latter tube for the production models of tank driving equipment.[50]

Driving Binoculars for Leaflet II Test

The American Optical Company sent its first engineering model of the newly designed binoculars to ERDL for acceptance tests in September 1951. These binoculars were fabricated from magnesium, the lightest material available which would meet all requirements. The binoculars needed only a lens with f/1.5 power instead of f/3.5 to make them acceptable. The new design for the headgear which had the power pack mounted on the back of the helmet as did the original binocular designs, was approved with minor modifications. However, the power supply being developed by another company was unsatisfactory. ERDL planned at this time to have 88 pairs of these binoculars available for the Leaflet II test.[51]

The next part of this chapter will trace the development of infrared tank commander and gunnery equipment until 1950 when the major tests were begun.

Section III. FIRE CONTROL EQUIPMENT

The tactical advantage to an armored force capable of identifying and engaging enemy materiel and personnel has long been recognized. However, since Soviet Russia captured many items of enemy equipment and is reported to be producing certain devices for use on their tanks, the possession of comparable infrared devices on our part becomes mandatory. See Chapter 5. To counter this threat, Army Ground Forces requested that ERDL develop tank gunnery equipment.

This project was begun 15 July 1946 and was given the code name "Leaflet II." By January 1947 the work was estimated to be three percent completed. This included basic design studies of viewers and radiation sources.[52] The scope of the project was to enable the tank commander to recognize and direct the fire on targets and the gunner to lay his guns and adjust fire accurately.

Some of the military characteristics that had been established included:

1. Maximum interchangeability of the equipment in all present and future tanks.

2. The gunner's sight to be mounted coaxially with the main armament and capable of a 360° traverse.

3. "The tank commander's viewing device shall be operable by the tank commander and, independent of turret rotation, capable of 360° traverse and the maximum practicable verticle coverage."

4. It should possess the maximum range "...compatible with good resolution and magnification."

5. The minimum acceptable range for the tank commander and gunner's viewers to be 400 yards with magnification.[53]

With this as a basis for direction, development continued and contracts were let for seven sets of tank equipment. Each set included two driver's periscopes, a tank commander's periscope, and a gunner's telescope. The radiation sources were 150 watt driver's headlamps and 18 inch 100 watt searchlights for the gunner and tank commander.[54] In the latter part of 1949 the equipment was demonstrated at Fort Belvoir, Virginia, by ERDL. At the conclusion of the demonstration, a conference was held in which not only the demonstration but all aspects of Leaflet II was discussed. The conclusions concerning the tank commander's and gunner's equipment were that the view range and clarity of the image of the tank commander's viewer and infrared projector was not satisfactory. They said that the "... clarity of the image, even at a few hundred yards, was not sufficient to permit recognition of the target to a degree sufficient to select the proper type of ammunition to use in firing on the target."[55]

The location of the 18 inch searchlight on top of the tank commander's hatch was not considered entirely satisfactory because of difficulty experienced in raising the hatch while in certain positions. It also raised the silhouette. However, this position was believed to be preferable to mounting it in another position which would require remote control operation. If at all possible a lamp of increased candlepower should be provided to increase range and beam spread. They did believe, however, that this equipment was sufficiently developed for field testing.[56] It is not surprising that the tank commander had difficulty in raising the hatch with an 18 inch searchlight mounted on it. A 12-inch projector to replace the larger one was developed in time for the tests by Army Field Forces.

ERDL was informed that the new policy in tank design was to eliminate the gunner's telescope and it would be necessary, therefore, to modify the driver's periscope by inserting an inverted V reticle until a new gunner's viewer could be developed.[57]

The members agreed that five sets of tank commander's viewers with positioning grips and five 18 inch incandescent infrared projectors of the highest beam candlepower obtainable should be made available to the field within six months. The same number of modified driver's periscopes and 18 inch projectors were also to be sent to the field for gunner's tests.[58]

Early in August of 1950 Lt. Col. Hamberg of Army Field Board No. 2 announced at a conference with members of ERDl that Board No. 2 ". . . intended to recommend the immediate procurement of sufficient IR equipment to equip a tank battalion for a troop test. . ." of infrared gunnery devices.[59] Shortly after, the "First Partial Report of Project 1490" was sent to the Office, Chief of Army Field Forces recommending that development of infrared equipment for the tank gunner and tank commander be accelerated and that a test unit of tank battalion size be designated; a location for the tests were also requested.[60]

In September 1950 OCAFF, in a letter to AC of S, G4, requested that enough equipment for a battalion troop test be made available as soon as possible. The letter also requested 30 sets of in-line driving binoculars for the battalion's logistical support vehicles.[61]

Prior to the receipt of the large quantity of equipment required to perform the battalion tests, Army Field Forces Board No. 2 carried out several preliminary tests at Fort Knox with a limited number of items. The final tests were conducted at Camp Irwin, California. A complete analysis of these tests is to be found in the next chapter.

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Section IV. SUPPLEMENTARY INSTRUMENTS AND COUNTERMEASURES

Metascope

During the war a small hand held device for detecting the use of infrared equipment called the Metascope, Type US/F, was developed. The purpose of this device was for identification and signalling between friendly troops and by paratroops for assembly on an infrared beacon in the drop zone. This device was issued to troops and although it became a standard item of equipment, it has certain inherent undesirable military characteristics. The phosphor type metascope must be provided with a means of charging the phosphor and the US/F Metascope uses radioactive materials to do this. The charging also takes a certain amount of time. However, the most serious limitation is the poor sensitivity of such material which causes short range and poor resolution.[62]

When the small unipotential image tube was developed it seemed to offer the solution to a more satisfactory metascope. The project for an image metascope was opened by ERDL in November 1947, but progress has been extremely slow.[63] ERDL tested the image forming metascope (Model T-3) in conjunction with the troop test conducted at Camp Irwin, California. The results of these tests were not available for inclusion in this report.

Warning Alarms

The December 1949 conference recognized the need for warning devices for armored units, and development has been continuing on such items of equipment.[64] The Engineer Research and Development Laboratories tested some of the newer warning devices at Camp Irwin. In the opinion of several people who were instrumental in the conduct of the battalion troop test and had an opportunity to see the equipment in operation, it did not meet the requirements of the armored forces.

Infrared Searchlights

Development of large infrared searchlights was begun early in the postwar period primarily for use by antiaircraft units. The armored forces requested two lights be provided for service tests in conjunction with Leaflet II equipment.[65] Two 24-inch, beach-defense searchlights with an infrared filter were delivered to Army Field Forces Board No. 2 and used with favorable results as a supplement to the gunner and tank commander's projector during the tests conducted in 1951 (Project 1534).[66]

Countermeasures

Countermeasures against enemy use of infrared equipment had not been fully explored until Army Field Forces Board No. 2 Projects 1534 and 1627 were carried out. However, it is known that certain dyes and materials are highly absorbent of infrared, while others are quite reflective. If the enemy were to employ infrared equipment against us on a large scale, protective coating for personnel and equipment could be produced (See Chapter 5.) However, the measures a front line soldier will take to counter an enemy infrared threat would be about the same as he would take to prevent visible light observation by the enemy. A bush will conceal a soldier in daylight and it will do the same against infrared equipment.[67] Cover and concealment would be the guiding principles. The tests discussed in the next chapter will include the first close examination of countermeasures made by the armored forces.

Far-Infrared

Because near-infrared equipment seemed to offer more advantages than far-infrared in employment with armored units, less attention has been given to it than to the former. For this reason development has lagged in comparison with near-infrared devices.

The reader will recall from Chapter 1 that far-infrared is not dependent upon a projector, but receives and transforms heat (infrared) radiation into visible light. The thermal radiation may be given off by any object through metabolism, combustion, or friction. The size of far-infrared detectors can be considerably smaller than near-infrared in that it does not require its own source of radiation. As no beam emmission is necessary it is not capable of being detected, nor can it be jammed.[68]

One of the first far-infrared detectors was the PND-3. It was designed to detect personnel by the warmth they emit. This was a portable device mounted on a tripod. Radiation signals were received by the instrument and transformed into audio signals. By February 1945 preliminary tests of this device were completed and evaluated. It could detect a man at 300 to 500 yards, and a light tank in operation, or before cooling, at 700 to 1100 yards.[69]

While these results were encouraging they were somewhat overshadowed by the limitations of the equipment and the characteristics of far-infrared relative to field use. The device was bulky and fragile. It was easily damaged by minor shocks and vibrations which was, of course, a prohibitive feature if it was to be used on tanks. The far-infrared detector indicated thermal differentials only, consequently, the operator was provided no means of identifying the objects having the different intensities of heat radiations. Often the signal from a man and a tank would be the same if the tank were at a greater distance. Not only would the operator have an almost impossible task in identifying the possible target, but the lack of image prevented a determination of range.[70]

As Army Field Forces felt a requirement for this equipment still existed, a contract was let to Designers for Industry, Cleveland, Ohio, to modify it. However, this company did not have any new models ready for field testing by the end of 1951.[71]

Another far-infrared detecting device called Penrod was developed in 1945, and in tests conducted at the end of 1946 it was found to have about the same detection capabilities as the PND-3. Although Penrod was more rugged than the PND-3, ground radiation seriously limited the operator's ability to identify or track the target. ERDL believed these difficulties could easily be overcome and immediately began modification of the equipment,[72] "figures 15 and 16." At the same time they contracted to have a scanning and recording device developed for use with Penrod. The equipment with these improvements was to be known as Scanrod. The first models of the scanning and recording device were unsatisfactory and service testing was postponed until an improved scanning-recording device could be developed.[73]

In 1948 Army Field Forces Board No. 2 was directed to conduct service tests of Penrod and Scanrod. When the equipment was finally received by ERDL, it was subjected to acceptance tests, but by the time the modifications were completed, the balometers had deteriorated and had to be sent to the manufacturer for repair.[74] The repaired balometers were not received until 1952, and both ERDL and Army Field Forces Board No. 2 said it was not sufficiently developed as yet and proposed that it be redesigned before a test was made.[75]

Some idea of ERDL thinking regarding far-infrared devices may be understood from the following. In the latter part of 1949 ERDL, in order to take advantage of the best characteristics of near- and far-infrared, proposed that a combination instrument, a heat detector and near-infrared viewer, be developed. The advantage of this equipment is that it would enable the range factor to be determined with much less projected radiation. Army Field Forces Board No. 2 thought the primary use of this equipment would be in defensive situations. The Board could see no immediate need for this proposed detector in armored units because of the projects on near-infrared already under way.

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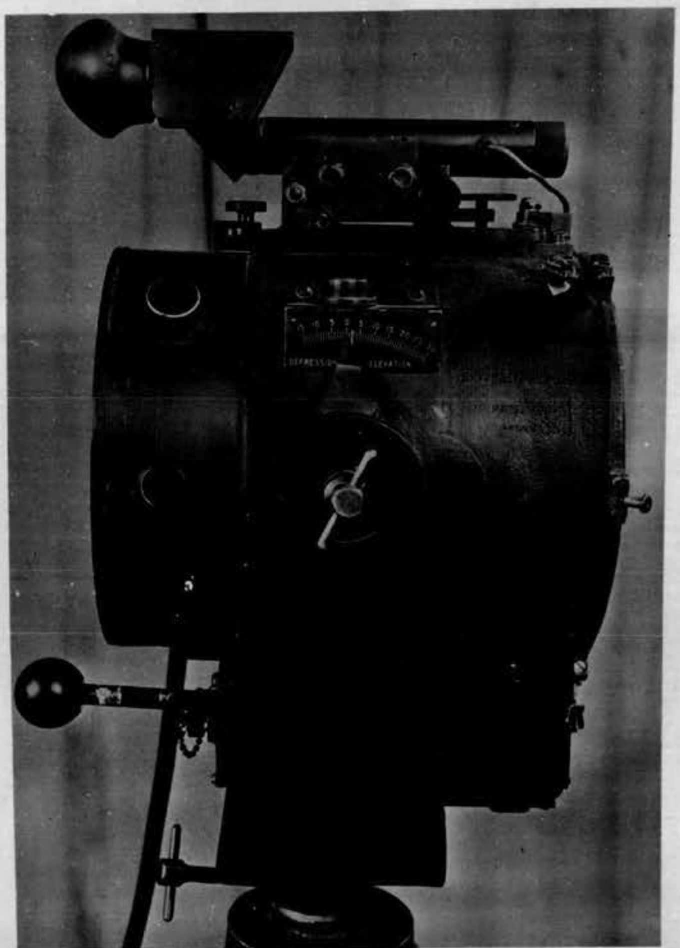

[redacted]

ARMY FIELD FORCES BOARD No. 2	P-1590	# 51-1628	FORT KNOX, KENTUCKY
Detector head used with both Penrod and Scanrod. Scanner-recorder is not shown.			

Figure 15

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ARMY FIELD FORCES BOARD No. 2	P-1590	# 51-1631	FORT KNOX, KENTUCKY
Complete Scanrod unit ready for operation.			

Figure 16.

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Another project which may have considerable influence on armor is the development of a seeking device for an anti-tank guided missile. Such a missile is being seriously investigated by Army Field Forces Board No. 4 and preliminary development and tests had been completed on a seeking device for such a missile by the end of 1950.[76]

The device is called the AN/DAN-3 (XN-1). The entire unit is in a cylindrical shell 5 inches in diameter and 15 inches long, and it weights less than 13 pounds. Laboratory tests of this unit included simulated stringent field testing during which vibration, acceleration, and captive flight tests were made. The device was considered ready for actual field tests upon the completion of these laboratory experiments.[77]

Infrared has certain advantages over most other seeking systems, such as radar, in that it is passive, it does not send a signal of its own. It gets its signal from the target radiating energy in the infrared spectrum. Some other advantages are that it is exceedingly difficult to jam and requires a very small amount of energy for operation. The future of infrared in such a role seems assured in view of the following analysis:

> In general, infrared radiation can be used very effectively where high accuracy and rapid response in detection and tracking are required but where the limitations of the detecting system size and weight prevent guidance application by radar means.[78]

Far infrared has many potential applications in armor which have not been explored as yet. It would appear certain that OCAFF will accelerate the investigation of radiation detecting devices when definite conclusions are reached as a result of Project 1627.

Section V. SUMMARY

This chapter has described the developments in infrared equipment as they pertain to Armor from 1945 until the two tests conducted by Army Field Forces Board No. 2 in 1952.

Tank driving devices were traced from their beginning in 1946 through the successful tests in 1950 which led to the subsequent adoption of this equipment.

Although wheeled vehicle driving devices were among the original items for which the army established a requirement, this chapter has shown that the problems of weight, dimension, and method of mounting the driver's binoculars had not been overcome by the end of 1951.

It may well be many years before satisfactory wheeled vehicle driving equipment is developed.

The project for tank fire control and tank commander's equipment was begun at the same time as that for the tank driving equipment. However, this was an entirely new field and the problem had to be started by determining the basic essentials involved; this required years of laboratory research. For this reason it was not until 1951 that development had reached a stage wherein infrared fire control equipment could be service tested. This chapter has outlined the scope of the project and the factors bearing on its development but has refrained from a detailed analysis of the actual developmental processes for these are highly technical and require far more than just a basic knowledge of the subject. The tests of the tank gunnery and tank commander's equipment were very lengthy and detailed. For this reason and because of their importance they are treated separately in the next chapter.

In a sense this chapter has brought the reader up to date regarding the development of infrared equipment for use by Armor and the next chapter concentrates all of this equipment in a battalion test and determines how infrared may effect the employment of an armored unit on the battlefield.

NOTES FOR CHAPTER 3

[1] Report of Test of Project No. 1105 - Infrared Vehicle Driving Equipment, (Fort Knox: Army Ground Forces Board No. 2, 8 Jan 1947).

[2] Ibid.

[3] Ibid, p 3.

[4] Report of Trip to Fort Riley, Kansas re: IR Night Driving Equipment, report of a demonstration attended by some members of The Armored Board (Fort Knox: The Armored Board, 18 April 1945).

[5] Trip Report to Camp Hood, Texas Re: IR Night Driving Equipment, report of a demonstration attended by some members of The Armored Board, (Fort Knox: The Armored Board, 23 April 1945).

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[6] Ibid.

[7] Op cit, Project No. 1105, p 3.

[8] Ibid, Appendix A, pp 5, 6.

[9] Ibid, Appendix A, p 2.

[10] Ibid, Appendix A, pp 3, 4.

[11] Ibid, Appendix C, p 2.

[12] Ibid, Appendix C, p 7.

[13] Ibid, Appendix C, pp 4, 5.

[14] Ibid, Appendix C, p 6.

[15] Ibid, Appendix D, p 2.

[16] Ibid, Appendix D.

[17] Ibid, Appendix D, p 3.

[18] Ibid, Appendix C, p 15.

[19] Ibid, Appendix C, p 16.

[20] Ibid, Appendix D, p 3.

[21] Ibid, Appendix D, p 4.

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[22] Ibid, Appendix D.

[23] Ibid, p 4.

[24] Quarterly Report on Research and Development and Services (Fort Belvoir: The Engineer Board, 1 Jan 1947), p 16.

[25] Ibid, p 88.

[26] Quarterly Progress Report, Research and Development, (Fort Belvoir: The Engineer Board, 1 April 1947), p 85.

[27] Corps of Engineers Annual Report, Research and Development, section: "Binocular, Infrared," by the Research and Development Laboratories (Fort Belvoir: Corps of Engineers, 31 December 1951), p 2.

[28] Ibid.

[29] Résumé of Conference, Infrared Driving and Fire Control Equipment for Tanks, report on a conference held regarding Project No. 8-23-10-003 by the Engineer Research and Development Laboratories (Fort Belvoir: Corps of Engineers, 12 Dec 1949), pp 4, 5.

[30] Ibid, p 7.

[31] Op cit, "Binocular, Infrared," pp 2, 3.

[32] Letter, OCAFF to AFF Board No. 2, file: ATDEV-5 400.112, subject: "Service Test of Near-Infrared Tank Driving Equipment," dated 26 Jan 1950.

[33] Test of Infrared Tank Driving Equipment, first partial report of Project No. 1490 (Fort Knox: AFF Board No. 2, 22 August 1950), p 1.

[34] Ibid, pp 2, 3.

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35Ibid.

36Ibid, p 3.

37Letter, OCAFF to AC of S, G-4, Logistics, file: ATDEV-5 451.6, subject: "Infrared Equipment for the New Family of Tanks," dated 30 March 1950.

38Test of Infrared Tank Driving Equipment, final report on Project No. 1490 (Fort Knox: AFF Board No. 2, 19 April 1951), p 4.

39Ibid, Appendix B, p 3.

40Ibid, Appendix B.

41Ibid; passim.

42Ibid, p 23.

43Ibid, p 24.

44Ibid, p 23.

45Ibid, Appendix B, p 4.

46Ibid, p 12.

47Ibid, Appendix B, p 21.

48Ibid, p 5.

49Letter, OCAFF to AC of S, G-4, Logistics, file: ATDEV-5 413.6/91, subject: "Test of Infra-red Tank Driving Equipment," dated 4 June 1951.

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[50]Op cit, Annual Report, section: "Photo Emissive Image Tubes," p 1.

[51]Ibid, "Binocular, infrared," pp 3, 4.

[52]Supplement to the Quarterly Report on Research and Development, (Fort Belvoir: The Engineer Board, 1 Jan 1947), p 25.

[53]Op cit, Quarterly Report, January 1947, p 16.

[54]Op cit, "Binocular, infrared," p 3.

[55]Op cit, Résumé of Conference, December 1949, p 4.

[56]Ibid, p 5.

[57]Ibid, p 3.

[58]Ibid, p 7.

[59]Report of Trip to Engineer Research an Development Laboratory (ERDL, Fort Belvoir, Virginia, 3-4 August 1950, report on a conference between members of The Armored School, Engineer Research and Development Laboratories and AFF Board No. 2 (Fort Knox, Automotive Test Section, AFF Board No. 2, 7 August 1950), p 1.

[60]Op cit, First Partial Report of Project No. 1490, p 4.

[61]Letter, OCAFF to AC of S, G-4, Logistics, file: ATDEV-5 413.7, subject: "Troop Test of Invisible Light Viewing Devices, Leaflet II (8-23-10-003)," dated 1 Sep 1950.

[62]Op cit, Annual Report, section: "Metascope, Image," p 1.

[63]Ibid, pp 1, 2.

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64 *Op cit*, Résumé of Conference, December 1949, p 7.

65 *Ibid*, p 7.

66 *Test of Near Infrared Gunnery Equipment (3-6-2-2)*, final report of Project No. 1534 (Fort Knox: AFF Board No. 2, 15 Feb 1952), p 3.

67 *Ibid*, p 7.

68 *First Interim Report PND-3 and Penrod*, report 913 by The Engineer Board (Fort Belvoir: 13 Feb 1945), p 17, 18.

69 *Ibid*, p 12.

70 *Ibid*, p 19.

71 *Op cit*, *Annual Report*, section: "Far Infrared Detecting Equipment," p 1.

72 *Op cit*, *Quarterly Report, January 1947*, p 43.

73 *Op cit*, "Far Infrared Detecting Equipment," pp 1, 2.

74 *Ibid*, p 2.

75 Letter, ERDL to C of E, file: TECRD MER 400.1, subject: "Proposed Redesign of Penrod," dated 16 May 1952.

76 *Military Characteristics for an Antitank Guided Missile*, report by AFF Board No. 4 (Fort Bliss: 20 Nov 1951), Annex E, p 2.

77 *Ibid*, p 2.

78 *Ibid*, p 3.

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CHAPTER 4

TESTS AND TEST RESULTS

SECTION I

INTRODUCTION

As it has been pointed out in the preceeding chapter, the development of infrared equipment has continued at an accelerated rate since the end of World War II. During this period many items of infrared equipment were designed and produced only to be found faulty while undergoing tests. This chapter is offered in the hope that the reader will have a better understanding of infrared and a greater appreciation of the numerous problems that are being encountered in the development of equipment which will permit the tank crew to see and fire at targets during the hours of darkness.

In presenting the details of some of the more important tests that have been conducted, attention is invited to the fact that the information contained herein is based on the findings of government agencies who have been charged with the testing of the equipment and therefore, does not represent the findings of this committee which actually did not participate in any of the tests. Every effort has been made to reduce the vast amount of test details to only those that are the most significant. For those who are interested in the technical aspects of the tests, it is recommended that they refer to the references which are listed at the end of this chapter.

Section II. ARMY FIELD FORCES BOARD NO. 2 PROJECT NO. 1534

On 7 October, 1950, Army Field Forces directed that Army Field Forces Board No. 2 conduct service tests of then current infrared driving and gunnery devices. These tests were to be conducted through facilities located at Fort Knox, Kentucky. The purpose of these tests was to supplement previous driving tests and to determine the suitability and adequacy of near infrared tank gunnery and tank commander's viewing devices.[1]

This undertaking was designated as Project 1534 which consisted of eight separate tests, each of which was designed to determine certain aspects of infrared application to Armor. These tests were planned efforts to determine the visual security accorded by the then available infrared illuminating devices and to determine the effectiveness of recently developed infrared filters. Tests were also conducted to establish the dependability and ease of maintenance of infrared apparatus and its components. During these tests, tactical applications of infrared were tested including aspects of cross-country operations, uses of infrared in the attack and in the defense. Considerations were given to counter-measures that might be effectively applied against an enemy equipped with infrared.[2]

An examination of these tests indicates a possible foundation for the contention that restrictions on equipment and personnel may have limited to some degree the completeness of this project. In spite of this apparent limitation, certain conclusions were reached which appeared to be well established by fact.

The equipment which was used in this test represented the latest achievements in the field of infrared development as pertained to Armor. Some of the major items that were made available for further testing were as follows:[3]

1. Two M46 tanks and two modified half-tracks on which near infrared driving and gunnery equipment had been mounted.

2. Each of the two tanks was equipped as follows:

a. Two binocular driver's periscopes, one for the driver and one for the assistant driver.

b. One binocular type gunner's periscope of near unity power with an inverted "V" reticle for aiming.

c. One 18-inch, 1,000 watt gunner's searchlight which was mounted on the gun shield coaxially with the gun.

d. One binocular periscope viewer for the tank commander.

e. One 12-inch, 450-watt tank commander's searchlight which was linked to the tank commander's viewer.

f. Three high voltage power supplies for the viewers.

g. One infrared warning alarm.

h. Two 150-watt headlights with filters.

i. One slip-ring assembly for transmitting power to the tank commander's searchlight and viewer to allow 360 degree traverse of the tank commander's equipment.

j. Spare parts, tools and connecting cables as were needed.

A 10 kw. electric generator and a 24-inch beach-defense searchlight was mounted on each of the half-tracks. Each light was equipped with an infrared viewer which incorporated an American image tube in a German case with German optics. "Figures 17 and 18" show the M46 tank and a half-track equipped with the above mentioned equipment.

Visual Security Tests

The first two of these tests were concerned with the visual security afforded by the 24-inch carbon-arc searchlights which were equipped with various types of newly developed filters. The results of these investigations revealed that infrared sources could be detected at ranges varying from 15 to 1550 yards depending upon the type of filter and the type of visual detector used.[4]

The effectiveness of the new filters was determined both in light of visual security and the degree to which target illumination was afforded at established ranges. In reality, few conclusions can be drawn with respect to benefits accrued by use of the new filters as opposed to those previously recognized.[5]

Dependability and Maintenance Tests

Tests to determine the dependability and ease of maintenance indicated that the current infrared viewers were reliable, but required modifications to simplify maintenance problems. The principle deficiency was noted when high voltage arching occurred within the infrared power units. The nature of repairs arising out of such deficiencies brought about the realization that the ordinary battalion maintenance facilities would have to be augumented if first and second echelon corrections are to be accomplished.[6]

Cross Country Test

The purpose of the cross-country test was to determine the ability of infrared equipped tanks to move across open country and to occupy an assembly area and then move to an attack position and thence cross a line of departure during the hours of darkness. While proving of great value as an aid in following a previously reconnoitered and marked trail, infrared was proved to be of no particular assistance in maintaining orientation. This deficiency arises out of the limited area of illumination provided by available infrared sources. During the conduct of a particular problem, an infrared equipped tank was able to maintain a specific course for approximately

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ARMY FIELD FORCES BOARD No. 2	P-1534	# 50-2552	FORT KNOX, KENTUCKY

Front view of an M46 tank fully equipped for infrared operation. This view shows the Corning glass filters applied to the headlights for driving. The driver's and assistant driver's IR viewers are installed. The 18-inch gunner's light is mounted on the gun shield. The 12-inch tank commander's light is mounted on the dome of the tank commanders hatch.

Figure 17.

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ARMY FIELD FORCES BOARD No. 2	P-1534	#50-2550	FORT KNOX, KENTUCKY
View of auxiliary infrared lighting vehicle. Searchlight in operating position.			

Figure 18.

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900 yards by following an infrared beam from a 24-inch searchlight.[7]

IR-Equipped Tanks in Defense of a Roadblock

In order to determine the advantages, if any, which accrue to tanks equipped with infrared, in an attack against an enemy not possessing similar equipment, two tanks with only standard equipment were placed in the defense of a roadblock and were subjected to an attack by two infrared-equipped tanks. In this instance, one defending tank was detected at a range of 150 yards while the presence of the other was established when the attacker came within 50 yards of the defense position. Conversely, the attackers were not seen until they had approached to within approximately 40 yards of the position. Detection at greater ranges was not possible because of leafless brush and trees which effectively obscured the location of the defending tanks. It is significant to note that observers who were located at the roadblock and who were equipped with the Sniperscope M2, easily located the infrared sources on the attacking tanks. These observations were made at a range of 500 yards. Judges of this problem considered that the infrared equipped tanks defeated the roadblock defense mainly because of their ability to lay the main armament of the tank through the use of the infrared viewers. As might be supposed, tanks equipped with standard equipment may have been able to fire at and destroy the attacker solely by virtue of firing at sounds entering the predesignated areas. Flares or illumination of any manner would have effectively aided in countering the attacker. The judges concluding that the requirement for the continuous operation of the auxiliary generators of the defensive tanks precluded early detection of the attacked by sound alone.[8]

IR-Equipped Tanks in Defense of a Road Junction

Another situation was developed whereby infrared equipped tanks were used in the defense of a road junction. In this case, the attacking tanks were able to approach to within 175 yards before being detected by the defenders who were equipped with infrared viewers. Dismounted infantry accompanying the attacking tanks, were able to approach to within 75 yards of the defender before they were detected. It is interesting to note here that the attacking tanks moved completely beyond the road junction without detecting the defending tanks and the accompanying infantry were able to detect the defenders by the noise of their generators. Presence of the infrared-equipped defenders by observers employing infrared viewing devices at a range of 500 yards. These findings indicate clearly that the advantages realized by a defender utilizing gun-laying devices are offset by an attacker who is able to detect infrared sources. On a moon-light night, the

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infrared-equipped tanks would be of no material value because standard vision devices are effective to greater ranges than infrared when visible light is present.[9]

IR-Equipped Tanks in Perimeter Defense

The effectiveness of infrared-equipped tanks was also tested in a perimeter defense problem which was staged in an open field. Two M46 tanks which were equipped with infrared viewing devices for the crew, were placed in the center of the field. The field was mostly covered with grass approximately two feet high except for tank trails that traversed the area. The field had been cleared of brush and trees for a radius of approximately 100 yards. The tanks were not supported by infantry in this problem. An infantry squad consisting of only six men was given the mission of defeating the two defending tanks. Although the limited equipment and personnel that were available for this problem precluded a realistic situation, the results proved to be very informative. It was found that the infantrymen were able to determine the direction of the defending tanks by observing tha tank turrets against the sky-line. When the tank lights and turret were turned in their direction, the infantrymen took cover and consequently were not observed by tha tank crew. From a tactical viewpoint, the tanks were defeated in this problem. One man, who realized a specific limitation of infrared viewers, carried a small bush in front of himself and thus avoided detection. The infantrymen were able to move to within 30 yards of the tanks and even then they were not detected in sufficient time to be fired at. The countermeasures employed by some of the attacking infantry is significant in that similar tactics may be expected when engaged with a well trained enemy. Crew fatigue received a great deal of consideration in this problem when it was found that the requirement for the gunner to continuously traverse the turret and for the rest of the crew to maintain constant vigilence became very tiresome from a physical viewpoint. It was concluded that one tank crew could not maintain efficient vigilence for longer than one hour. This problem would be somewhat removed in normal situations where more tanks are used in a perimeter defense and the individual tank crew would have only a small sector to observe.

Countermeasure Tests

Throughout the conduct of the tests which have been discussed thus far, it was found in several instances that certain countermeasures were effective against infrared equipped vehicles and personnel. These observations prompted the establishment of a test to investigate the extent that countermeasures can be applied effectively.

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The first phase of the test was designed to test the vulnerability of infrared sources to aerial observation. An observer who was equipped with a M2 Sniperscope and a Metascope flew over the test area in a liaison plane and reported that by using the Metascope he could observe the 24-inch searchlights with the old type filters, at a range of approximately 4-1/2 miles. By using the M2 Sniperscope, he was able to detect the glow of the searchlight at a distance of approximately 10 miles. At no time did the observer detect the red-hot mufflers on the tanks.[10]

Sub-tests to determine the effect of colored smoke on infrared vision were conducted. It was found that smoke reduced the effective seeing range of the viewers to 50 yards and less depending on the location of the smoke with respect to the line of sight of the target. Further tests in this regard revealed that an observer is blinded when other infrared sources are directed into his viewer. In this case each of two observers could only see the light source used by the other. It was, therefore, concluded that although the range to an infrared source is difficult to estimate, an effective countermeasure could be the use of high velocity weapons which are equipped with infrared viewers for sighting.[11]

The proper use of camouflage is an excellent passive countermeasure to be employed against an enemy equipped with infrared equipment. Trees and heavy brush have proven to render targets undectable. The use of paints with low infrared reflectivity on military vehicles is effective in reducing the range at which vehicles can be seen. This reflectivity is, however, much greater than that of natural foilage.[12]

Conclusions of Army Field Forces Board No. 2

Based on the test results as summarized above, the Army Field Forces Board No. 2 concluded that:[13]

1. The infrared gunnery equipment supplied for this test is unsatisfactory and should not be considered for issue to units of Army Field Forces at this time.

2. The inherent characteristics of near infrared gunnery equipment appear to limit its tactical value for offensive use.

3. Near infrared gunnery equipment may prove to be of material tactical value when used defensively. However, visual security will be reduced if the enemy is equipped with infrared devices.

4. Limited equipment and personnel available to this board precluded a thorough tactical evaluation of all phases of infrared warfare.

5. The results obtained will be of material aid in planning tactical tests in the forthcoming troop tests.

6. A thorough evaluation of infrared warfare should be made in the troop test to determine its practicability.

7. The auxiliary generator of the Medium Tank, M46, is not quiet enough to permit a realistic evaluation of the tactical use of near infrared gunnery equipment.

8. Armor and Infantry should be utilized in the troop test of infrared equipment.

Recommendations of Army Field Forces Board No. 2

Army Field Forces Board No. 2 recommended that:

1. The infrared gunnery equipment be modified to correct the deficiencies that were reported in the first partial report and as setforth in the results of this test.

2. The principles involved in the tactical use of near infrared gunnery equipment be thoroughly evaluated in the battalion troop test.

3. Active participation and support be given this troops test by both the Armored and Infantry Centers.

Section III. ARMY FIELD FORCES BOARD NO. 2 PROJECT 1627

This section is devoted to a discussion of the most recent comprehensive tests of infrared equipment which were conducted at Camp Irwin, California, during the period 5 May through 3 July 1952. In general, the purpose of this project was to determine the suitability of the available infrared equipment and to investigate the training requirements connected therewith. The capabilities of infrared in various tactical situations were also to be considered to an extensive degree.

On 20 August, 1951, OCAFF directed AFF Board No. 2 to begin planning for the conduct of the test. The Board was to assume responsibility for the overall coordination, supervision and evaluation

[redacted]

of the tests and test results.[14] At this point the reader is cautioned that the final report of AFF Board No. 2 concerning this test has not been officially coordinated and therefore the results which are reflected in this section are for information only and do not represent the reactions of those official agencies which are concerned with the evaluation of infrared equipment. Due to the magnitude of the Project, the committee feels that many of the details would be of little or no interest to the reader and has therefore confined this analysis to only the more significant aspects.

In establishing the plan for the conduct of the tests under this project it was determined that the AFF Board No. 2 would conduct the first phase which consisted of an investigation of the operational features of the infrared equipment. The Armored Infantry and Artillery Schools would conduct the second phase encompassing the tactical employment of infrared by various units within their respective arms.[15] It must be borne in mind that tests to supplement the results obtained in the operational tests were conducted concurrently with the tactical tests.

The following listed items of equipment were made available for both the operational and tactical portions of this portion:[46]

1. <u>Tank Mounted Equipment.</u> (74 Units)

   a. Two binocular driver's periscopes, one for driver and one for assistant driver.

   b. One two-power monocular gunner's periscope with an aiming reticle.

   c. One 18-inch, 1,000 watt, gunner's IR searchlight mounted on the gun shield coaxially with the gun.

   d. One binocular periscopic viewer for tank commander (two-power).

   e. One 12-inch, 450-watt, tank commander's searchlight linked to the tank commander's viewer.

   f. Three high voltage power packs for viewers.

   g. Two 150-watt headlights with filters.

   h. One slip-ring assembly for transmitting power to tank commander's searchlight and viewer to allow 360° traverse of tank commander's equipment.

[redacted]

i. Spare parts, tools, connecting cables, etc., as needed.

2. Half-track Mounted Equipment. (12 Units)

a. A 10-kw. electric generator on each half-track.

b. A 24-inch carbon-arc, beach-defense searchlight with an IR filter.

c. An IR viewer for direction of searchlight beam.

3. Other Equipment.

a. Five 60-inch searchlights with IR filters mounted on 2-1/2-ton trucks.

b. Long-range viewers for use with searchlights.

c. Sniperscope, Infrared Set No. 1, 20,000 volt.

d. Image Metascope, Type XR-3.

e. Metascope, Type US/F.

f. In-line binoculars for driving of tactical and general purpose vehicles. See "figure 19."

Section IV. OPERATIONAL TESTS

The operational tests on the tank driving and gunnery equipment and on the wheeled vehicle driving equipment served a dual purpose in that they permitted the training of personnel and the collection of data pertaining to the factors listed below.[17]

1. The facility of installation and removal of equipment.

2. The comparison of the mobility of tracked and wheeled vehicles when using infrared and standard blackout driving lights.

3. Convoy operations utilizing infrared and standard driving equipment.

4. The detection and identification ranges of the gunnery equipment for various targets, using the various illumination sources.

[redacted]

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ARMY FIELD FORCES BOARD No. 2	P-1627	#52-2086	FORT KNOX, KENTUCKY

View showing In-line binoculars mounted on drivers head in position for driving. Equipment shown consists of:

(1) In-line Binoculars.
(2) Power Pack
(3) Switch Box.
(4) Voltage Divider.
(5) Cable to furnish vehiular power for operation of binoculars.

Figure 19.

5. The effect of smoke, dust and camouflage.

6. The effects of firing the bow machine gun, the coaxial machine gun and the tank gun.

7. The accuracy obtained using the infrared sights.

8. The effectiveness of the gunner's infrared sight for firing on a simulated enemy infrared source.

9. The visual security of the infrared sources and the auditory security of the power generators and the tank engines.

10. The reliability of the equipment during the above tests.

11. The training requirements for the use of infrared equipment.

Installation and Removal

The initial installation of infrared equipment on the M46 tanks was performed by trained Army and civilian technicians. Periodically, the tank crews were timed in the installation and removal of that part of the infrared equipment which would allow standard equipment to be substituted. The average time to install the equipment was 67.4 minutes. The reverse procedure required an average time of 74.2 minutes. During the course of this test it was noted that the gunner's and tank commander's searchlights could not be conveniently carried within or on the outside of the tank. Therefore, the stowage of this equipment when not in use, is a complication which must be considered further. Infrared headlights for both wheeled and tracked vehicles are permanently installed and consequently do not create a stowage problem. The in-line binoculars are provided with an adequate stowage box.[18]

Driving Tests

In order to compare the advantages of infrared tank and wheeled vehicle driving equipment over that of standard blackout driving techniques, a series of test runs were made in which each method was employed. The results of these tests showed that based on the accomplished speeds, the infrared equipment was only of marginal value in desert terrain. Speeds on nights when there was no moon were only marginally better than for blackout driving because of the high level of natural illumination which prevails in the desert and high reflectivity of the sandy trails. See "figure 20." Infrared driving equipment was found to be adversely affected by the dusty conditions. Speeds attained using the blackout drive light were usually better than that obtained using infrared. However, the security of the blackout driver's light did not compare with that obtained favorably using infrared. In the final analysis, it was believed that all vehicle drivers should receive in addition to the standard drivers course, two hours of basic theory, nomenclature, installation and removal, and maintenance; four nights of individual tank driving; and four nights of convoy driving.[19]

Convoy Driving

Tank and wheeled vehicle convoys were conducted to compare the degree of facility obtained using infrared driving equipment, with that obtained using standard blackout driving devices. With the exception of the periods when general dust conditions prevailed or there was illumination from the moon, the convoys using the infrared could move at a faster rate of speed.[20]

Detection and Identification

Test No. 4 was conducted to determine the range at which various targets could be detected and identified by the tank commander and the gunner. Targets for this test consisted of tracked, wheeled vehicles, and a squad of infantry. Ranges were determined for both moving and stationary targets. Tanks equipped with standard vision devices were including in this test to obtain comparison data. The results obtained are summarized below:[20]

1. The gunnery equipment allowed detection (D) and identification (I) of targets on a level plain and for targets silhouetted against a white sand background at average ranges (in yards) of:

TARGET DETECTION AND IDENTIFICATION TABLE

SOURCE	STATIONARY TARGETS				MOVING TARGETS			
	Level Plain		Silhouetted		Level Plain		Silhouetted	
	D	I	D	I	D	I	D	I
12-inch	371	288	733	524	467	329	554	429
18-inch	417	388	775	579	463	367	608	463
24-inch	692	442	829	683	767	592	1033	750
18 & 24-inch	617	475	1013	783	804	675	996	796
60-inch	892	529	981	731	1067	721	1056	850

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ARMY FIELD FORCES BOARD No. 2	P-1627	#52-2094	FORT KNOX, KENTUCKY
Photograph taken on infrared sensitive film showing a portion of the wheeled vehicle driving course. Photograph indicates conditions prevailing under low levels of illumination, the high reflectivity of sand and trails.			

Figure 20.

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2. On moonlight nights standard vision equipment was as effective as the IR devices using supplemental IR sources, and were superior to the IR devices using only the tank mounted sources.

3. For conditions of starlight the ranges obtained using the IR devices were greater than those obtained using standard tank sighting devices. Ranges obtained using standard binoculars, (MMAI night glasses), were comparable to those obtained using tank-mounted sources.

4. Supplemental tests showed that a tank silhouetted against a white sand background could be detected at ranges of 2200 to 2500 yards using the Long Range Telescope and Periscopes, and the 24-inch and the 60-inch searchlights for illumination. Identification of the tank targets were made at ranges between 800 to 1,000 yards.

Effect of Smoke and Camouflage

During tests to determine the effectiveness of smoke and natural camouflage against infrared vision showed the range at which targets could be seen was materially reduced. Tanks painted various colors were difficult to detect when their color closely matched the background of the target. Uniforms with varying reflectivities also made personnel difficult to detect in the same manner. The terrain at the test site was devoid of trees which have a high reflectance to infrared. See "figure 21." It has been shown in tests at Fort Knox, Kentucky, that a tank shows to be black in an IR viewer and can not be seen when it is parked behind a leafless bush even at a close range (75 yards).[22]

Field Firing Tests

During field firing tests in which the coaxial machine guns were fired at 6x6 panel targets at ranges of 400 to 500 yards, it was found that approximately 50 percent hits were obtained. On firing the tank main armament, 90-mm with HE ammunition, 52.5 and 55.6 percent hits were obtained on hull targets that were located at 600 and 700 yard ranges. The gunners and the tank commanders involved in this test reported that they were momentarily blinded by a bright flash in their infrared viewer. This flash in addition to the dust that was kicked up by the muzzle blast prevented satisfactory adjustment of fire.[23]

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ARMY FIELD FORCES BOARD No. 2	P-1627	# 52-2110	FORT KNOX, KENTUCKY
Photograph of a Medium Tank, M-46, taken using infrared sensitive film showing the low reflectivity of OD paint and the high reflectivity of sand			

Figure 21.

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Accuracy Tests

Maximum infrared illumination was provided for the controlled accuracy tests. The results showed that good accuracy can be obtained by using the infrared gunner's sight at an average range of 500 yards. Because of the obscuration which is created by the muzzle flash and dust, the requirement for first round hits must be emphasized.[24]

Effectiveness of Gunners Sight

Tests to determine the effectiveness of the gunner's infrared sight for firing on simulated infrared sources showed that a high velocity weapon equipped with an infrared sight is effective for destroying infrared sources. Infrared sources can be seen at line-of-sight ranges using an infrared viewer. Simulated enemy sources (18-inch infrared lights) were placed in impact areas at ranges unknown to the tank gunners. The gunners experienced difficulty in estimating ranges, but were able to destroy the sources with relatively few rounds by adjusting the observed HE bursts in relation to the sources.[25]

Visual Security

The visual security afforded by the various illumination sources was determined by using observers who were dark-adapted and others equipped with MMAI binoculars. It must be pointed out that the observers knew the approximate location of the sources and, therefore, it can be assumed that an enemy might not detect the source at the ranges that the observers did in this problem. In observing all of the various sized infrared sources, it was determined that the observers who were equipped with night glasses detected the sources at far greater range than did the dark-adapted observers.

Auditory Security

Inasmuch as it had been long realized that the noise of the auxiliary generators and the tank engines created a problem in auditory security in defensive situations, a specific test was designed to determine auditory security ranges. Although a special muffler was provided for the auxiliary generator, it proved to be of little more value than the standard muffler. The power plants were heard at the following average ranges (in yards):[26]

[redacted]

AUDIBLE SECURITY RANGES

POWER PLANT	RANGES
Tank Engine (at 1200 rpm)	1501
Auxiliary Generator w/special muffler	862
Auxiliary Generator w/standard muffler	1020
Generators for 24-inch S/L	1053
Generators for 60-inch S/L	657

Dependability Test

The results of the dependability tests of the equipment showed that the overall maintenance required for the tank gunnery equipment was excessive. Some of the more pertinent findings were as follows:[27]

OPERATIONS vs MAINTENANCE

	Hours of Operation	Hours of Maintenance	Reliability	Remarks
Tank Driving Periscopes (Engineer design)	43.7	1	Yes	
Tank Driving Periscopes M19 (Ordnance design)	24.5	1	No	*
Tank Gunner's Periscope	11.2	1	No	**
Tank Commander's Periscope	42.9	1	Yes	
In-line Binoculars (Wheeled vehicle drivers)	5.8	1 (Shop)	No	***

* Modifications required to make the M19 (Ordnance Driver's Periscope) more reliable, have been reported to the developing agency.

** The tank gunner's periscopes were not reliable and required excessive maintenance.

[redacted]

*** The in-line binoculars required excessive maintenance and were found to be insufficiently rugged or reliable for field use.

Maintenance Requirements

As it has been pointed out above, the various components of infrared equipment required rather extensive maintenance. The nature of the malfunctions and required adjustments under field conditions clearly indicated the need for well trained mechanics and technicians. Infrared driving equipment requires a small amount of maintenance as compared to the infrared gunnery equipment. Therefore, it was considered that one trained man in each tank company could maintain the company driving equipment and that there should be an officer or warrant officer and two enlisted men at battalion to perform the more technical repairs. In the case where a tank unit is equipped with both driving and gunnery equipment, one man in each platoon would be needed to diagnose malfunctions and replace parts. More advanced repairs could be accomplished by the battalion maintenance platoon which should include one officer and four enlisted men who are specialists with infrared equipment. Higher echelons of maintenance support would have to be provided by maintenance units of the Engineer and Ordnance services.[28]

Training Requirements

Tank units equipped with reliable infrared gunnery equipment would require thorough training to become familiarized with the numerous factors which are peculiar to infrared. These factors include: the appearance of military targets differs when viewed through an infrared device; the effect of target foreground and background; the use of IR devices for countermeasures; the muzzle blast which is temporarily blinding and prevents sensings, or adjusting fire at short ranges; and the visual security of IR illumination sources. Training would be required for operators of supplementary IR illumination sources. The operators would be required to be qualified in the operation and maintenance of searchlights and power plants. This would require the assignment of additional enlisted men to a tank battalion. Units would require extensive training in defensive and offensive exercises. Based on the experience gained in this troop test, it is believed that a tank unit, thoroughly trained in the daylight use of tanks, would require a minimum training period of from three to four months prior to attempted offensive use of IR gunnery equipment in direct combat with an enemy not so equipped with IR devices. For defensive use, less training probably would suffice.[29]

Section V. TACTICAL TESTS

Although the emphasis in this report has been directed toward the application of infrared with respect to wheeled and tracked vehicles, it is at the same time realized that armor cannot achieve its maximum effectiveness without the assistance of Infantry and Artillery. Therefore, it is considered necessary that a brief summary of the Infantry and Artillery tactical tests be included with that of The Armored Center, to round out the overall picture as to how infrared may be of use to armor.

THE ARMORED CENTER TESTS: The following is a brief summary of the tactical tests conducted by The Armored Center.[30]

Reinforced Tank Platoon in a Night Attack

In the conduct of a reinforced tank platoon in a night attack problem, the tank platoons were accompanied by a platoon of infantry and two half-track illumination vehicles from an assembly area, to an attack position, to a line of departure, and, thence, to an objective. Infrared equipment was utilized by all participating troops. The objective was marked by two 60-inch IR searchlights which were placed on the flanks of the platoon attack sector approximately 1300 yards from the objective. The units were moved forward and stopped by the chief umpire at various ranges to check on the control of the attack and to determine if any targets had been seen.

The results of this problem showed that the tank platoon with IR driving devices satisfactorily made road marches from the assembly area to the attack position on dark nights along marked routes. On a moonlight night, the drivers preferred not to use the IR equipment as they found that they could observe better without infrared. Due to the restricted field of view using IR viewers, it was found on the attack, that control and orientation were difficult. It was necessary for platoon leaders and tank commanders to leave their hatches open in order to maintain direction and platoon formations. The bulk and weight of the tank commander's hatch cover hindered alternate opening and closing of the hatch. The most effective means of detecting targets was by the use of IR illumination from the supplementary vehicles. Targets which consisted of LVT hulls silhouetted against a sand hill were detected up to 1300 yards with the aid of two 60-inch and two 24-inch IR searchlights. See "figure 22." However, effective fire could only be placed on them at approximately 700 yards. Using only tank mounted IR searchlights, targets were detected up to 400 yards. Infantry with sniperscopes, aided by tank-mounted IR searchlights could detect targets up to 250 yards.

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View showing a platoon of tanks with 24-inch and 60-inch IR sources on one flank, overlooking a plain. The sources are approximately 60 feet higher than the targets.

Figure 22.

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Reinforced Tank Company in a Night Attack

A reinforced tank company in a night attack problem was established whereby the company moved from an assembly area to an attack position, to a line of departure, and thence, to the objective. The objective was 1500-1700 yards from the line of departure and was marked by the beams of two 60-inch IR searchlights which were located on the flanks of the line of departure. The objective was held by a tank platoon which was standard equipped, was also equipped with IR visible-light flares, and searchlights which were used in some phases to compare the effectiveness of an attack using IR with the effectiveness using white light.

Results of this problem re-emphasized the difficulty of maintaining control and orientation in the attack using the IR equipment on a dark night. The drivers preferred using the IR driving devices rather than the standard blackout lights. Targets which were illuminated by 24-inch and 60-inch IR searchlights detected at an average range of 525 yards by IR tanks, at 400 yards by infantry men with sniperscopes. Without supplementary IR illumination, IR tanks detected targets at an average range of 300 yards. Targets were detected at an average range of 750 yards during problems using direct illumination provided by two standard 60-inch searchlights which were located approximately 1500 yards behind the line of departure. The standard tanks detected all targets except silhouette targets at ranges in excess of the IR tanks for this problem. Artificial moonlight could not be provided because of the clear atmosphere in the test areas. Tank crews and infantry believed that IR was of no material assistance during visible light problem, except for the movement up to the line of departure. During the firing phase, IR tanks fired on IR sources and targets located at the objective. The IR sources were not hit when fired on from a range of 1700 yards. However, they were hit effectively by 90-mm HE fire at 900 yards. Two LVT hull targets were hit at 1100 yards and another was hit at 700 yards using the IR equipment. Range estimation, sensing and adjusting fire was extremely difficult using the IR equipment, particularly using HE ammunition. The muzzle blast, initial blinding, and dust on firing the 90-mm gun made sensings extremely difficult.

Reinforced Tank Company in the Defense

The effectiveness of a reinforced tank company supported by supplementary IR illumination vehicles was tested in a problem, in which a company was placed in defense of three strong points against an attack by a reinforced tank company. The attacking force utilized both standard and IR equipment. Visible light flares and searchlights were utilized in one problem to compare the effectiveness of IR with

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visible light. Six night defense problems were conducted which included a firing problem using IR, also a firing problem using visible light.

The results of this problem indicated that the 60-inch IR searchlights equipped with the Long Range viewers were of material assistance to the defense in; that they permitted the detection of the aggressor blackout driving lights at 2000 yards and the identification of the aggressor tanks at 700 yards. See "figure 23." The IR tanks and infantry with sniperscopes detected blackout driving lights at 1200 yards. Of the seventeen tanks employed in the defense, eleven of them detected the attacking tanks at an average range of 370 yards; only one tank detected the attacking infantry. The infantry with sniperscopes detected attacking tanks at an average range of 460 yards. Of the nine infantry squads which were in the defense, only four squads were able to detect attacking infantry at an average range of 350 yards. When the attacking force employed IR sources, those sources were detected at 3000 yards, or line-of-sight ranges. During the problems which were conducted during moonlight, the aggressor was detected at approximately the same ranges as on dark nights. In these instances, the aggressor infantry was able to maneuver to within ten yards of an IR defending unit. Flares and visible-light searchlights apparently assisted IR defenders only in that normal vision could be used. Visible light searchlights materially aided the aggressors in detecting the defending forces. It is significant to note that the crew members of the aggressor force preferred visible light to infrared for the attack. During the firing problem using IR, the 24-inch searchlights were necessary in the firing at targets located over 300 yards away. The muzzle blast and dust made sensing and adjusting by the firing tanks almost impossible.

Road March Exercises

Two tactical road marches were conducted using the tanks and wheeled vehicles of the test battalion to compare the degree of facility obtained in a tactical march using IR and standard techniques. IR-equipped tanks and wheeled vehicles, drivers using the in-line binoculars, traveled 29.4 miles under darkness and moonlight conditions. The battalion then traveled the same route using standard blackout equipment under the same natural light conditions.

The column using IR equipment averaged 8.5 mph during the moonlight phase and 7.8 mph. during the darkness phase. Using blackout driving devices, the column averaged 8.9 mph. during the moonlight phase and 8.5 mph. during the darkness phase. The overall average rates of march using IR and blackout equipment were 8.1 mph. and 8.7 mph. respectively. Tank crews preferred normal blackout

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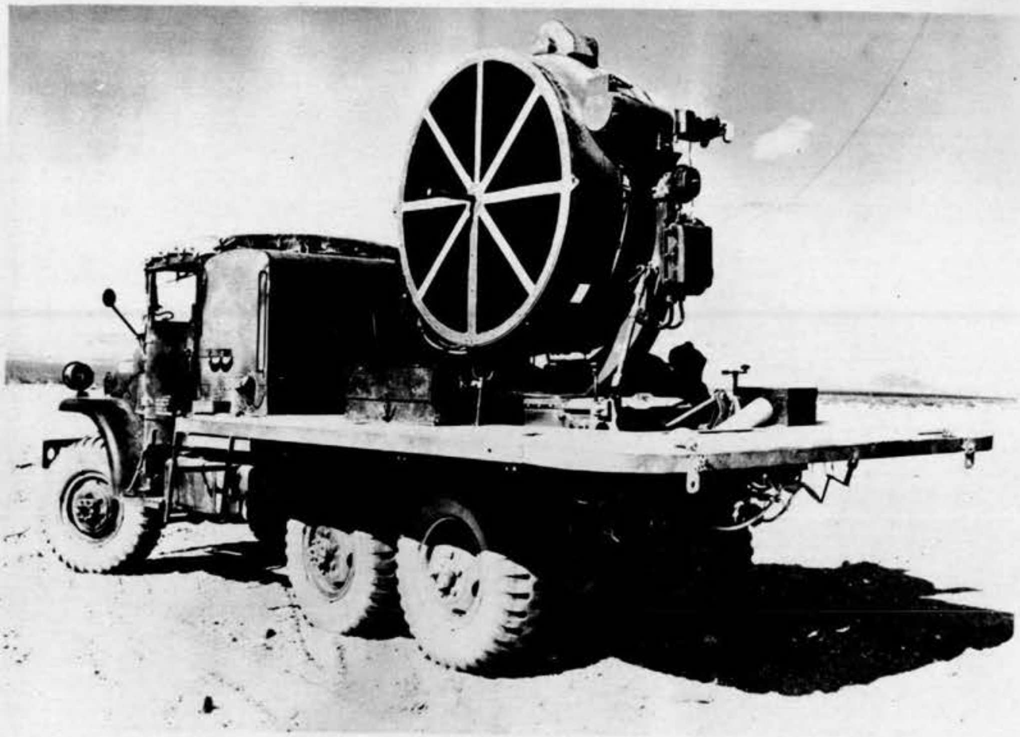

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View showin a 60-inch searchlight, mounted on a 2½ ton truck Used to provide supplementary IR illumination on targets.

Figure 23.

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driving on a moonlight night. However, the roads guides, and markers were more difficult to see using the standard blackout driving equipment than with the IR driving equipment.

Conclusions

The Armored Center concluded, in general, that:[31]

(1) The infrared tank driving equipment is satisfactory but that the infrared tank gunnery equipment is unsatisfactory because of its limited range, mechanical unreliability and extreme difficulties in range estimation, sensing and adjustment of fire.

(2) The 60-inch truck-mounted and 24-inch half-track mounted IR searchlight vehicles are unsatisfactory for tactical use by armored units because of lack of cross-country mobility and vunerability to ground fire but that these units are of value for search and detection vehicles against an enemy not equipped with IR devices.

(3) The tactical use of presently available near infrared gunnery equipment for offensive operations appears to be limited except for special operations but appears to be of value for close-in defense against an enemy not equipped with IR devices.

(4) Additional tactical tests be conducted at Fort Knox, Kentucky, to tactically evaluate IR equipment under conditions other than those prevailing at Camp Irwin, California.

Recommendations

The Armored Center recommended that:[32]

(1) The IR gunnery equipment supplied for tests at Camp Irwin, California, be considered unsatisfactory for issue to armored units.

(2) Tests to further evaluate the tactical value of infrared be conducted at Fort Knox, Kentucky.

(3) Research be continued to improve the efficiency of IR driving and IR tank gunnery equipment with a minimum of illumination equipment.

[redacted]

Tactical Tests Conducted by The Infantry Center

A brief summary of each of the tests is as follows:[33]

The Infantry-Tank Team in a Night Attack

An infrared-equipped rifle company, reinforced with a tank platoon, conducted a night attack on a limited objective in which infrared equipment was used by all participating troops. The results indicated that a supported night attack can be conducted using infrared equipment. The use of supplementary IR illumination provided by 24-inch half-track mounted and 60-inch truck mounted IR searchlights greatly extended the effective range of the sniperscope which was mounted on organic weapons. Using supplementary IR illumination, infrared equipment for the conduct of supporting mortar, machine gun, and artillery fires was considered a definite asset to the conduct of the attack. Infrared equipment was considered to assist in movement to the objective and the reorganization for defense.

The Rifle Company, Reinforced, in Defense at Night (Non-Firing)

A defense using infrared equipment with auxiliary light-sources showed that infantry can successfully defend a position. Infrared equipment properly employed in the defense was considered to have tremendous value. Development of techniques for the employment of auxiliary supplementary IR light sources is considered necessary.

The Rifle Company, Reinforced, in Defense at Night (Firing)

Defense problems, during which infantry weapons were fired, included a comparison of direct visible light provided by standard 60-inch searchlights with infrared light supplied by auxiliary IR searchlight vehicles. Using visible light, targets were engaged by all weapons with difficulty at ranges from 50 to 1300 yards. Using infrared, long range, close defensive, and final protection fires were conducted with little difficulty. Ranges were again between 50 and 1300 yards.

Rifle Company Reinforced as Motorized Patrol at Night

A reinforced rifle company, motorized, successfully conducted a road march and platoon-sized patrols. The use of the infrared

[redacted]

driving equipment allowed night movement of the unit at speed which approached daylight speeds.

The Infantry Center considers that because of the special atmospheric and terrain conditions prevailing at the test site that it is not possible to secure conclusive date, nor was it possible to adequately compare the employment of visible light and infrared. The test afforded The Infantry School the first opportunity to investigate the infrared auxiliary sources in support of sniperscope-equipped infantry weapons. Many of the sniperscope mounting brackets supplied for the various weapons were improvised, had not been previously service tested, and were unsatisfactory in some respects. The tactical maintenance support was not properly tested in that maintenance was performed by representatives of the Engineer Research and Development Laboratories in the interest of expediting completion of the tests.

The Infantry Center Conclusions

The Infantry Center concluded the following:[34]

(1) Infrared equipment, properly employed, enables the user to conduct night combat operations under conditions closely approximating daylight.

(2) Existing infrared equipment, although offering immediate advantages, is not adequate or suitable. The need for further development exists.

(3) Results cannot be considered as conclusive, since the tests were conducted under relatively ideal conditions existing in the desert. There is need for additional tests to be conducted under varying weather, atmospheric and terrain conditions to obtain additional comparative and detailed information to include the development of techniques, on tactical application of infrared equipment.

The Infantry Center Recommendations

The Infantry Center recommended the following:[35]

(1) That infrared devices be tested to the fullest extent as a possible solution to the existing need for night sighting, detection and observation equipment.

[redacted]

(2) Than an intensified program of research and development be continued in order to provide infrared equipment with the desired military characteristics.

(3) That additional tactical tests be conducted at The Infantry Center to provide additional comparative and detailed information on the tactical application of infrared equipment as it applies to infantry use and to develop tactical principles and techniques in the application of infrared equipment.

Tactical Tests, The Artillery School

The following is a summary of the results of tests conducted by The Artillery School.[36]

Observation and Adjustment of Artillery Fire

Tests designed to determine the value of IR equipment in the observation and adjustment of artillery fire utilized 60-inch and 24-inch IR illumination vehicles equipped with long range telescopes. The tank commander's IR periscope in an M46 tank was also used in fire problems on targets which were illuminated using the supplementary IR sources. Observers were able to adjust artillery fire on targets at ranges up to 2,060 yards using both the long range telescope and the tank commander's periscope. The long range telescope was considered the better viewer because of more distinct images. The location of the observing equipment, the terrain, and the atmospheric conditions for the tests were considered optimum. It was considered that an observer cannot maintain a constant vigil. Using the equipment was too fatiguing to the observers. The field of view of the long range telescope (approximately 5 degrees) was considered too narrow. However, effective fire was registered by utilizing normal vision to bring adjusting rounds in the field of the long range telescope. Coordination between the observer and an IR source located at a flank was difficult. This difficulty was not present when the observer utilized an IR source which had the IR viewer mounted on that source.

Test of Infrared Intercept Receiver

A test involving use of Infrared Intercept Receiver (Signal Corps Equipment) for directing artillery fire on simulated enemy IR sources resulted in the artillery fire being over on the three targets. Two Signal Corps viewers were used, one on each end of a base line, to provide azimuth data to a plotting station which provided the artillery fire direction center with coordinates of the IR sources. Errors were found which precluded accurate artillery fire.

Joint Infantry and Artillery Test

Artillery fire was integrated into the Infantry tactical problems. Artillery fire was placed on an objective approximately 200 yards right and 200 yards beyond the base point without difficulty. Registration on the base point was made during daylight hours. Two targets of opportunity were designated by the infantry commander. One target at a distance of 1300 yards was successfully engaged with artillery fire. However, the second target at 1000 yards was not fired on because it could not be identified using either the 24-inch or 60-inch IR searchlights and the long range telescope.

The Artillery School Conclusions

The Artillery School concluded the following:

(1) Effective observed fire can be placed on targets at observer distances up to 2,000 yards under conditions of terrain and atmosphere found at Camp Irwin, California.

(2) There is no noticeable difference between moonlight or dark night in the use of IR equipment.

(3) IR illuminating equipment is too large and bulky. It is difficult to adjust the light on a target when the light is some distance from the observer position.

The Artillery School Recommendations

The Artillery School recommended the following:[38]

(1) That further testing be made in other types of terrain than at Camp Irwin, California.

(2) That infrared binoculars, approximately six power, with a field of view at least 100 mils, with scale be developed so that both eyes can be used. This will reduce eye fatigue and give depth perception.

[redacted]

(3) That the long range viewer be increased to at least twice the field of view of present viewer and with appropriate mil scale.

(4) That the tank commander's viewer be equipped with a mil scale so as to be used by an artillery observer.

(5) That a system be devised for remote control of 60-inch and 24-inch IR searchlights. This system is needed when the observer is some distance from the lights.

Conclusions of Army Field Forces Board No. 2

Based on the overall results of the operational and tactical tests in this project, the AFF Board No. 2 concluded that:[39]

(1) IR tank driving equipment is of sufficient tactical value to justify its provision for tanks.

(2) Tank Driving Periscope, M19, when modified to correct deficiencies, should be suitable for field use. Installation of the Periscope M19 requires evaluation to determine the suitability of mounting and cabling for vehicles to be supplied with this driving aid.

(3) Tank driver's periscopes, supplied by the Engineer Corps, are also suitable for field use except for minor deficiencies.

(4) Inline binoculars supplied for driving of wheeled vehicles are unsatisfactory for service use.

(5) Inline binoculars, modified to correct deficiencies. A thorough service test be given to determine their suitability for service use.

(6) The infrared tank gunnery equipment is unsatisfactory for issue to units of Army Field Forces but is satisfactory for further tests to determine the tactical value of near infrared for offensive and defensive operations.

(7) The maintenance required on the gunners' and tank commanders infrared equipment was excessive.

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(8) Thorough training in numerous factors in the use of IR gunnery equipment would be required prior to any attempted use in direct combat against an enemy not equipped with IR devices.

(9) The tactical value of infrared tank gunnery equipment for offensive and defensive operations appears to be limited. At present, the requirement for the special illumination vehicles, the special equipment, additional logistical support, additional training, additional maintenance and the cost of the special equipment appears not to be justified.

(10) The infrared gunnery equipment is of value for counter measures purposes of firing on hostile near infrared sources. However, other countermeasures against possible offensive infrared operations are available.

(11) Additional tactical evaluation of the tank gunnery equipment in terrain other than desert terrain is required.

(12) Development of near infrared gunnery equipment for the new family of tanks should be held in abeyance pending the determination of its tactical value. Development should not be undertaken if the daylight performance of the tank is compromised, or if the equipment sources the use of costly, complicated or unreliable components.

(13) Special mufflers supplied by the Ordnance Corps for auxiliary generators of Medium Tank, M46, were not sufficiently better than standard mufflers in noise suppression to justify their use.

(14) The Long Range Tank Gunner's Periscope provided adequate seeing range when used with supplemental illumination, but it is of little value when used with the tank-mounted IR source.

(15) The Long Range Tank Gunner's Periscope is large and bulky, would require field service installation, and maintenance by trained technicians. Any future development of gunner's equipment should point toward a simplified viewer.

(16) The 60-inch truck-mounted IR searchlight is unsatisfactory for service use.

(17) The 24-inch half-track mounted IR searchlight with the Long Range Telescope, even though not fully satisfactory, would be effective for surveilance supplying supplemental IR illumination and adjustment of artillery and mortar fire in combat in its present form. See "figure 24."

(18) Additional tactical tests to further evaluate the principles involved in the use of infrared equipment, to obtain more detailed comparative information, and to determine the extent of requirements should be conducted under conditions other than those existing at Camp Irwin, California.

Recommendations of Army Field Forces Board No. 2

The Army Field Forces Board No. 2 recommended that:[40]

(1) The Ordnance Corps Tank Driving Periscope, M19, be modified to correct the deficiencies listed, be standardized, and furnished with combat vehicles for which Army Field Forces has stated a requirement for infrared driving devices.

(2) Production models of IR driving equipment be tested under climatic extremes established by Army Field Forces.

(3) Infrared inline binoculars for the driving of wheeled vehicles, be modified to correct deficiencies and be service tested.

(4) The IR tank gunnery equipment supplied for tests at Camp Irwin, California, be considered unsatisfactory for issue to armored units.

(5) The development of near infrared gunnery equipment for the new family of tanks be held in abeyance pending the determination of its tactical value.

(6) Tests to further investigate the tactical value of near infrared for offensive and defensive operations under terrain and weather conditions other than those prevailing at Camp Irwin, California be conducted.

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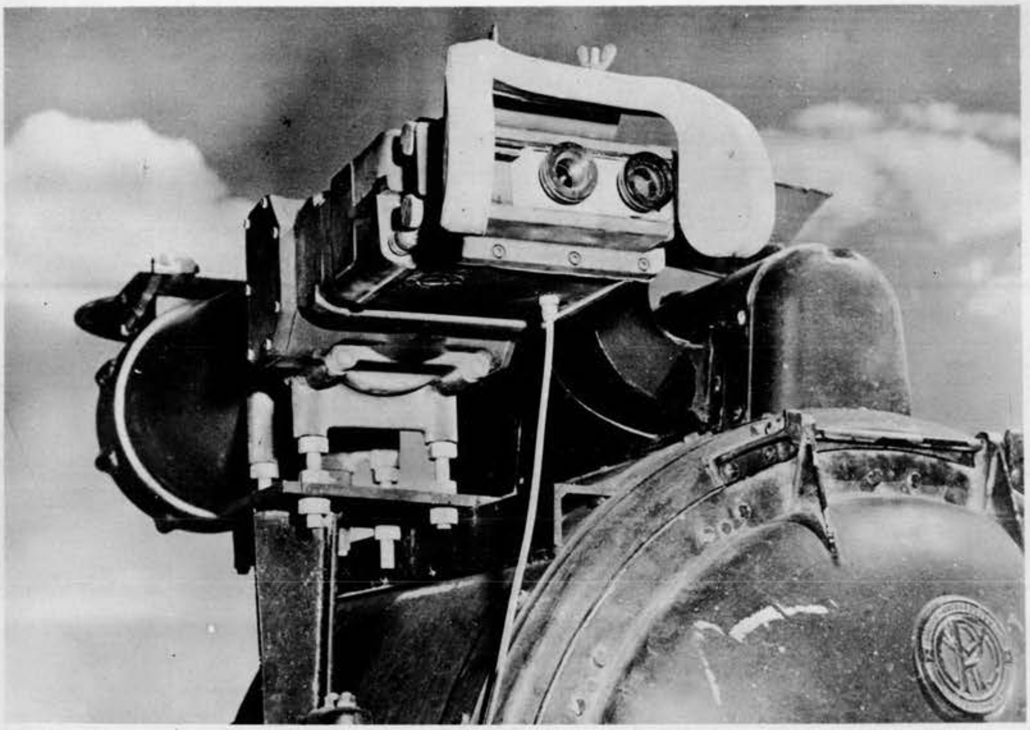

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Close up view of a Long Range Viewer, Infrared, mounted on a 24-inch searchlight. View shows eyepieces which are used to give selective magnification (3X or 6X).

Figure 24.

Section VI. SUMMARY

An analysis of projects 1534 and 1627 revealed numerous limitations of infrared equipment. In spite of these limitations, the results obtained gave rise to encouragement and renewed the overall concept that infrared does have favorable military characteristics. It may be expected that further development and testing of the infrared program will provide another and more secure method of battlefield illumination.

NOTES FOR CHAPTER 4

[1]Letter, OCAFF to AFF Board No. 2, file: ATDEV-5 413.6 (C) subject: "Service Test of Near Infrared Gunnery Equipment," dated 9 Oct 1950.

[2]Test of Near Infrared Gunnery Equipment (3-6-2-2), final report of Project No. 1534 (Fort Knox: AFF Board No. 2, 15 Feb 1952).

[3]Op cit, Description of Material used in Project 1534, p 2.

[4]Op cit, Details of Tests, Appendix C, p 5.

[5]Ibid, p 5.

[6]Ibid, p 5.

[7]Ibid, p 6.

[8]Ibid, p 6.

[9]Ibid, p 6.

[10]Ibid, p 7.

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[11]Ibid, p 7.

[12]Ibid, p 7.

[13]Op cit, Final Report, p 8.

[14]Letter, OCAFF to AFF Board No. 2, file: ATDEV-5 451.6/143, Subject: "Leaflett II Troop Tests," dated 20 August 1951.

[15]Letter, OCAFF to The Armored and The Infantry Centers, file: ATDEV-5 451.6/280, Subject: "Troop Test of Leaflet II Equipment" dated 12 January 1952. (To Prepare a Plan for the Conduct of the Tactical Portion of This Test).

[16]Troop Test of Leaflett II Equipment, Plan of Test Project No. 1627 prepared by AFF Board No. 2 (Fort Knox: 14 April 1952), p 2.

[17]Troop Test of Leaflet II Equipment, Draft Report of Project No. 1627 (Fort Knox: AFF Board No. 2, undated).

[18]Ibid, p 12.

[19]Ibid, p 14.

[20]Ibid, p 15.

[21]Ibid, p 16.

[22]Ibid, p 18.

[23]Ibid, p 19.

[24]Ibid, p 20.

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[25] *Ibid*, p 21.

[26] *Ibid*, p 22.

[27] *Ibid*, p 23.

[28] *Ibid*, p 24.

[29] *Ibid*, p 25.

[30] *Ibid*, pp 26, 31.

[31] *Ibid*, p 32.

[32] *Ibid*, p 32.

[33] *Ibid*, pp 39, 40.

[34] *Ibid*, p 42.

[35] *Ibid*, p 43.

[36] *Ibid*, p 45.

[37] *Ibid*, p 46.

[38] *Ibid*, p 47.

[39] *Ibid*, pp 49, 50.

[40] *Ibid*, pp 51, 54.

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CHAPTER 5

SOVIET INFRARED

In considering the status of infrared in the Soviet Union two truths are soon apparent. The most obvious of these is the fact that information coming from behind the iron curtain is exceedingly meager. It is recognized generally that Soviet counter-intelligence is unsurpassed and greatly excells that of our own. Hence, what is offered here must be accepted with due consideration to the limitations imposed by this committee's inability to possess complete and up to date knowledge of infrared in the Soviet Union.

However, proceding from known information, meager as it may be, and by careful analysis, checking and rechecking of many bits of information it is possible to present a reasonably accurate picture of infrared presently in the hands of the Soviets.[1]

The second most obvious deduction from available information is that the majority of Soviet infrared equipment either presently in use or under development is patterned after German devices.

Having accepted these two premises, let's examine what we do know about infrared and its development in the U.S.S.R.

Though sources vary in dating Soviet military applications of infrared, it is conceded generally that the first authenticated use of infrared by the Soviet Army occurred in the Finnish Campaign of 1940. In this instance infrared was utilized in perimeter defenses and was employed as a warning system linked to automatically controlled machine gun fire.[2] A description of the exact mechanics of this application of infrared is not available and no other similar mention of this particular use of infrared has been obtained.

In absence of contrary reports it is deduced that the Soviets possessed no vehicular or weapon mounted infrared devices at the close of World War II. It is reported, however, that the Russian Armed Forces became exceedingly interested in the applications of infrared after several night engagements with the Germans in which the Soviets were severely beaten. German successes were attributed to the use of infrared gunnery equipment. An unconfirmed report credits a small German force with the destruction of sixty-seven Russian tanks in a single night engagement.[3]

If credence can be accorded these reports, which, in some measure at least, appear to be true, it is obvious that Soviet interest in infrared was heightened greatly by the capture of large

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quantities of German infrared equipment at the close of World War II. Some reports reveal that as much as five hundred to one thousand night driving and night firing devices were captured at one time.[4] The quantity of such captured material is not particularly important except that it indicates German progress in being capable of large scale production requiring extensive facilities and numbers of qualified personnel. More significatnt than the capture of manufactured material is the seizure of factories and scientists which took place when Germany was defeated.

While it is considered desirable to be acquainted with Soviet infrared equipment in some detail, the meagerness of information mentioned previously precludes such a presentation. The most this committee can offer is a brief discussion of German infrared devices which passed into Soviet control during and after World War II. Some sources have provided mile hints that more explicit knowledge of Soviet equipment and infrared development exists. However, it must be concluded that if available, the security classification of such information prohibits its wide spread dissemination. It is emphasized that suspected knowledge of such information is pure conjecture on the part of this committee.

It has been observed that the Germans made considerable effort during World War II to put near infrared equipment into the field. German army units were equipped with a complex system for night driving. Tanks were equipped with infrared telescopes that permitted the tank commander to view scenes several hundred yards ahead and to direct fire against unsuspecting targets.[5] It is reported that recent Soviet developments have been concerned with the manufacture and use of a reflecting mirror which permits dual observation in tank night driving equipment. This modification would, of course, tend to increase the capabilities of vehicular equipment for night operations.[6]

In addition to night driving and night gunnery devices, it is quite certain that practically all infrared techniques developed by the Germans are known and have been or are being exploited by the Russians.[7]

These techniques include applications of infrared in photography, detection of aircraft by infrared emissions from their exhausts, uses in communications systems and guided missile seeking devices. One of the outstanding infrared devices developed by the Germans was the so-called WPG Geraet, or heat radiation finder, which was installed along the French Coast overlooking the Channel. These heat detectors were able to observe all allied shipping in the Channel and even detected the Allied invasion fleet when because of our jamming, the German radars were incapable of doing so.[8] Attention is

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invited to these developments, not because they apply especially to INFRARED FOR ARMOR, but because they indicate the magnitude of equipment, facilities and knowledge that came into Soviet hands in 1945.

One of the more enlightening if not too well confirmed reports of actual Soviet equipment comes from a former prisoner of war. This source has described the mounting of 16-inch infrared searchlights on Soviet T-34 Tanks and the use of 30-inch infrared searchlights with what appeared to be infrared range finders. This latter equipment was alledgedly mounted on Russian type half-tracks.[9]

With earlier mention that Soviet counter-intelligence surpasses our own it may be appropriate to note that Soviet collection of information is enhanced by our own either intentional or inadvertent dissimination of information, particularly information bearing on our scientific accomplishments.

This observation is pointed up by the almost daily notice of exposure or compromise of scientific or military information which for obvious reasons may be damaging when in hands of any potential enemy. A specific example in point is the statement of a German scientist formerly employed by the Soviets. This individual has stated that "US publications form the medium of scientific information exchange and actually influence research and development projects. German scientists learn to rely on United States publications which are rapidly distributed whereas German publications are difficult to obtain."[10]

In view of the wide disemination our own scientific developments receive and taking into account the great affinity the Soviets have for the collection of such data it must be assumed that the Russian Armored Forces are fully aware of our infrared potential. Being aware of our capabilities as concerns infrared they must be expected to have developed counter equipment and counter techniques to reduce the effectiveness of our uses of infrared.

A recently discovered countermeasure concerns samples of Soviet Army uniforms which upon testing were found to have a low degree of infrared reflectance. Even though current information indicated that this discovery of infrared proof clothing was an inadvertent accident it is obvious that individuals wearing such clothing would be more difficult to detect through the use of our present infrared means.[11]

Undoubtedly, Soviet activity in the field of camouflage against infrared detection was and continues to be stimulated by German achievements during World War II. It has been observed that the Germans went to extreme lengths to develop infrared camouflage dyes and paints in

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order to protect their equipment and personnel against the expected use of active infrared devices by the allies.[12]

We have observed that practically all infrared techniques and equipment developed by the Germans are known and are being exploited by the Soviets, however, more recent reports indicate that the Russians have attained a large measure of self-sufficiency in this field. In this connection, it appears that most German scientists in Soviet hands are now confined to basic and applied research and work on infrared components.[13] The most sound basis for this contention lies in the words of a German electronics expert formerly working under Soviet control. This person has stated in substance that few German scientists in Russia are ever admitted into the "inner sanctum" of military development; rather many Germans have been released from the Soviet area and have been sent into East Germany where they are expected to build a pool of scientific and technical "know how" upon which the Soviets may turn for solution of specific problems.[14]

To date all available reports indicate that Soviet endeavors in the field of infrared have been pointed toward developments in the near infrared regions. This field, though somewhat limited, encompasses the use of infrared as night viewing devices both as an aid to night movement of vehicles and as an aid in the aiming and firing of all types of weapons. It also involves the detection of near infrared and subsequent countermeasures against our use of near infrared equipment.

At this writing the only revealation of Soviet interest in the far infrared region appears in the British claim that the Joseph Stalin 3, a Soviet tank of post war design, is so well shielded that under running conditions there is no exposed surface area of the tank which emits heat of more than twenty-five degrees Centigrade.[15] Though unconfirmed this report may indicate Soviet awareness of our efforts in the field of far infrared. It might also indicate Soviet knowledge of the great heat output of our own current family of tanks and armored equipment.

From the above it might be supposed that it is unlikely that the Soviets have made great strides in the development of far infrared equipment for ground operations. But it must also be conceded that in the event of war with the Soviets in the immediate future, the Russian Armed Forces may be expected to utilize in quantity near infrared combat devices. It is reasonable to expect also that these devices will be improved patterns of German World War II equipment. "The known Soviet emphasis on tank warfare may be expected to achieve additional tactical significance in night operations by extensive use of tank mounted infrared devices."[16]

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Because of its brevity, this chapter is tendered somewhat apologetically. Its major purpose, however, has been to emphasize that the Soviets do possess and can be expected to use large quantities of ground combat infrared equipment. In the event of war with the Soviet Union the Armored commander must expect large scale use of infrared devices both in their active and pssive capacities. It is established that the Soviet Armed Forces have developed equipment and techniques of employment which may permit even greater capitalization of their reputed inclination for night combat.

The possibility of large scale use of infrared as an aid in all aspects of night warfare by the Soviets poses dangerous threats to our success in the event of hostilities. Un-preparedness against such ground fighting equipment may cause tactical disadvantages of grave consequence.[17]

It is concluded then that our tactical concepts should include interception and location of enemy infrared sources. Our training must encompass individual and unit camouflage against infrared and it must include battlefield illumination and tactical control of ground weapons in night engagements. Its object should be to counter Soviet use of infrared by avoiding surprise at its use and to develop understanding of effective countermeasures in the event that it is used.

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[3]Appraisal of Russian Infrared Developments, by Panel on Infrared, Working Group on Foreigh Intelligence (Washington: Department of Defense, 20 May 1950), p 3.

[4]Ibid, p 3.

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[5]An Introduction to Military Infrared Techniques, prepared by The Panel on Infrared, Committee on Electronics (Washington: Department of Defense, 1 March 1952), p 44.

[6]Op cit, Soviet Army Engineers, pp 6, 4.

[7]Op cit, Appraisal of Russian Infrared Developments, p 2.

[8]Op cit, An Introduction to Military Infrared Techniques, p 60.

[9]Soviet Infrared Potential, by Army Map Service, Corps of Engineers (Washington: Department of Army, January 1953) p 17.

[10]Op cit, European Infrared Developments, p 2.

[11]Op cit, Soviet Army Engineers, p 5,

[12]Op cit, Soviet Infrared Potential, p 21.

[13]Ibid, p 2.

[14]Ibid, p 3.

[15]Ibid, p 3.

[16]Op cit, Soviet Army Engineers, p 6.

[17]Op cit, European Infrared Developments, p 3.

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CHAPTER 6

TACTICAL CONSIDERATIONS

SECTION I

INTRODUCTION

General Carl von Clausewitz, in his Principles of War, has said that warfare has three main objectives. These objectives are: (1) To conquer and destroy the enemy, (2) To take possession of his material and other sources of strength and (3) To gain public opinion. He has further said that there are certain rules that must be observed in order to accomplish these purposes. <u>One of these rules is never to waste time.</u>

For centuries it has become customary that, with the coming of darkness, armies stopped to lick their wounds, resupply, perform necessary maintenance and rest in preparation for continuation of its mission on the following day. Raids and patrol type action were conducted at night but night attacks of any magnitude were restricted because of rather apparent limitations.

In more recent years much has been done to provide the necessary illumination required to conduct successful night attacks. The ability to "see" at night with the aid of artificial illumination, infrared devices and techniques and other aids may provide us with the ability to take advantage of time that had not heretofore been fully utilized. Today and in the future, we must take full advantage of every opportunity whether it be during periods of daylight or darkness.

It has been said that Armor is the arm of decision. Its fire-power, armor-protection and shock action provides a commander with the means to achieve the ultimate goal - destruction of the enemy and his will to fight. The ability for armor to conduct successful night attacks is dependent on many factors. Chief among these is surprise and control. Tanks cannot obtain surprise by stealth; surprise must come from secrecy and from the speed and shock with which the attack is delivered once it has been launched. The possession of equipment which can aid armor in conducting successful night attacks may have considerable bearing on the outcome of any future engagement.

Section II. ILLUMINATION IN BATTLE

The object of battlefield illumination is to provide friendly troops with the advantage of daylight or moonlight and at the same time to impose conditions of darkness on the enemy. The application of infrared techniques is one method of battlefield illumination. Another and effective method of illumination is provided by the use of standard beach defense searchlights. However, the element of surprise is not considered as great with the visible light provided by the searchlight as might be with the invisible light of infrared.

The employment of infrared must be so as to deny or minimize the element of rusprise from a night attack by the enemy and to strengthen the defense by making aimed fire practicable. The use of infrared could provide for greater control and permit ease and rapidity of movement on the battlefield at night.

Section III. FACTORS GOVERNING EMPLOYMENT

The following factors, which may govern the tactical employment of tanks equipped with infrared devices, have been determined from tests discussed in previous chapters.

Capabilities

The IR-equipped tank, in addition to the characteristics of a normal tank, also possesses the following capabilities:

1. The IR-equipped tank can be used in offensive and defensive roles by day or night. The installation of the IR equipment will not prohibit the employment of the tank in its normal role. Thus, it would not limit the tank to employment in only special operations.

2. The tank crew would be able to detect and bring aimed fire to bear on enemy troops without the use of visible light radiations.

3. The illumination sources of infrared cannot always be detected without the use of special equipment by an enemy, however, there is a visual security range associated with each source.

4. The crew of an IR-equipped tank can detect targets at ranges from 400 to 600 yards depending on conditions of weather and terrain.

5. The equipment would enable the user to gain surprise over the enemy providing the noise associated with the power generators could be muffled or reduced.

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6. The method of installation would permit the tank commander and the gunner independent operation throughout 360 degree traverse.

Limitations

There are certain limitations that must be considered that bear on employment of an IR-equipped tank.

1. Direction at night is difficult to maintain without adequate preparation.

2. Supplementary troops, Armored Infantry or Infantry, must also have special equipment in order to take full advantage of the IR illumination.

3. Coordination with adjacent or supporting troops will be difficult to maintain.

4. Noise is associated with the power plants which are required for the illumination source.

5. Fog, smoke or dust raised by vehicles, shell fire or chemicals materially reduce the seeing range of IR.

6. Camouflage is particularly effective against IR vision.

7. An enemy equipped with an IR viewer can see an IR source at long ranges.

Section IV. CONSIDERATIONS FOR EMPLOYMENT

Offensive Operations

Night attacks are generally characterized by a decrease in effectiveness of aimed fire, difficulty of movement of both men and vehicles and difficulty in maintaining direction.

The employment of reliable infrared equipment in night attacks by armor, would greatly improve its capabilities in this type of operation. The psychological effect of tanks on the enemy would be improved because of increased mobility under blackout conditions. IR would facilitate preliminary reconnaissance and could be a definite aid in maintaining direction and control. Thus, troop leading would be enhanced by the ability of a commander to better observe the conduct of the operation. Infrared gunnery devices,

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when augmented by supplemental infrared searchlights, would facilitate the detection and destruction of enemy targets by these means. Direct fire could be brought to bear on targets up to ranges of 500-700 yards with present equipment. It would be desirable to increase this range up to 1,000 yards. It may be expected that improvements in current IR driving and gunnery equipment will contribute materially to the successful conduct of night operations by armor.

Defensive Operations

In defensive operations, the primary importance of infrared lies in its ability to detect an enemy threat or his use of infrared equipment. IR could assist in the organization of a defensive position by aiding reconnaissance and permitting a more effective sighting of weapons. Enemy patrol activity, infiltration or night attacks could be detected earily by security elements. This would provide a psychological and a physical aid to the defenders.

Night counterattacks, using IR equipment, could be launched with greater speed and violence which would increase the possibility of early success.

Night Marches

Under favorable weather and road conditions, units equipped with the infrared driving equipment could make effective rapid moves behind the security of friendly lines. Thus an organization, equipped with the infrared driving equipment, could complete a move in less time than a similar organization using the standard blackout driving equipment. This would improve the time factors in executing night moves and would permit longer moves under the cover of darkness. This capability enhances the possibility of surprise, insures more efficient movement in terms of traffic control, crew and driver safety, unit march control and further insures better tactical dispersion on roads and routes.

Countermeasures

Countermeasures are those precautions taken to minimize or restrict the advantages of infrared employment by the enemy. Such measures as protective paints and dyes, camouflage clothing, use of natural vegetation and smoke are some of the more common measures. Countermeasure tests have been summarized in Chapter 4 and, therefore, requires no further elaboration at this time.

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Maintenance

In an armored unit, maintenance is always a problem of paramount importance. The adoption of infrared equipment will materially add to the work load of not only the crew member, but the company and battalion maintenance sections. An examination of the maintenance problems incurred in recent tests indicate that existing maintenance facilities and personnel available at first and second echelon levels are insufficient to handle the increased burden. Some maintenance difficulties created by the adoption of infrared have been presented previously. A resume of these difficulties includes such factors as the need for advanced technical and mechanical knowledge and ability. The relatively unbalanced ratio of maintenance requirements as opposed to operational benefits impose further limitation.

In those cases where an armored unit is equipped with both gunnery and driving devices, it is considered necessary that maintenance sections be augmented by additional qualified personnel.

Training

Upon the adoption of infrared driving and gunnery devices it would be necessary for armored units to undergo an extensive period of training. One source has stated that approximately three or four months of IR training would be required to qualify personnel for combat operations. It is the considered opinion of this committee that the impact of this additional training need not lengthen materially, the overall training cycle as it is believed that the bulk of IR training could be accomplished concurrently with other subjects.

Section V. SUMMARY

In this chapter certain considerations have been presented that bear on the employment of infrared for armor. It should be pointed out that these considerations are based on tests conducted on existing equipment and may be affected by further development. The tactical employment of infrared may have a great deal of influence in the conduct of successful night attacks and it is, therefore, imperative that armor posses the maximum ability to fight at night.

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CHAPTER 7

CONCLUSIONS AND RECOMMENDATIONS

As a result of the study outlined in the previous chapters, it is possible to draw certain conclusions with reference to the applications of infrared as an aid in night operations for Armor. The conclusions drawn by the committee are necessarily based on reports of tests, official documents and personal interviews. This is due to the fact that the equipment discussed was field tested prior to the time that the committee became engaged in this study.

Conclusions

Based on this study the committee concludes:

1. That infrared possesses certain desirable characteristics that may aid materially in the conduct of night operations.

2. That the infrared tank driving equipment, with minor modifications, is deemed acceptable and should be standarized and included as an item of issue to armored units.

3. That the infrared tank gunnery equipment, in its present form, is not considered satisfactory. It does, however, possess sufficient merit to warrant further field testing.

4. That the infrared driving equipment for wheel vehicles has proven to be of tactical value. With the exception of the drivers in-line viewer, it has reached a stage of development to qualify it for adoption by The Armed Forces.

5. That the military use of near infrared is subject to countermeasure. A well trained enemy equipped with infrared detecting devices may nullify the advantages of secrecy and surprise.

6. That the present infrared warning equipment is not perfected and that continued development is necessary to meet the need for devices which will provide warning of enemy approach.

7. That the adoption of infrared equipment would have a noticeable effect on the training program and the

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maintenance requirements of an armored unit. In both cases, additional time and personnel would be required to achieve maximum results.

8. That the USSR is in possession of and has the capability of using large quantities of near infrared ground combat devices in the event of global war.

9. That unsufficient evidence is available at this time to permit the committee to draw specific conclusions with respect to a basis for issue or determination of concepts of employment.

It is the considered opinion of this committee that infrared possesses sufficient military potential to justify further investigation. It is considered that full benefits have not been realized mainly because of equipment inadequacies. Expectations for greater achievements in the field of infrared will be realized only by vigerous and positive action in research and development.

Recommendations

In view of the aforementioned conclusions, the committee recommends:

1. That recommendations for the modification of existing equipment as set forth by AFF Board No. 2, as indicated in Chapter 4, be adopted.

2. That additional tactical and operational tests be conducted under less optimum conditions than those that existed at Camp Irwin, California.

3. That a program be initiated immediately to indoctrinate combat troops in basic countermeasures which may be employed to minimize the effectiveness of an enemy's use of infrared.

4. Assuming that the IR driving equipment will be perfected and accepted as an item for general use in combat units, it is recommended that early consideration be given to the implementation of an infrared driver training program.

5. That research and development be directed towards the following:

   a. Increased ruggedness and reliability of tank gunnery equipment.

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b. Reduction in size and weight of infrared sources.

c. An increase in effective seeing range of both driving and gunnery equipment.

d. An overall increase in both visual and audible security.

6. That direct searchlights be considered as an interim aid for tank gunnery until such time as the development of IR gunnery devices will assure comparable performance.

7. That the Armored School include in its curriculm for officer classes, a unit of instruction on infrared and its military applications.

The past few years have seen many significant changes in the science and art of war. The principles, however, remain unchanged. Among the interpretations of these principles is the thought that continuous and unrelenting pressure against an enemy is the best assurance of his early defeat. A natural assumption arising out of early success in war is that the more quickly an enemy is made to yield, the less costly in terms of lives and material will be the victory.

The inability to wage effective war during the hours of darkness has detracted from the concept of constant pressure. The search by American scientists to create new means of overcoming this difficulty has resulted in the development of infrared.

Though its full potential has not been achieved, research and development should be continued to capitalize on the inherent characteristics of infrared to provide armor with the maximum ability to fight at night.

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13. Letter, OCAFF to AFF Board No. 2, file: ATDEV -5 400.112(C), Subject: "Service Test of Near Infrared Tank Driving Equipment," dated 26 January 1950.

14. Letter, OCAFF to ACofS, G-4, Logistics, file: ATDEV-5 413.6/91, Subject: "Test of Infrared Tank Driving Equipment (3-6-2-2)," dated 4 June 1951.

15. Letter, OCAFF to AFF Board No. 2, file: ATDEV-5 415.6/143, Subject: "Leaflet II Troop Tests," dated 20 August 1951.

16. Letter, OCAFF to the Armored and The Infantry Centers, file: ATDEV-5 451.6/280, Subject: "Troop Test of Leaflet II Equipment," dated 12 January 1952.

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