FMFRP 0-58

Problems in Desert Warfare

U.S. Marine Corps

PCN 140 000580 00

DEPARTMENT OF THE NAVY
Headquarters United States Marine Corps
Washington, DC 20380-0001

19 October 1990

FOREWORD

1. PURPOSE

FMFRP 0-58, Problems in Desert Warfare, provides an overview of the problems encountered in desert warfare and some of their solutions.

2. BACKGROUND

a. Desert operations have much in common with operations in the other parts of the world. The unique aspects of desert operations stem primarily from deserts' heat and lack of moisture. While these two factors have significant consequences, most of the doctrine, tactics, techniques, and procedures used in operations in other parts of the world apply to desert operations. The challenge of desert operations is to adapt to a new environment.

b. FMFRP 0-58 was originally published by the Air Command and Staff College in 1982 as a student report. Major Allan R. Becker wrote the report. FMFRP 0-58 was published in August 1990 as Operational Handbook 0-58.

3. SUPERSESSION

Operational Handbook 0-58, Problems in Desert Warfare; however, the texts of FMFRP 0-58 and OH 0-58 are identical and OH 0-58 will continue to be used until the stock is exhausted.

4. RECOMMENDATIONS

Users' comments are valuable to improving this manual. Submit comments to --

Commanding General
Marine Corps Combat Development Command (WF12)
Quantico, VA. 22134-5001

5. CERTIFICATION

Reviewed and approved this date.

BY DIRECTION OF THE COMMANDANT OF THE MARINE CORPS

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DIST: 14000058000

REPORT NUMBER 82-0205

TITLE PROBLEMS IN DESERT WARFARE

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PREFACE

The author's purpose in studying desert warfare was to identify the basic, continuing problems the desert poses for military operations and make the results readily available to other military readers. The study was prepared from unclassified material to permit greater distribution and encourage its use at the unit level. In researching the study, the author found that most classified information on desert problems was classified due to the information source, not because of the actual problem itself, and that virtually all identified desert problems could be found in unclassified material. The problems discussed in the study should provide a basic level of knowledge for anyone who will be involved in desert operations and should present a point of departure for further study of particular, specific problem areas.

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EXECUTIVE SUMMARY

REPORT NUMBER 82-0205

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TITLE PROBLEMS IN DESERT WARFARE

I. Purpose: To identify the operational and logistical problems encountered by military forces operating in equatorial deserts and derive lessons learned that are applicable to today's forces.

II. Problem: Though desert warfare occurs frequently, United States military forces have not conducted large scale combat operations in the desert since World War II. The experiences of World War II and those of Arab-Israeli forces in 1967 and 1973 need to be studied, updated, and distributed so the basic lessons learned in these conflicts can be used to prepare United States forces for future desert operations.

III. Data: By the end of World War II the United States had developed a desert training program based on experience gained during the early years of the war. Much of the information taught in that program, such as basic desert survival, medical problems, and vehicle and aircraft maintenance procedures, remains valid today and provides a good starting point for this study of desert warfare problems. A second source of information on desert warfare is the recent Arab-Israeli wars which provide valuable information on the effectiveness of modern weapon systems. The final category of sources of information is the numerous government sponsored studies of the Arab-Israeli wars that focus on lessons learned in the conflicts. When these three major sources of information are studied together they provide a comprehensive overview of the problems encountered in the desert.

CONTINUED

IV. Conclusions: The 1967 and 1973 Arab-Israeli wars proved beyond doubt that high-intensity, sophisticated air and ground combat can be conducted in the desert with existing United States and Soviet equipment. The study concludes that the problems of desert warfare are merely inconveniences that hamper operations and can be overcome. This is the same conclusion that the United States Army reached in World War II. United States forces can learn the basics of desert living and fighting if properly trained and exercised in the actual desert environment.

V. Recommendations: The conclusions of this study indicate that virtually all problems encountered in desert warfare can be resolved by thorough training and the basing of units in the desert. Desert training should first be conducted in the classroom and then extensively exercised in an actual desert for long periods of time. In addition, United States forces should be based at locations where they operate daily under desert conditions, either in the southwest United States or overseas. It is only through actually living and training in the desert that United States forces can fully develop their desert warfighting potential.

Chapter One

INTRODUCTION

SIGNIFICANCE

Desert warfare is unique because of the hostile environment in which it is fought. Military operations in the desert are characterized by fluid, highly mobile, shifting battles among widely dispersed units. Engagements of ground forces are frequent, rapid, and often occur during darkness so opposing forces can avoid detection and the extreme daytime temperatures of the desert. Deserts are generally sparsely populated, relatively empty and undeveloped. Desert terrain lacks vertical development, as well as natural cover, and the hostile desert climate can severely impair the effectiveness of both men and equipment. Deserts of political and military importance exist throughout the world. They range from the Death Valley (below sea level) to the Sahara and Atacania (elevations over 10,000 feet). Desert surfaces vary throughout the world and include alluvial plains, bare rock, eroded rock-strewn areas, dry lake beds, salt flats, dry marshes, dry riverbeds, and shifting sand dunes. All deserts, however, are characterized by a lack of rainfall and many, the Sahara for example, experience the highest temperatures registered on earth.

This study of desert warfare problems concentrates on the Sahara Desert since it is a typical equatorial desert and extensive military operations have been conducted there in recent years. The Sahara is of particular interest to the United States because of the continuing instability in the region and the possibility of the U.S. Rapid Deployment Force deploying to the area. U.S. military experience in the Sahara goes back to World War II when air and ground operations were conducted across North Africa. Since then additional experience in desert warfare has been gained from the recent Arab-Israeli wars and U.S. training exercises.

A thorough understanding of the problems encountered in desert warfare is important to military leaders since the United States has not conducted large scale military operations in a desert environment since World War II. U.S. forces are trained and equipped primarily for a central European war and their only recent combat experience occurred in the jungles of Southeast Asia.

The terrain, climatology, and development of the desert is totally different from Europe or Southeast Asia and it causes the conduct of desert warfare to differ fundamentally. The differences result from ambient temperature extremes, lack of water, sand and dust, optical phenomena and illusions, terrain, and electromagnetic effects. These desert characteristics should be of prime interest to U.S. military commanders preparing forces for desert combat since they influence day to day operations, battlefield tactics, and regional strategy.

STUDY OBJECTIVE

The purpose of this study is to identify operational and logistical problems, unique to the desert, that U.S. forces are likely to encounter when deployed to a desert region. The study deals primarily with experiences of U.S. forces fighting in North Africa during World War II and with observations of the recent Arab-Israeli wars. The study begins with the biomedical problems the desert poses, followed by the electromagnetic, optical, and mobility problems. The final chapters concern aircraft maintenance and operation, desert survival, and conclude with the author's conclusions and recommendations. It is the author's hope that the historical experiences presented and discussed herein will provide other military readers additional insight into the nature of desert warfare and allow them to avoid the same problems and pitfalls experienced in the past.

Chapter Two

BIOMEDICAL PROBLEMS IN THE DESERT

BACKGROUND

The severe desert environment causes unique biomedical problems for military personnel. The extreme heat and low humidity of the desert affect human water requirements, acclimatization, physiological processes, and treatment of the sick and wounded. Other problems not directly associated with heat and humidity that also cause medical problems are diseases, insects, and chemical agents. Meteorlogical conditions, such as glaring sunlight, windstorms, and drastic daily temperature changes also cause medical problems. While the average temperature in the Sahara is about 52°F in the winter and 90°F in the summer, the extremes vary between 20°F and 130°F, with temperature drops of 25-50°F occurring at sunset. These temperature variations are greatest on the plains and tend to decrease at higher altitudes. (8:B-1)

To appreciate the seriousness of medical problems that may confront a deployed military force one need only look at the U.S. operation in Lebanon in 1958. In the first week of the operation, 1,100 of the 5,000 man force became ill with diarrhea. (8:B-2) In World War II whenever U.S. troops first entered a desert region, both in the United States and overseas, they encountered many heat casualties, By the end of the war, however, the U.S. Army concluded that environmental heat was just an additional handicap that could be tolerated and would not prevent effective military operations, provided preventative measures were taken. (8:B-2) The following discussion will address the most significant medical problems experienced to date in desert regions. It is extremely important for commanders at all levels to be knowlegeable of these medical problems and to conduct training and preventative measures to minimize their affects.

WATER REQUIREMENTS

Inhabitants of temperate zones do not appreciate the importance of water to everyday life as do the inhabitants of equatorial deserts. For example, there is no one word in the English language that means "to die of thirst", yet in Arabic there are eight degrees of thirst expressed in the language. Arabs express thirst in terms of simple thirst, burning thirst, vehement thirst, burning thirst with dizziness, and lastly excessive thirst -- the thirst that kills. (8:B-15)

In desert combat all movement is driven by the availability of water. A military column may run out of fuel and face no immediate danger, however, when the same column exhausts its water supply, the entire force becomes vulnerable. Troops in combat must be assured a plentiful supply of water if they are to conduct effective operations. Locating water in the desert is a major problem, since most subsurface desert water is highly mineralized and rapid, large scale purification facilities are normally not available. (8:B-15) The problem of locating water in the desert is so serious that Soviet desert combat units are assigned special detachments for drilling wells. (11:Ch 14)

Thermal regulation is the main physiological problem the human body encounters in the desert when water is in short supply. The body's primary physiological cooling mechanisms are sweating, panting, and salivation. Another, less important mechanism, is the distribution of heat through the blood system where it is dissipated by radiation, conduction, and convection. These mechanisms are reduced in effectiveness when ambient air temperature is higher than body temperature. When temperatures are high, however, evaporation increases and partially compensates for the inability of the other mechanisms to adequately function. (8:B-11)

The thermodynamics of sweating are simple. Water evaporates at any temperature and the evaporation process uses energy in the form of body heat. As sweat evaporates from the body surface the body is cooled. The body rotates sweating among the groups of sweat glands and the prevention of sweating on one part of the body normally increases sweating over another part of the body. The ability to sweat increases with acclimatization and sweating can occur at rates from 0.5 to 3.0 quarts per hour. (8:B-13) The sweating process is essential for body cooling and it can consume large quantities of water during strenuous activity in hot weather. For example, a man walking at 3 miles per hour in 100°F heat requires about one quart of water per hour to continue the evaporative process and maintain body fluids. In general, desert troops need up to 12 quarts of drinking water each day (Soviet planners allocate 8.5 liters per man per day) when engaged in hard physical activity. (11:Ch14) The water should be consumed in small amounts so water loss through excessive urination is kept to a minimum. Under normal climatic conditions, thirst is an adequate indicator of the body's need for water. In the desert, however, thirst is not an adequate means of determining the body's true water needs and dependence on thirst can lead to involuntary dehydration.

(8:B-16) The sheer bulk and weight of water required to support a military force constitutes a significant logistics problem. In addition, the water must be of sufficient quality to encourage drinking by the troops. (8:B-5)

The loss of body salt is a common side effect of sweating. The salt deficiency develops as salt is lost from the body through sweating and it is not possible to build up the body's salt supply in advance. To try to do so is not a good physiological practice. Standard military rations provide sufficient salt for normal desert activity. The Israeli Army did not use salt tablets during the Sinai campaign in 1973 and they experienced no cases of heat exhaustion. It is necessary to give special attention to men who manifest anorexia to ensure they intake sufficient amounts of salt. (8:B-16)

ACCLIMATIZATION

Unfortunately, an individual arriving in the desert from a temperate zone is initally unable to perform hard physical work until he acclimates to the desert. The acclimatization process can take from two to four weeks and in some cases it may not be possible. Acclimatization remains with an individual for about two weeks after leaving the desert, however, it will continually decrease during the period and should be considered when rotating troops into and out of the theater or granting leave. (8:B-6)

Acclimatization is necessary for the human body to gradually adapt to the desert's high ambient temperature and low humidity. The process also conditions the body to solar radiation, biting insects, blowing sand and dust, limited water, the sun's glare, optical illusions, and mirages that affect troops in the desert. In extreme instances the body must adapt itself for exposure to temperatures as high as 150-160°F. The acclimatization process eventually conditions the individual to tolerate the temperature, humidity, and solar exposure of the desert environment. (8:B-6) Rapid, successful acclimatization requires planned, disciplined periods of progressively longer physical activity in the desert climate. Exposure to heat alone will not promote acclimatization. The individual must engage in physical activity for acclimatization to occur. (8:B-23) The last, and perhaps most important aid to effecting acclimatization is to keep the troops in top physical condition. This allows them to better withstand the stresses of exposure to the desert environment and to engage in a more rigorous program of activity during the acclimatization period.

DISEASE

In preparing for World War II, U.S. medical officers were greatly concerned about the appalling list of diseases common to African and Middle Eastern deserts. (8:B-26) These diseases include malaria, yellow fever, typhus, small pox, dysentery, sandfly fever, and all forms of venereal disease. The diseases are transmitted by biting insects, prostitutes, and unsanitary messing conditions. (8:B-6) The lack of water in the desert is the major cause of the poor sanitary conditions found among the native population. Most water supplies are heavily contaminated and must be purified prior to consumption. The use of human feces for fertilizing is common and local fruits and vegetables must be thoroughly cooked before eating.

The most frequently encountered diseases among troops in the desert are malaria, gastro-intestinal diseases, and venereal diseases. Malarial control of the troops prior to deployment into the desert is extremely important. Once in the desert, malaria must be kept under control, since recurrent malarial attacks are extremely dangerous where water is in short supply. Malarial control in the desert will be difficult unless a new insecticide is developed that will replace the no longer used, but highly effective, DDT. (8:B-27) Gastro-intestinal diseases can be expected to cause the greatest manpower loss. For example, during the first week of U.S. operations in Lebanon, over 20 percent of the 5,000 man force contracted diarrhea. Gastro-intestinal diseases are usually transmitted through the food and water supply, which in turn are often contaminated by the lack of effective sewage disposal. Venereal diseases are the third major group of diseases common to the desert. In addition to the serious affects of the venereal diseases themselves, they make the patient more susceptable to heat injury. Venereal diseases can be expected to create a serious loss of manpower if effective indoctrination and control programs are not instituted and strictly enforced. (8:B-26-27)

Fever and dehydration also seriously compound the effect of heat stress on the body. Hormonal and catabolic responses to disease increase the body's requirement for water and change the physiology of the cardiovascular system. The body's response to thermal stress creates cardiovascular side effects deterimental to the body's overall efficiency, particularly during illness. The superficial blood vessels in the body dilate causing an increase in the overall capacity of the circulatory system. This forces the body to draw fluids from other parts of the body into the circulatory system in order to prevent hydraulic inefficiency. The effect of this fluid transfer appears as orthostatic insufficiency and decreased cardiac efficiency. The transfer of plasma water also causes an increase in the red blood cell and protein concentrations in the body. The sum effect of these body responses is increased viscosity of the vascular fluids which in turn creates an added burden on the heart. This additional strain on the heart can be fatal if the effects of heat stress are not relieved by the body's normal evaporative dissipation of heat. (8:B-14)

U.S. troops stationed in desert areas during World War II found insects such as flies, sand flies, mosquitoes, ticks, lice, and fleas very irritating and annoying. (7:17-18) They reported swarms of flies that appeared from nowhere and descended upon them causing constant irritation and scratching. The sand fly poses an even greater problem since it transmits sand fly fever. Concentrations of mosquitoes, potential malaria carriers, were also found along coastal areas with the insects making their appearance at dusk and then disappearing around 8 o'clock in the evening. (7:26) To protect deployed troops from disease carrying insects the troops must be issued ample supplies of insect repellent. The repellent should be generously applied around the neck, wrist, and ankles so that clothing openings may remain open and permit circulation of cooling air. (8:B-9)

FOOD PROBLEMS

The nutritional requirements of troops in the desert do not differ from those in other parts of the world, with the exception of the increased water requirement. The messing system includes all aspects of food processing, preparation, service and storage. It faces unique sanitation and spoilage problems, due to the desert climate, that make it a potential source of gastro-intestinal diseases. (8:B-27) The everpresent shortage of water compounds the problem of sanitation throughout the messing system, since large quantities of water are needed to clean and sanitize utensils.

At first it would appear that dehydrated rations are ideal for use in the desert, however, in reality they offer few advantages. The food processing procedure used to dehydrate and freeze dry foods leaves a residual bacteria population that is capable of rapidly multiplying when exposed to high temperatures. Rehydrated food that is allowed to stand, such as in large mess halls, can quickly spoil and become a source of dysentery. A further disadvantage is that dehydrated foods require water for reconstitution, and as a result increase the water transportation and distribution requirement. Lastly, troops do not accept rehydrated rations as readily as canned rations and the refusal to eat can become a critical problem since it sharply limits the body's salt intake. (8:B-28) As a result, individual meal service rations are advantageous at operating locations where sanitation problems may be encountered. The individually packed rations also eliminate the need for water and fuel used to clean the mess kits and eating utensils.

TREATMENT OF WOUNDED

The desert environment, combined with the mobile nature of desert warfare, creates problems in first aid treatment and evacuation of wounded. Since desert operations are frequently conducted by small, mobile, dispersed units, normal battlefield first aid may not be available. In addition, the dispersal of the units increases the problem of evacuating casualties from the battle area. In World War II it was learned that the standard military ambulance was not suitable for use in the desert. It had poor traction, was too hot inside, and it had too high a silhouette. The Jeep was quickly modified to carry litters and it provided an effective substitute for the ambulance. (8:B-17) In modern operations, troops will be heavily dependent on helicopters for evacuation of wounded from dispersed fighting positions. As a result of the dispersal of units and problems providing forward medical care, it will be necessary for combat troops to be highly trained in first aid.

In the desert, low humidity combined with unfiltered solar ultraviolet rays keeps the surface bacterial count lower than that of other areas, such as farms or urban centers. As a result, it is expected that a decrease in the frequency of secondary wound infection will occur in the desert, as compared to other regions. (8:B-18) The heat and low humidity, however, also have negative medical effects, such as accentuating shock and increasing the need for intravenous fluids.

Troops exposed to the desert environment for any length of time can expect a variety of ailments that effect their performance and comfort. During a recent British operation in Kuwait, the troops found that the sand laden wind caused many cases of conjunctivitis (inflamed eyes), epistaxis (nose bleeds), cracked and bleeding lips, and a few cases of sore throat. The British also found that skin creams and lotions were in great demand among the troops. (8:B-18)

CLOTHING

Clothing in desert regions serves different functions than it does in cold climates. In the desert, clothing provides protection from radiant and convective heat gain and also acts as a partial vapor barrier around the body. In deserts, loose clothing that permits extensive ventilation and is vapor permeable is best. Impermeable garments and equipment, such as bulletproof vest and some chemical warfare outfits, create serious barriers to the body's normal evaporative cooling process. The effects are compounded when boots, helmets, masks, and gloves are worn. As a result, troops should not be expected to engage in prolonged heavy activity when clothed in impermeable garments. (8:28)

In World War II, desert troops tightly closed all the openings and ventilation ports of their uniforms in an effort to prevent insect bites. This had the effect of eliminating the circulation of cooling air and increasing the body's heat load. Today, troops should be issued adequate amounts of insect repellent so all exposed skin around clothing openings can be heavily treated with insect repellent. This permits the clothing openings to remain open and thereby increases the circulation of air and evaporation of sweat. The net result is that the troops are able to function more effectively in high temperatures. In the British Kuwait operation, the troops found the need for a head covering which provided protection from the sun, would not be blown away by the wind, and could accomodate earphones and goggles. They also preferred loose trousers to tight ones for desert operations and found that sweat rags they used needed to be highly absorbent and, most important, nonabrasive. (8:B-18)

CHEMICAL WARFARE

Chemical warfare in the desert should be considered an everpresent possibility and troops must be trained and equipped to function in a chemical environment. The high temperature, low humidity, and meteorological phenomena of the desert combine to influence the employment and effectiveness of chemical weapons. The desert's high temperature increases the volatility of mustard and V agents (nerve gas) and the low humidity slows down the process of degradation hydrolysis. These effects cause an increase in the persistency of many agents when employed in the desert. The lack of vegetation on the desert's surface generally permits higher surface winds which will dissipate gas clouds more quickly than in other areas. At nighttime the usual temperature inversion will tend to trap chemical agents near the surface and make them more persistent between dusk and dawn. During daytime the reverse occurs and the use of chemical agents is prohibitive. As a result, the time of day chemical agents are employed is critical to their effectiveness and persistency.

During the daytime, both ultraviolet and infrared radiation affect the way chemical agents penetrate the body. Ultraviolet radiation produces hyperemia (redness) of the skin which allows easier penetration of V agents, while infrared radiation brings more blood to the skin causing increased penetration of both mustard and V agents. Sweating increases the blistering effect of mustard gases, while in the case of V agents it retards penetration through the skin because the V agents are soluble in sweat. (8:B-30-31) The need to wear chemical warfare equipment can be expected to significantly degrade morale since troops wearing impermeable outfits must function in a high humidity micro-environment that creates extreme heat loads which in turn cause fatigue, exhaustion, and inefficient performance.

Chapter Three

COMMUNICATIONS-ELECTRONICS PROBLEMS IN THE DESERT

BACKGROUND

The desert produces several unusual phenomena that affect the performance of communications-electronics equipment. The most significant is ducting, a phenomenon that causes radio waves to bend either toward, or away, from the earth's surface. A second phenomenon is multipath propagation. It reduces electromagnetic signal strength and affects radar performance. A third phenomenon is signal attenuation caused by dust clouds and the fourth is the static discharges that occur around radio antennas. The effects produced by these phenomena are well understood and occur in specific frequency bands. These phenomena are important to both commanders and equipment operators. They must understand the performance limitations the desert imposes on their equipment and exercise preventative measures whenever possible to minimize the degradation these phenomena cause. A brief discussion of each phenomena follows.

DUCTING PROBLEMS

The temperature extremes which occur between day and night in the desert frequently create severe temperature inversions. These inversions cause the index of refraction to be non-linear in the vertical plane. This inhomogeneity in the lower atmosphere causes an upward deflection, or ducting, of electromagnetic signal during the day and a downward ducting during the night. Ducting occurs almost daily in the desert, whereas in a temperate climate, such as Washington D.C., it occurs only 4.6 percent of the time. The effects of ducting are significant in the UHF, SHF, and microwave frequency spectrums. (8:17)

During the day, radio waves from ground stations are subrefracted upward and a vertical duct is created. Stations outside the direction and range of the duct receive either a faded, weaker signal, or no signal at all. This upward ducting is the primary cause of signal fading in the desert. Due to this fading, the radio horizon distance for an antenna in the Sahara is 1.8 to 5.5 percent less than for the same antenna operated in the United States. The variation in percent of reduction is due to the use of maximum and minimum monthly averages of the index of refraction in both the Sahara and the United States. Experience indicates that communication equipment operated in the Sahara Desert requires 4 to 8 db more than in the United States for equal coverage. (8:A-15)

Night ducting results in the opposite effect and can considerably increase radio and radar range. At first the range increase appears desirable, however, some tactical considerations tend to negate the advantages of the increased range. For example, increased radio range may transmit friendly communications well beyond normal radio range and make them subject to exploitation by the enemy. The increased range may also cause friendly radio coverage to overlap creating frequency congestion. Further, it is also possible that civilian communications from well outside the battle area may be received and mistaken for enemy jamming or intrusion. Any civilian signals received will also compound the frequency congestion problem. The extended range of radar signals produces undesirable clutter on radar scopes and makes target acquisition and tracking more difficult. A final problem is that radar operators may attribute the increased range to good radar performance and then be deceived when atmospheric conditions change and the effect of ground ducting is reduced. The experience of the equipment operator, on that particular system at that particular location, is the critical factor in determining whether ducting or equipment malfunction is occurring. (8:A-15)

MULTIPATH PROPAGATION

The non-linear index of refraction, caused by desert temperature inversions, also creates multipath signal propagation problems. The multipath propagation problems are centered in the C and S frequency bands and cause the loss of a large percentage of targets on early warning and GCI radars. In a United States government test conducted over a western desert, 83 targets flew controlled profiles 25 miles from the radar at altitudes between 1,000 and 4,000 feet above the desert. Test results showed that radar tracking loss occurred on 50 percent of the aircraft targets involved in the test. (8:17-18)

ATTENUATION

A third major communications problem encountered in the desert is attenuation of electromagnetic signals due to absorption by dust clouds. Electromagnetic attenuation becomes appreciable (0.2db per kilometer) in the X band and higher frequencies and is more pronounced when larger dust particles and denser dust clouds are present. In extremely dense dust clouds, attenuation also occurs in the lower frequency bands. (8:18) The most common source of dust clouds that affect military communications are moving vehicles and helicopters. Generally, the effects of electromagnetic attenuation are minimal for the frequency bands and ranges used for communication within vehicle convoys.

STATIC

A fourth phenomenon common to the desert is radio static caused by the electrification of dust clouds. The static results mainly from corona discharges from atennas and other metallic objects. The amount of static increases as dust cloud density and wind velocity increase. (8:A-7)

IMPACT ON MILITARY OPERATIONS

The phenomenon described in the previous paragraphs cause various degrees of degradation, including unpredictable performance, for many electronic systems. Understanding and anticipating these problems allows the military force to train for operations in a degraded electronic environment and also avoid tactical errors caused by misinterpretation of radar and radio performance. Of the four phenomenon described, ducting and multipath propagation are potentially the most serious problems. The remaining problems, attenuation and static discharges, have less impact on military operations since they are recognizable and can be accommodated.

The problems caused by signal ducting and multipath propagation are insidious; there is no way to detect when, or to what extent, they are affecting equipment performance. Changing atmospheric conditions determine the severity of the ducting and, consequently, the maximum range of a radar, or radio, signal will vary considerably through the course of a 24 hour day. Although the ducting effect is unpredictable, an experienced radar operator, familiar with the local radar scope picture, should be able to compensate for the increased clutter through frequent tuning and careful scope interpretation.

The effects of multipath propagation on radar performance are also insidious. This phenomenon appears in the C and S frequency bands and poses a serious limitation on the effectiveness of radars in those frequency spectrums. Radars in these bands should not be relied upon for early warning and GCI control in the desert.

Chapter Four

OPTICAL PROBLEMS IN THE DESERT

BACKGROUND

The desert is envisioned as an ideal optical environment. The openness of the terrain and lack of clouds often permit unlimited visibility. The excellent visibility of the desert, however, also creates disadvantages such as the inability to avoid detection by the enemy. The desert optical environment should be addressed in two basic conditions; the undisturbed desert and the disturbed desert. In the undisturbed desert, optical phenomena are natural effects caused by solar heating, whereas in the disturbed desert they are primarily meteorological or man-made. The major optical advantage of the desert is visibility and it is primarily due to the lack of trees, vegetation, and clouds. The major disadvantage is dust and in most desert battles the problem is usually too little visibility rather than too much. (8:E-5)

THE UNDISTURBED DESERT

In the undisturbed desert, optical problems result from heating of the desert surface and convection in the atmosphere immediately above the surface. This solar flux and the low thermal conductivity of desert soil results in high surface temperatures which in turn cause a strong convective motion of the air over the surface. This air motion causes heat shimmering and the appearance of a haze along the desert surface. The haze severely restricts vision in the horizontal and its effects vary with wind and the surface dust content. During World War II, visibilities as low as 400 yards were common in the haze and aircraft could not be detected from the ground unless they passed nearly directly overhead. (7:29) Because of the haze, the Israelis found early morning the ideal time for photo reconnaissance missions. Interestingly, however, they flew most of their reconnaissance missions at noon when the Arabs were relaxing and taking a midday rest. (8:E-6)

Solar radiation heats the desert surface and causes shimmering. This shimmering reduces the resolution and stability of small images and makes it difficult to focus or precisely align optical instruments on them. Surface glare is another problem of the desert. It produces an effect similiar to "snow blindness" and hampers the effective use of optical instruments. The combined effect of glare, haze, and shimmering is to blur the edges and fine detail of images making detection, identification, ranging, and tracking almost impossible. These effects also cause problems in such basic functions as aiming a rifle at a small target in the desert. (7:13)

THE DISTURBED DESERT

By far the most serious impediment to optical functions in the desert is dust. In battle the dust problem becomes very serious because of heavy vehicle movements, shell bursts, muzzle blasts, and smoke generated by the battle. The Israelis found dust and smoke to be the major cause of optical problems. Problems occurred when troops attempted to acquire targets, aim, fire, and follow tracers. (8:E-8) Visibility in battle was so poor that Israeli tank commanders fought with their heads out of the hatches to overcome the limited visibility. The fact that they continued to operate with open hatches after heavy casualties among tank commanders indicates the seriousness of the visibility problem in the battle area. (8:E-8) Dust also causes considerable physical damage to optical equipment by deterioriating lens coatings and filtering into all orifices and openings causing substantial damage to bearing surfaces. The Israelis state that the very fine, highly abrasive dust of the Negev and Sinai Deserts deteriorates optical equipment so rapidly that they must be recoated and polished every 18 months. (8:E-10) The combined effects of dust and heat also accelerate the deterioration of rubber componets, such as eye pieces and lens covers. Combat troops must be trained to operate their weapons in a heavy smoke and dust laden environment if they are to obtain maximum performance from their weapons in the dusty desert environment.

Desert sandstorms and dust storms are another source of optical problems. Sandstorms, sometimes misidentified as dust storms, consist of large particles and extend only a few feet above the desert surface. The smaller particles of dust storms sometimes reach several thousand feet into the air. Dust storms can produce zero-visibility and last for several days at a time, severely limiting combat operations and reconnaissance. In World War II, Rommel frequently used dust storms to conceal his movements and preparations for attack. Blowing sand and dust also create a "sandblasting" effect that deteriorates optical equipment and damages lenses. Optical lenses should, therefore, be covered at all times when the equipment is not in use. (8:E-8)

Thermal infrared imaging systems have been tested for use in the desert's haze and dust environment, but have not performed well due to attenuation and scattering by silicate compounds unique to desert dust particles. Tests conducted from aircraft have been significantly more successful than ground tests, due to the much smaller amount of dust that must be penetrated when viewed from directly above. The tests suggest that haze and dust effects may not be as serious as previously thought. (8: E-11-12)

VISUAL REFERENCES

The final optical problem is the lack of visual references, such as hills, trees, vegetation, that can be used to help pinpoint a location. This poses a potential problem for artillery, forward air controllers, pilots, and gunners since it will be difficult to visually reference, or acquire, a target that is momentarily sighted against the barren desert background. Ground troops would be wise to use this to their advantage and intentionally establish their positions away from visible features that could be used as fire control reference points by the enemy.

Chapter Five

MOBILITY

BACKGROUND

The vast expanse of maneuvering terrain causes desert warfare to be very fluid and makes mobility a prerequisite for effective combat operations and logistical support. In the desert, as in any other war zone, the ability to concentrate superior firepower at the decisive time and place normally determines the victor. Because of the openness of the desert and wide dispersal of units, vehicular mobility determines the ability to mass and engage forces. Desert terrain varies from salt flats to impassable mountains and vehicles designed for one terrain or purpose may be significantly less effective when used on different terrain. For example, wheeled vehicles operate well on paved roads and salt flats, but are severely restricted on soft sand or bedrock fields. Tracked vehicles, on the other hand, operate on virtually all surfaces, but cannot achieve high rates of speed on any. In general, tracked vehicles are best for desert combat operations and wheeled vehicles are best for rear area support functions where they can operate on the existing road network. (8:C-1,6)

MOBILITY PROBLEMS

The major mobility problem in the desert is controlling the contamination of engines caused by airborne dust particles. Dust is generated by the wheels and tracks of moving vehicles and is distributed by the air currents surrounding the moving vehicles and natural desert winds. In the desert's low humidity, dust particles lack cohesiveness and once disturbed the smaller particles remain airborne for extended periods. The airborne particles are ingested into engine air filters and cause the filters to clog, restricting air flow in to the engine. When filters are not properly maintained poor engine operation (reduced power, excessive fuel consumption, overheating and premature engine failure) results. U.S. military specifications stipulate a service life of at least 20 hours for air filters, however, most U.S. vehicles do not meet this specification. For example, the Army's 2½-ton truck (M44A2) will require air filter servicing every 2-5 hours when operated in zero-visibility conditions in the desert. (8:C-4) Another problem is higher engine operating temperatures caused by dust accumulations on radiator fins and other componets. The dust acts as insulation which drastically reduces cooling efficiency and causes overheating or engine failure. Besides degrading the efficiency of heat exchangers, the dust particles cause abrasion of fan blades and suspension componets, and reduce the visibility of vehicle drivers. (8:C-17)

Another series of vehicle problems are caused by the desert's high ambient temperatures (over 110°F). The cooling and lubricating systems of most U.S. vehicles are marginal, to inadequate, at the 125°F temperature stipulated in the military specifications. Performance of these systems is further reduced when dust and oil are allowed to build-up on vehicle heat exchangers and other componets. The combination of high ambient temperatures, inadequate cooling systems, and rough terrain often necessitate that vehicles be operated in lower gears. As a result, maintaining engine operating temperature within limits, not actual engine power, is often the limiting factor in operating vehicles in the desert. High ambient temperatures also cause a loss of rated engine power that can be significant when combined with high pressure altitude. A one percent loss of power occurs with each 10°F temperature rise (most engines are rated at induction air temperature of 60°F) and an additional three percent is lost for each 1,000 feet above sea level. In the desert, at an altitude of 2,000 feet above sea level with the engine intake air (under the hood) temperature ranging from 200-250°F, a typical vehicle experiences a 20 percent loss of rated power. (8:C-23)

Standard military vehicle maintenance procedures are adequate for use in the desert, provided the maintenance depot is air conditioned, or as a minimum it is supplied with filtered air. Field maintenance is more difficult, but it can be performed if certain precautions are observed. Vehicles should be allowed to cool for a minimum of four hours and it may be necessary for mechanics to wear heavy gloves when handling componets in order to avoid burns. When conducting field maintenance extreme care must be exercised to avoid introducing dust or sand particles into critical componets.

Chapter Six

AIRCRAFT MAINTENANCE AND OPERATIONS IN THE DESERT

AIRCRAFT MAINTENANCE

Aircraft maintenance in the desert is an endless struggle against sand and its effects. In 1944, U.S. aircraft mechanics enroute to North Africa were taught:

> Sand is the foremost foe of your equipment. Not only the sand on the terrain, but the dust found in suspension in the air. Whenever the hard crust of the desert has been broken, there is dirty work afoot. There is the deadly scratching, gouging action of quartz-hard grains and pebbles, and the terrific abrasive qualities of dust with the fine consistency of talcum powder.... The life of an airplane and its parts is unbelievably short once you let sand and dust get the upper hand. (5:1)

The problems sand and dust cause aircraft are similiar to those they cause vehicles. The particles cause abrasion, clogging of filters, contamination of fluids, and deterioration of seals. Each of these effects are potentially disastrous, not only for the obvious flight safety reasons, but also because they reduce the combat effectiveness of the force.

When preparing a particular model and series of aircraft for desert operations, applicable maintenance technical orders should be consulted to determine any unique problems the aircraft may encounter. The technical data provides the approved hot weather and desert maintenance procedures. In addition, the following general maintenance rules should be observed when maintaining aircraft in the desert.

1. Locate maintenance sites on hard stands whenever possible, or on terrain where fine sand grains of high quartz content are at a minimum.

2. If possible, locate maintenance sites to the windward of abrasive, loose sand areas. Consider carefully the direction of prevailing winds and avoid locating maintenance sites in the path of blowing sand that results from disturbances

of the deserts surface.

3. When conditions permit, improvise some sort of shelter which will minimize sand interference with servicing. A canvas lean-to, a half-tent, an improvised nose hanger, or a sand-break around the airplane, placed to windward are effective.

4. Keep the maintenance site free of sand and dust.

5. During violent sand and dust storms, postpone repairs and service (if possible) until the storm abates. Do only such work as cannot be injured by dust or sand.

6. These general rules cover conditions peculiar to desert maintenance. Rigidly follow the detailed aircraft technical manual for normal servicing. (5:2-3)

The following general rules provide guidelines for the prevention of damage caused by sand and dust abrasion.

1. The most injurious action of sand and dust results from its adherence to oil-bearing surfaces. When mixed with oil, desert dust becomes an efficient grinding agent. Guard against it constantly, especially around close fitting parts or parts that work against friction. Clean, inspect, and lubricate regularly, frequently, continuously. This is a must.

2. Surfaces that must be lubricated should be cleaned of sand and dust, inspected, and re-lubricated (lightly) much more often than during non-desert operations. Many surfaces (normally lubricated in non-desert areas) can be best operated dry in the desert. They must, however, be cleaned of sand and dust and inspected as frequently as possible.

3. Lubricate sparingly and only where absolutely necessary. Sacrifice lubrication rather than risk the grinding, abrasive action of sand and dust.

4. On landing, immediately seal all openings on the aircraft with dust-proof covers and after engine shut-down immediately install the intake and exhaust covers. Keep all covers on the aircraft while on the ground. After servicing, replace seals immediately.

5. Do not lay tools on the desert ground. Every article, large or small, is either lost, stolen, or damaged when placed on the ground in the desert. If you must lay parts or tools on the ground, place them on a clean ground cloth or put them in a suitable clean receptacle.

6. Metal parts removed brom aircraft should be carefully cleaned, sealed in containers, and stored in lockers and bins away from sand and dust. (5:2-3)

In addition to the above rules, certain precautions should be observed when performing maintenance in high daytime temperatures. While the heat is uncomfortable, it poses no problems that cannot be overcome if some basic "heat facts" are kept in mind. First, surface temperatures are determined by the heating effect of the sun minus whatever cooling effect may occur due to the wind. When there is no wind, or the velocity is low, aircraft skin temperature will run between 1.4 and 1.5 times higher than the free air temperature. During Red Flag 80-4 in Nevada, ramp temperatures frequently exceeded 125°F. It was so hot that several men wearing steel toed boots blistered their feet and had to replace their boots with tennis shoes. (9:Ch 4) Whenever possible, aircraft should be parked under at least a partial cover to shade and cool the section of the aircraft under maintenance. In the shade the aircraft skin temperature will be somewhere between the free air temperature and 1.4 times free air temperature. In the daytime, metal surfaces of the aircraft will often be too hot to touch and maintenance personnel should be issued gloves or mitts that will permit them to handle metal tools or surfaces. Mats and pads should also be used to protect knees and elbows and it is also advisable to wrap tool handles with cord or tape to avoid burned hands. As a final precaution, whenever possible, maintenance on exposed aircraft should be scheduled for early morning, late afternoon, evening, or night, when the desert heat is less intense. (5:4)

AIRCRAFT OPERATIONS

Experience of the U.S. and its allies indicates there are no significant problems that inhibit aircraft from operating in the desert. High performance aircraft will, however, need to operate from sites with hard surface runways and suitable maintenance facilities in order to conduct sustained operations. Virtually all aircraft experience degraded performance when operated in the desert at high ambient temperature and high pressure altitude. For example, during Red Flag 80-4 the U.S. Air Force found the performance of the A-10 severely degraded when the aircraft was operated in the desert. The high temperatures and pressure altitudes reduces "G" available, increased turn radii, caused excessive airspeed bleed-off, and decreased the aircraft's overall effective and survivability. (9:Ch 2) The effects are well understood and are addressed in detail in each aircraft performance manual. (8:D-5) There are, however, unusual desert conditions involving sun, sand, wind, and visibility which call for pilot awareness and modification of techniques.

During preflight pilots and crewchiefs must keep in mind that aircraft surfaces exposed to the sun will be very hot. Both should wear gloves. Because running engines generate dust clouds, ground operating time should be kept to an absolute minimum and as many preflight checks as possible should be preformed prior to engine start. Once engines are running, pilots should minimize the use of power and avoid blowing dust and sand at other aircraft, personnel, or ground equipment. This holds true for all taxiing and in extreme instances it may be desirable to tow aircraft to the end of the runway for engine start.

After engine start, pilots must carefully monitor the temperature and pressure of the various lubricants, hydraulics and coolants on the aircraft. Avionics cooling will probably be inadequate during ground operations and it will be necessary to operate the avionics systems only after becoming airborne. The most logical approach to this problem is to briefly turn on the equipment for a ground check, then turn it off as soon as possible and not operate it again until airborne. Another ground problem occurs at the end of the runway where quick-check and arming delays create the potential for overheating and blowing dust and sand. The marshalling crewchief and the pilot must be aware of the location of each aircraft in order to avoid blowing sand or hot jet wash on other running aircraft. The effects of blowing sand on running aircraft are obvious. High temperature jet wash blowing on an aircraft will often activate aircraft temperature sensors, such as engine inlet duct temperature or radar cooling, and cause mission essential systems to fall off the line. The jet wash temperature problem will be significant during the heat of the day. Whenever possible, aircraft start, taxi, and takeoff should be staggered to avoid these problems.

Once airborne, the desert presents unique problems for the pilot. Visibility is extremely good, and as a result distances are very deceptive. Generally, an inexperienced pilot will underestimate range and should multiply his range estimate by a factor of three to compemsate for the good visibility. The intense, glaring sunlight of the desert is another problem and, tactically, it makes undetected enemy attacks a constant possibility. When on the offense, pilots should attack with the sun at, or near their back whenever possible. Attacking from the sun also eliminates most shadows that degrade optical weapon guidance and make visual target acquisition difficult for pilots. Though attack for the sun is generally a good rule, it should not be followed to the point of making tactics predictable. (5:9-10)

Dust storms also cause visibility problems over the desert. They rise as high as 8,000 feet above the surface and often reduce visibility to less than 100 yards. Dust storms are a factor in tactics, since maneuvering and suprise attacks often occur under their cover. They also provide concealment for withdrawing forces and evasive maneuvers. Intelligent use of moving dust can be a factor in tactics and may make a suprise attack or tactical withdrawal successful. Other visibility problems are caused by heat distortion. Heat distortion, the result of heat waves at the surface, causes images to shimmer and makes positive identification difficult. Heat distortion also affects depth perception during landing and causes pilots to flare too high. The depth perception problem can be minimized by using objects and references in the pilots periphereal vision to help judge height over the runway. (5:10)

HELICOPTER OPERATIONS

U.S. helicopters and V/STOL aircraft have only limited experience flying in the Middle East and North African deserts. The combination of high elevation and extremely high temperatures frequently requires heavy lift helicopters to use their absolute maximum performance to overcome the degradation of their lift capability. Operations with little, or no, excess power in the hot, elevated, arid areas, calls for steep, dangerous, landing approaches. Airborne sand and dust also create hazards during landing approaches and hovering. Sand and dust are picked up and circulated by the helicopter rotors and create local sandstorms that envelop the hovering helicopter. The pilot requires visual references to continue the hover, or land, and when they are lost in the dust cloud he must immediately transition to an instrument takeoff or risk loss of aircraft control. (5:32-33,37)

Helicopters and V/STOL aircraft experience excessive corrosion of engines, propellers, rotors, and other componets when exposed to sand and dust particles during takeoff, hovering, and landing. Sustained operations increases maintenance and spare part requirements for these aircraft because of the corrosion caused by this "sandblasting effect". Dust build-up on intakes and aerodynamic surfaces also affects engine and aerodynamic efficiency and must, therefore, be carefully monitored. (8:D-5)

AIRCRAFT GROUND PROTECTION

One of the most important lessons learned in the Arab-Israeli wars is the vulnerability of unsheltered, runway dependent aircraft. (6:46-47) In 1967, a full 98 percent of the Arab aircraft destroyed were destroyed on the ground, either parked on open ramps, in open bunkers, or taxiing toward the runway. (10:49; 3:199) Following the war, the Egyptians constructed twenty new airfields, each with multiple runways and hardened aircraft shelters. They erected bombproof hangers, dispersed their aircraft, and when the 1973 war occurred the Israeli Air Force was unable to destroy Egyptian aircraft on the ground.

(2:21; 12:Ch 5) The Egyptians also used decoy aircraft on their ramps in an effort to confuse the Israeli pilots; however, the Israelis attacked from such close range that they were usually able to discern which were decoys and not expend ordnance on them. (4:258) One Israeli officer credited their success in identifying decoys to both the poor quality of the decoys and good intelligence. He stated that on attacks near Ismailia some decoys were hit, but on the Sinai airfields, where intelligence was better, there were no mistakes. (1:85) The lessons learned by the Egyptians in 1967, and their total success in resolving the identified problems prior to the 1973 war, clearly highlights the importance and effectiveness of passive protection measures for aircraft on the ground.

SUMMARY

In summary, the problems caused by the desert environment vary from the normal only insofar as the natural characteristics of the desert emphasize the sun and suprise during flight. On the ground sand and dust are the major problems, however, they can be controlled through a well managed maintenance program. Pilots and maintainers who understand the desert can minimize it's negative effects and at the same time maximize the advantages the desert offers.

Chapter Seven

DESERT SURVIVAL FOR AIRCREWS

BACKGROUND

At the start of World War II U.S. airmen were poorly prepared for desert combat or survival. The Desert Training Center in the southwest United States proved of little value in training aircrews for the war in North Africa primarily because the program was based on limited survival experiences that occurred in United States deserts. The problem of survival in the North African desert during World War II was further compounded by the fact that no organized search and rescue force existed. Searches that did occur for downed airmen were planned and executed by their squadron mates when the battle situation permitted.

Following the war, the consensus among rescued airmen was that the survival training and briefings they received were woefully inadequate. The men were simply not trained or briefed on what to do when forced down in the desert. (7:1,28,32) The remainder of this chapter will discuss several specific aspects of desert survival experienced by airmen during World War II in North Africa, and include ditching and bailout, the survival environment, mirages and illusions, water, and signaling.

DITCHING AND BAILOUT

Desert surfaces vary greatly from eroded rock-strewn areas to dry lake beds. When faced with the decision to ditch or bailout, the pilot must carefully consider the terrain he is over. Although ditching is often possible because of the flat, barren desert terrain, ditching should be made prior to fuel starvation so that aircraft power is available when executing the forced landing. In World War II many pilots attempted to stretch their range prior to ditching and flew the aircraft until it ran out of fuel. After rescue, they all agreed that a power-on ditching was much safer than a dead-stick landing in the desert. (7:5) With today's high performance jet aircraft, ejection would be preferable to ditching in virtually all situations.

Sandstorms and high desert winds also cause problems for airmen forced to bailout. They found that parachute descents were particularly hazardous during sandstorms and they were often buffeted about and tossed in all directions by the winds. In one instance an airman was so badly peppered with flying sand and pellets that he could hardly stand when he reached the ground. Another airman's face and hands were raw and bleeding when he landed due to the abrasive effect of flying sand. Parachute landings were usually uneventful, although some serious sprains, bruises, and abrasions occurred when airmen descended into rough terrain. The desert of southern Libya and the Sinai caused the greatest number of minor injuries due to the numerous large rocks and boulders found in those areas. (7:4)

Once on the ground, airmen found it extremely difficult to locate other crew members or the aircraft crash site. In one instance a British bomber crew bailed out of their aircraft as close together as possible, however, in the four days that followed till they were rescued, none of them saw any of the other crew members. Another crew bailed out of their light bomber in a poorly planned manner and spread themselves over twelve miles of desert. Numerous other instances demonstrate the value of carefully planning for emergency bailout and in one instance a well planned bailout resulted in a crew of six men all landing within four hundred yards of each other. (7:4-5)

SURVIVAL ENVIRONMENT

The effects of sun and heat, combined with the lack of water, proved the most dangerous environmental factor that confronted downed airmen. The bright sun was hard on eyes, extremities, skin, and sunburned hands were reported as particularly painful. The daily temperature extremes of the desert were terribly bothersome. The daytime heat caused exhaustion and severely limited physical activity, whereas the bitter cold night limited sleep and caused exposure problems. (7:12,20,34) Dust and blowing sand were frequently mentioned as problems and the medical reports on many rescued airmen indicated mild to serious sinusitis, probably due to irritation caused by the dust particles. The men also complained of continuous sore eyes caused by the sun's glare and abrasions of the eyelids and eyeballs caused by blowing sand and dust particles. These airborne particles also got into ears, nostrils, and mouths and sometimes caused severe irritation. One survivor reported the abrasions on his eyes, caused by dust particles, reached the point where his eyes watered so badly he could not see, and when the watering stopped his eyelids were like emery cloth. (7:12,20) Many survivors talked of the need for sunglasses or goggles to protect their eyes from the sand and sun. Sunglasses intended for survival must be carried in a safe location, either in the airman's personal equipment or the survival kit, so they will remain with the airman through the bailout and landing.

Most desert survivors reported the presence of flies and other insects, even in remote areas. In one instance, flies were so bothersome in the middle of the day that rest or sleep was impossible. Another survivor reported he was not bothered by flies until be fell and scratched his arm; almost immediately flies appeared and he was unable to keep them away from the minor wound. Sand flies are even more troublesome due to their small size, painful bite, and the fact that they an crawl throught the finest nets. Sand flies often carry sandfly fever, however, their worst effect appears to be the constant scratching that results from their bites. Insect repellent is the best way to keep sand flies away since they are small enough to penetrate most mosquitoe nets. Mosquitoes should also be expected in the desert. The are reported to be particularly abundant near the coast and inland marshes. Desert survivors found little in the way of desert wildlife to bother them. Instead, the irritation and annoyance caused by flies, sand flies, ticks, mosquitoes, lice, and fleas proved to be the most significant problem and it was limited primarily to the daylight hours. (7:17,21,26)

MIRAGES AND ILLUSIONS

Mirages are common to the desert and pose a potential problem for survivors. They are caused by the uneven density of the air near the surface and appear as a sheet of water on the desert. Mirages cause problems primarily in travel since they make it difficult to judge distance and obscure the intermediate terrain that is hidden by the mirage. Mirages can be expected to hamper vision, navigation, and in some instances to magnify or conceal objects. Under these conditions visual acquisition of aircraft or vehicles is difficult as is trying to signal them. Though reports of mirages are very common, in most cases they were easily recognized as mirages and caused only minor difficulties. (7:13)

Another desert optical illusion is caused by atmospheric refraction and results in distant objects appearing closer than they actually are. The conditions and effects are similiar to those that cause electromagnetic ducting and when the conditions occur distant objects appear closer and objects below the horizon are visible. Under slightly different conditions atmospheric refraction causes light waves to reach the observer by two or more different paths, causing distorted or multiple images of the object. Illusions also occur at dawn and dusk. The most interesting of these is the false-dawn illusion that occurs when the sun's spectral light appears on the western horizon. The fact that the sun initially appeared in what was thought to be the west has caused many anxious moments for desert survivors. (7:13)

WATER

Few airmen can expect to land in the desert with an adequte water supply. In nearly all desert survival reports, airmen attempted to obtain water by searching for wells, cisterns, or oases. Some sought relief from thirst by sucking on small pebbles, chewing grass or leaves, and sucking the juices from snails. Without water the lips usually became the first part of the mouth to dry out, crack, and become painful. The use of a chap-stick, or some type of grease will help prevent drying of the lips. After about five days without water, survivors reported the skin began to peel from their tongues and mucous membranes. In World War II, many survivors found relief from thirst by locating water in the radiators and supplies of abandoned and derelict vehicles that were abundant in the North African desert. Other, less imaginative survivors, overlooked this potential source of water. During World War II airmen were specifically warned that alcohol, in any form, should be avoided in a survival situation. Alcohol should be considered a food, not a source of water, since alcohol requires water for digestion and excretion from the body. (7:15,17,34-35)

TRAVEL

Experience from World War indicates an uninjured man is capable of traveling 12 to 18 miles a day on average terrain at the beginning of the survival experience. As heat and the lack of water take effect, the daily distance decreases. Generally, this becomes noticeable about the fifth day, and by the fourteenth day many men were able to travel only 1 to 2 miles a day. The average time spent walking by World War II survivors was 5 days, however, 20 days or more were not uncommon and one group traveled for 29 days. The greatest distance traveled by a group of survivors was 350 miles and the average distance was 50 miles. (7:8)

It appears nighttime travel and daytime rest would be best in the desert, however, the survivor must consider that his chances of contacting passing vehicles or aircraft will be less at night than during the daytime. In World War II, men who traveled at night sought daytime shelter in caves, in the shade of trees or rock piles, and many found that burying themselves in a shallow depression tended to reduce water loss, aid relaxation, and allow some sleep. Those who traveled during daylight hours found the physical effects of the sun and heat severely handicapped their ability to travel. The most satisfactory time to travel is the early morning or late evening. (7:34-35)

Standard issue flightsuits proved quite satisfactory for desert travel. Whenever possible gloves and headgear should be retained for protection from the sun, however, substitutes can easily be made from parachute cloth if necessary. Government issue boots are also very satisfactory for desert use. Several survivors, however, experienced difficulty replacing their shoes due to the swelling of their feet that occurred when the shoes were removed during rest stops. One group of six survivors was forced to continue their travel barefoot because they could not get their swollen feet back into their shoes. Other men who walked barefooted across alkaline swamps or salt flats reported they suffered alkali burns on their feet. (7:19,35)

SIGNALING

Most signaling problems encountered in World War II have been resolved over the years. The creation of dedicated rescue forces and development of modern survival equipment will no doubt make desert rescues more rapid and successful. Optical problems in the desert, however, continue to affect signaling and rescue operations. The desert haze, coupled with the effects of mirages,complicate signaling. The haze often limits visibility to 400 yards, or less, and makes it impossible to see aircraft or survivors unless looking directly up or down through the haze. The haze also makes it very difficult to positively identify ground parties as friend or foe; consequently, survivors often hesitate to establish contact with ground parties or aircraft until they are relatively sure of identification or are desperate enough to surrender if necessary. (7:28-29)

Though modern survival radios and signaling devices will usually lead to quick rescues in the future, airmen must be prepared to communicate with less sophisticated signaling and communications techniques in the event the modern equipment is is lost or fails. The experiences of World War II airmen discussed above provide a valuable source of information on basic desert survival.

Chapter Eight

FINDINGS

CONCLUSIONS

The 1967 and 1973 Arab-Israeli wars proved beyond doubt that high-intensity, sophisticated air and ground combat can be conducted in the desert with existing United States and Soviet equipment. Throughout the world native populations live in deserts and indigenious military forces operate daily in them. It logically follows that United States forces can learn the basics of desert living and fighting if properly trained and exercised in the desert environment. The documents researched for this study support this observation and lead to the following conclusions concerning desert warfare.

1. Medical problems can be controlled through education, training, careful sanitation and messing procedures, and ample supplies of insecticides and insect repellents. Acclimatization problems can be minimized by maintaining troops in top physical condition while in garrison and by a comprehensive acclimatization program when deployed.

2. Electromagnetic problems are not significant and they can be overcome with training, except in the case of multipath propagation in the C and S radar frequency bands. Radars in these bands should not be relied upon for early warning or GCI control.

3. Mobility in combat is best provided by tracked vehicles; however, wheeled vehicles perform well in rear support areas where they can operate on the existing road network. Extreme care must be taken to keep engine cooling systems and air filters free of sand and dust. Vehicle performance will often be limited by engine operating temperature, not by available power. Careful operator maintenance is required to keep military vehicles in operation.

4. Optical illusions and mirages do not present major problems if they are understood by the troops. The shimmering of images caused by surface heat can significantly degrade visibility and make optical tracking systems ineffective. Blowing sand and dust cause wear on optical lenses and

equipment and, consequently, optical equipment must be protected at all times.

5. Aircraft maintenance can be effectively performed in the desert if precautions are taken against sand, dust, and the daytime high temperatures.

6. Aircraft operations are degraded by the high daytime temperatures. The high temperatures result in longer take-off rolls, reduced thrust, and smaller payloads. Temperature affects virtually all aircraft. Blowing sand and dust also deteriorate aircraft componets and are a factor in helicopter and V/STOL operations.

7. Modern survival equipment should permit rapid recovery of downed aircrews in most cases. When evading, or without survival equipment, it is possible to survive in the desert for several weeks and travel substantial distances if properly trained in desert survival techniques.

RECOMMENDATIONS

The conclusions listed in the preceeding section indicate that virtually all problems encountered in desert warfare can be resolved by familiarizing the troops with the desert environment and then conducting extensive training exercises in the desert. To achieve this realistic training, the following recommendations are suggested.

1. Training and Indoctrination. Desert problems occur because troops are unfamiliar with the environment. These problems, which include most medical, optical, electromagnetic, and mobility problems identified in the study, can be resolved by thorough training and indoctrination. The training should first be conducted in the classroom and then extensively exercised in the field in actual deserts for long periods of time.

2. Operational Training. Both air and ground forces must train as they intend to fight in the desert. Current training exercises are of too short a duration to identify long range problems and provide the forces the desert experience they need to develop and refine maintenance and employment procedures. The United States should base combat and support units at locations where they operate daily under desert conditions, either in the southwest United States or overseas. It is only through actual operations in the desert that United States forces can fully achieve their desert warfighting potential.

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