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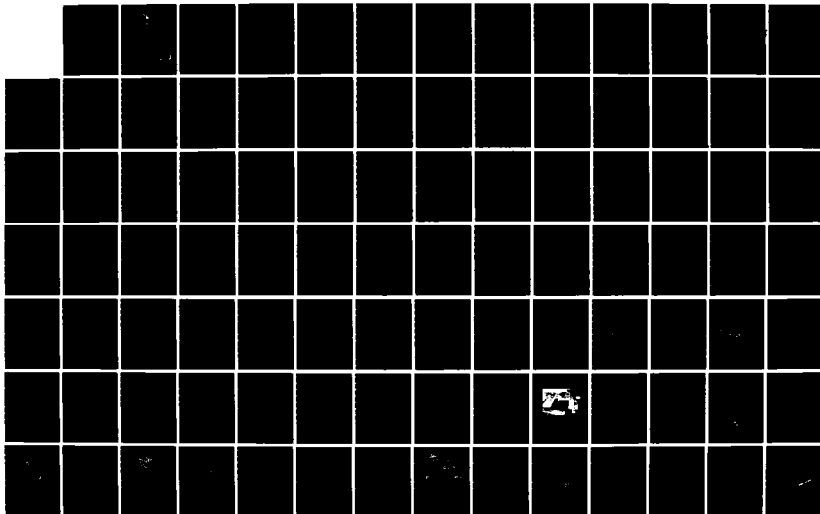
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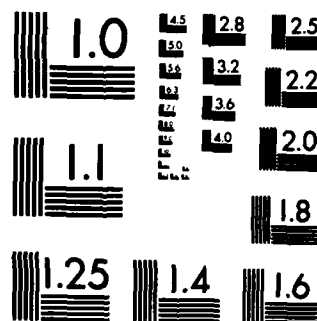
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A COMPREHENSIVE EXPEDIENT METHODS

FIELD MANUAL

THESIS

Roy V. Bousquet
Captain, USAF

AFIT/GEM/LSM/B4S-3

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This investigation uncovers expedient methods for use by Air Force Civil Engineers during contingencies or contingency training. A literature review of magazine articles, course handouts, pamphlets, regulations, and manuals was conducted to find published expedient methods. Unpublished expedient methods were found by surveying Civil Engineering officers, enlisted personnel and civilians stationed in the CONUS. A total of 70 expedient methods were uncovered to supplement AFM 88-34, Field Engineering Handbook: Expedient Methods, to form a comprehensive expedient methods field manual. *↗*

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A COMPREHENSIVE EXPEDIENT METHODS
FIELD MANUAL

THESIS

Presented to the Faculty of the School of Systems and Logistics
of the Air Force Institute of Technology

Air University

In Partial Fulfillment of the
Requirements for the Degree of
Masters of Science in Engineering Management

Roy V. Bousquet, B.S.

Captain, USAF

September 1984

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Preface

This study developed a comprehensive expedient methods field manual by combining published and unpublished expedient methods to supplement AFM 88-34, Field Engineering Handbook: Expedient Methods. The published expedient methods were found after an extensive literature review. A survey of Civil Engineering personnel was used to find unpublished expedient methods. The final product provides a valuable guide for Civil Engineers for home station training and during actual contingencies.

In gathering the expedient methods and designing the supplement to AFM 88-34, I received a great deal of help from some very special people. I am deeply indebted to my thesis advisor, Capt Jeffrey S. Thomas, for his wisdom and guidance throughout this research effort. I would also like to thank Maj Charles E. Beck for his valuable assistance in editing this study. Finally, I extend my deepest gratitude to my wife Corinne for her patience and understanding during the many nights that I was consumed with work and confined to my desk.

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Abstract

This investigation uncovers expedient methods for use by Air Force Civil Engineers during contingencies or contingency training. A literature review of magazine articles, course handouts, pamphlets, regulations, and manuals was conducted to find published expedient methods. Unpublished expedient methods were found by surveying Civil Engineering officers, enlisted personnel and civilians stationed in the CONUS. A total of 70 expedient methods were uncovered to supplement AFM 88-34, Field Engineering Handbook: Expedient Methods, to form a comprehensive expedient methods field manual.

A COMPREHENSIVE EXPEDIENT METHODS FIELD MANUAL

I. Introduction

Overview

This thesis identifies expedient methods which supplement AFM 88-34, Field Engineering Handbook: Expedient Methods. The result is a comprehensive expedient methods field manual for use during contingencies. A literature review is used to uncover published expedient methods that are not included in AFM 88-34, while a survey of all Air Force bases in the continental United States (CONUS) is used to discover unpublished methods. The published and unpublished expedient methods are then combined to supplement AFM 88-34 to form a more comprehensive field manual.

This chapter discusses the need for a comprehensive expedient methods field manual. This discussion begins with a general background of the Civil Engineering mission during contingencies, and is followed by an examination of the specific areas of work expected of Civil Engineers to complete their mission. The research problem relating to accomplishing these specific areas of work during contingencies is then discussed. This chapter also includes the research objectives, assumptions, and the scope and limitations of this thesis.

Issue

The Department of Defense Directive 1315.6, "Responsibilities for Military Troop Construction Support of the Air Force Overseas," identifies the mission of Civil Engineering in a contingency environment (15:6). This directive identifies the following tasks that Civil Engineers can expect to perform during war [15:6]:

- a. emergency repair of war damage to air bases,
- b. force beddown of Air Force units and weapons systems,
- c. operations and maintenance of Air Force facilities and installations,
- d. crash rescue and fire suppression, and
- e. construction management of emergency repairs of war damage and force beddown.

Although Defense Directive 1315.6 identifies the Civil Engineering mission during wartime contingencies, other contingencies exist in addition to war. Military exercises and natural disasters also constitute contingencies. During contingencies, Air Force Civil Engineering forces must use expedient methods (i.e., quick and temporary forms of construction, maintenance, and repair) to keep base facilities operational. Such methods cover the 16 areas of work expected of Civil Engineers during contingencies [41]:

1. Building systems
2. Non-airfield pavements
3. Airfield pavements
4. Aircraft arresting systems
5. Airfield Lighting systems
6. Electrical power production
7. Overhead and underground electrical distribution systems
8. Interior wiring systems for buildings
9. Water wells
10. Potable water distribution systems

11. Sanitary distribution systems
12. Sewage treatment plants
13. Plumbing
14. Liquid fuel systems
15. Heating systems
16. Refrigeration and air-conditioning systems

Problem Statement

The last extended contingency in which Civil Engineering forces used expedient methods to perform their mission was the Vietnam conflict nearly a decade ago. Because of this time span, the majority of today's Civil Engineering members have never operated in a wartime contingency. Their knowledge in expedient methods can only come from actual peacetime contingencies or expedient methods training.

Since peacetime contingencies are not very common, expedient methods experience must come from home station training. Chapter 3 in AFR 93-3 identifies the need for home station training. This regulation states that every Base Civil Engineer, Air National Guard and United States Air Force Reserve Civil Engineering Unit Commander must ensure that home station training is "designed and executed to achieve a high state of readiness [8:15]." This same regulation also identifies expedient methods as one of the home station training requirements (8:16). The specific words are as follows:

A great deal of simulation will be necessary in this [expedient methods] type of annual training. Realistic training scenarios should be developed to best derive the learning experience desired [8:16].

The need for home station expedient methods training is also emphasized at the Contingency Engineering Course at the Air Force Institute of Technology, School of Civil Engineering at Wright-Patterson AFB, Ohio. A draft Prime BEEF Managers Handbook served as a course handout during the February 1982 class. The handout provides the following guidance:

The most likely time to encounter the need of expedient repair methods is during the bomb damage repair (BDR) phase of a base recovery operation. Therefore, training should concentrate heavily on the types and peculiarities of the facilities and utility systems found in friendly foreign countries. The prime concern is to get bases operational as safely and expeditiously as possible. A great deal of simulation will be necessary in this type [of] training. Realistic training scenarios should be developed to best drive the learning experience desired [12:23].

Although realistic scenarios are recommended for expedient methods training, a 1982 Functional Management Inspection team found many Air Force installations lacking in "hands-on" training for expedient methods (13:4). The inspection team identified this training as critical for "supporting Civil Engineering contingency readiness to meet worldwide combat support roles [13:1]." Furthermore, it is the author's opinion, based on five years of experience within the Civil Engineering (CE) organization at base level, that only senior CE officers and noncommissioned officers who served in Vietnam, and CE personnel who have peacetime contingency experience have any practical knowledge of expedient methods. Few of these procedures are

published in existing pamphlets, manuals, training guides, and handbooks. Therefore, very little of this practical knowledge of expedient methods is available to the inexperienced CE personnel. As the experienced senior CE members retire from active duty, much of their valuable expedient methods knowledge is lost.

Finally, AFM 88-34 contains only some of the known expedient methods that are useful to Civil Engineers during contingencies. Numerous other expedient methods have been tried and reported since AFM 88-34 was published in 1967. The other published expedient methods are scattered among numerous Air Force and Army pamphlets, manuals, training guides, and handbooks. Therefore, no single field manual exists that includes all the expedient methods for each of the 16 areas of work required by Civil Engineers during contingencies.

Statement of Purpose/Objectives

The purpose of this thesis is to provide expedient methods information for Civil Engineers deployed to contingency environments. This purpose is accomplished by fulfilling three objectives:

1. Identification of published expedient methods not included in AFM 88-34 that would be useful to Civil Engineers for completing the 16 areas of work expected of them during contingencies.

2. Collection of additional expedient methods for these

16 areas of work from Civil Engineers who have had past contingency experience but have never had their expedient methods procedures published.

3. Design of a supplement to AFM 88-34 that combines the published and unpublished expedient methods and provides a comprehensive expedient methods field manual for rapid use in contingency environments.

Assumptions

This thesis assumes Civil Engineers will be deployed to the worst possible location, namely a bare base in a hostile environment. The following factors will be applicable in this "worst-case" scenario:

1. The base will have few supporting facilities, utilities, and equipment that can be utilized by the deployed forces.

2. Some of the deployed equipment, utilities, and/or facilities will become useless due to normal wear-and-tear, or by hostile enemy action.

3. Replacements for the damaged equipment, utilities, and facilities will not always be readily available.

4. The deployed Civil Engineers with prior contingency experience will be very busy with their own work and will not always be available to give guidance to the less experienced personnel.

Even though this thesis assumes Civil Engineers are deployed to a bare base, less severe deployments are also

possible. Both the worst-case and these less severe deployments would require expedient construction, maintenance, and repair procedures to keep the equipment, utilities, and facilities operational. However, the assumption of a worst-case scenario identifies expedient methods that would not otherwise be identified.

Scope and Limitations

Since Civil Engineers can be deployed worldwide (8:5), this thesis examines expedient methods for widely contrasting environments. The environments considered include desert, arctic, and jungle regions. These regions present the most hostile weather conditions for the deployed Civil Engineering forces and their equipment.

No classified information is used in this thesis. The basic sources include military regulations and manuals, training guides, private authors, guest lecturers, and personal interviews.

Organization of This Report

This report is organized to meet the academic requirements of a Master's thesis. However, it is also designed to provide the practical requirements of an expedient methods field manual.

The usual thesis documentation is included in this report. Chapter 2 is the literature review that uncovers published expedient methods not included in AFM 88-34. Chapter 3 gives the methodology for completing the

literature review and the survey that uncovers unpublished expedient methods. Chapter 3 also explains how the published and unpublished expedient methods are combined to form the supplement to AFM 88-34. Chapter 4 summarizes the results of the literature review and survey. It also provides recommendations based on these results. Appendix A is an exhibit of the survey package and Appendix B is the actual supplement to AFM 88-34. Appendix B can be removed from this report, added to AFM 88-34, and used during deployments as a guide for completing required expedient methods.

II. General Background to Expedient Methods

Chapter Overview

This chapter provides information about the role of Civil Engineering during contingencies. Readers familiar with AFM 88-34 or expedient methods should skip this chapter. The discussion begins with definitions, a brief history of Civil Engineering mobilization, and an explanation of the importance of expedient methods for deployed Civil Engineers. The final portion of the chapter provides a literature review of expedient methods. This review introduces the primary areas to be included in the supplement to AFM 88-34. The actual supplement, found in Appendix B, presents each of these areas in a form similar to that found in AFM 88-34.

Definitions

The following alphabetical list of terms provides a reference for material presented in this chapter:

Bare base. A base having a runway, taxiway, parking areas adequate for the deployed force, and possessing an adequate source of water that can be made potable [40:29].

Contingency. An uncertain future event sufficiently within the realm of possibility to warrant advance planning. Includes potential military operations, civilian or military emergencies, natural disaster relief [40:29].

Deploy. To relocate a unit, or an element of it, to an area of operations or to a staging area. Deployment begins when the first aircraft, personnel, or items of equipment leave the home base. The force is deployed after the last

component of the unit has departed [40:29].

Expedient methods. The field construction, repair, and maintenance techniques used during contingencies. It is work performed in an innovative manner (often without the proper tools, materials, equipment, replacement parts, or personnel), yet sufficient to provide, restore, and maintain critical facilities, utilities, and equipment in an operational state without creating serious safety hazards (8:16).

Force beddown. The immediate beddown of mission forces and the operation of critical facilities and utilities. The force can be bedded in various types of facilities that make up Harvest Eagle and Harvest Bare sets, or they can be bedded by renovation/converting existing facilities on standby bases or colocated operating bases [2:16].

Harvest Bare. Nickname given to a bare base system. Harvest Bare is a concept in mobility which offers deployment of all supporting buildings to a bare or fixed base. These buildings are of light modular design and may serve as containers for those items used in the building when set up. Harvest Bare consists of shelters, utilities, and base maintenance equipment and support subsystems. Harvest Bare assets are designed to support 4500 personnel in various increments and are designated as War Reserve Materials (WRM) and maintained in a ready status [8:29].

Harvest Eagle. A nickname given to a selected package of essential items of equipment and supplies required to support forces/personnel under bare base conditions. It is an air transportable housekeeping package designed to support activities deployed to remote areas where it is not feasible to pre-position assets. Harvest Eagle sets are designed to support 1100 personnel, and are designated as War Reserve Materials (WRM) and maintained in a ready to deploy status [8:29].

Prime Base Engineer Emergency Force (BEEF). An Air Force, major command, and base level program that organizes the civil engineering force for worldwide direct and indirect combat support roles. It identifies and postures both civilian and military authorizations and skills for the dual role of performing peacetime real property

maintenance and wartime engineering requirements. The Prime BEEF program includes all military civil engineering personnel at all levels of command [8:5].

The Concept of Expedient Methods

During contingencies, Prime BEEF teams are tasked with force beddown, emergency repairs, and operations and maintenance functions (15:6). These functions are all accomplished by using expedient methods, quick and temporary forms of construction, maintenance, and repair.

Expedient methods of construction are used during base build-up. Harvest Bare and Harvest Eagle sets "provide all the support facilities, utilities, and equipment required to turn a runway into an operable airfield [39:28]." Expedient maintenance is the work that keeps facilities, utilities, and equipment operational often without the proper tools, materials, replacement parts, and personnel (8:16). "Expedient repair methods provide for minimum essential restoration of a facility or system to useful operation in the least time, with the least effort and often without the benefit of the best material or equipment... The prime objective is to make operational repairs as safely and expeditiously as possible [8:16]."

One method of performing expedient repairs involves the cannibalization of other equipment. "Cannibalization - the removal of serviceable items from one item of equipment for use on another - is an issue closely related to forward support... Cannibalization may be used when parts are not

available from the supply system and an item of equipment can be repaired using parts from other unserviceable equipment [38:4]."

Many other examples of expedient methods have been used in past deployments. As support requirements change, the deployment kits are modernized. New forms of expedient methods must then be developed to install and service the new equipment, facilities, and utilities included in the modernized deployment kits.

Therefore, to perform their mission effectively, CE personnel must be familiar with both past and current expedient methods of accomplishing construction, maintenance, and repair. This work may also have to be done under the most hostile conditions. Shortages of food and water, inadequate tools and equipment, inclement weather, and enemy action must be dealt with so the overall mission can continue.

The Evolution of Civil Engineering Mobilization

Since the development of modern air warfare, Civil Engineers have used expedient methods to make air base facilities, utilities, and equipment operational. During World War II, advancing ground forces were required to establish forward operating bases; air units also advanced to provide air support for these advancing ground troops. These forward air units could either build required base facilities or operate in the open (46:24).

During the 1950s, techniques were developed to prepackage needed equipment for shipment to forward bases. This initial deployment kit was nicknamed Grey Eagle. It included tents, field kitchens, medical facilities, power generators, administrative supplies, and various equipment. All items of the Grey Eagle kit were installed, repaired, and maintained with expedient methods. Unfortunately, this early kit was heavy, bulky, and required many hours to erect (46:24).

By the late 1960s, deployment kits were designed to be light, modular, and C-130 transportable. Some shelters were their own containers. The new concept was to provide everything to support a deployed force in any environment. Hardware included equipment to support weapons systems plus transportation, housing, mess, aircraft maintenance, airfield lighting, electrical power, water, sewage, heating, cooling, medical, and civil engineering facilities (46:24).

Today's concept of deployment has remained basically unchanged since the late 1960s. The idea is to "rapidly deploy a force, complete with shelters and support facilities, capable of independently supporting and launching sustained combat operations with the same independence as fixed theater installations. The assumption is that tactical forces will continue to have a bare base requirement to conduct sustained air operations on a worldwide basis in support of national policy [46:25]."

Harvest Eagle and Harvest Bare kits provide the

equipment necessary to establish an operating base for, respectively, short term and long term deployments. Expedient methods are used not only to erect the equipment, facilities, and utilities provided in these kits, but to keep them operational. As these deployment kits are modernized, new expedient methods must be developed to erect, repair, and maintain them.

Engineering Needs

Civil Engineers must be familiar with various expedient methods to operate effectively in hostile environments. The purpose of this chapter is to uncover expedient methods that were used in past deployments and can be used to guide expedient methods in future contingencies.

The expedient methods to be examined cover the 16 areas of work required by Civil Engineers during contingencies. The work requiring expedient construction, maintenance, and repair have been divided into three major categories: (1) facilities, (2) pavement surfaces and support systems, and (3) utility systems. Facilities includes shelters, field-fortifications, and facility hardening. Pavement surfaces and support systems includes non-airfield pavements, airfield pavements, aircraft arresting systems, and airfield lighting systems. Utility systems includes electrical power production, overhead and underground electrical distribution systems, interior wiring systems for buildings, water wells, potable water distribution systems,

sanitary distribution systems, sewage treatment plants, plumbing, liquid fuel systems, heating systems, and refrigeration/air-conditioning systems.

Since many of these work areas are provided by the Harvest Bare and Harvest Eagle deployment kits, these kits are discussed in detail. However, many useful and perhaps critical items are not included in either deployment kit. Expedient methods that provide and service these "nonstandard" deployment items are also examined.

Facilities

General. Shelters protect airmen, equipment, and supplies from enemy assault and the weather. "The best shelter is usually the one that will provide the most protection with the least amount of effort [20:3.1].". Therefore, existing facilities should be fully used. Also, natural shelters such as caves, mines, or tunnels should be used before artificial shelters are constructed (20:3.1). Constructing shelters consumes valuable time that can be used elsewhere in making a base operational.

There are basically three classifications of shelters. Surface shelters, the first type, are built above ground elevation. The surface shelter requires "the least amount of labor to construct, but it is hard to conceal and requires a large amount of cover and revetting material [20:3.1].". Most shelters in contingency environments are surface shelters due to their expediency of construction.

The second type, underground shelters, are labor and time intensive to construct but "provide good protection against radiation because the surrounding earth and overhead cover are effective shields against nuclear radiation [18:3.11]." Cut-and-cover shelters, the third type, are dug partly into the ground and are covered with a thick layer of rock, logs, sod, and excavated backfill. The cut-and-cover shelters are also time consuming to construct but "provide excellent protection from weather and enemy action [20:3.11]."

During contingencies, facilities should be constructed as soon as possible. Therefore, surface shelters are usually built first. The other classes of shelters are built if there is sufficient time. Because the surface shelters offer little protection against enemy action, they must be hardened. Proper siting of surface shelters reduces the need for immediate hardening. "Wherever possible, shelters should be sited on reverse slopes, in woods, or in some form of natural defilade such as ravines, valleys, and other hollows or depressions in the terrain... All shelters must be camouflaged or concealed [20:3.11]."

Deployed Shelters. Since deployed forces must operate in extremely hot or extremely cold areas of the world, the Harvest Bare and Harvest Eagle deployment kits provide surface shelters that offer protection against the elements. These kits contain modular, expandable, and canvas shelters. "Modular and expandable shelters and canvas tents provide all the structures needed on a bare

base to provide billeting, shops, hangars, and storage. All expandable and general purpose shelters can be set up for immediate use or packaged for redeployment by the same people who will use them [1:8.1]."

Hasty Shelters. In a deployment, the shelters provided in the Harvest Bare and Harvest Eagle kits may be destroyed. They can be destroyed during transport to the site, or weather and enemy action can destroy the shelters after they have been set up. If no replacements are immediately available, some hasty (expedient) shelters must be constructed until the replacements arrive.

Hasty shelters are constructed with a minimum expenditure of time and labor using available materials. They are ordinarily built above ground or dug in deep snow. Shelters that are completely above ground offer protection against the weather and supplement or replace shelter tents which do not provide room for movement [20:3.1].

Field Fortifications. Although shelter from the weather is important to keep the deployed forces healthy and able to perform their mission, shelter against enemy action is also necessary if the deployed forces are to survive in contingency environments. Therefore, Civil Engineers must be familiar with the various expedient field fortifications they can construct to increase the probability of individual and base survival.

Field fortifications include numerous types of passive measures to better ensure the air base's survivability. The most common types are emplacements, revetments, bunkers, bomb shelters, and obstacles (17:85,93,96,105). Emplacements

(i.e., foxholes) are simply and hastily constructed defensive positions that are camouflaged, concealed, and "permit each individual to accomplish assigned fire missions [17:85]."

Revetments are retaining walls that prevent unstable soils from collapsing in defensive structures. "Revetments may be constructed of sandbags, sod blocks, and other expedients [17:93]."

Bunkers are emplacements with overhead protective cover. "The protective cover and roof of a bunker should be designed so that it moves freely but is rigid enough to displace as a unit. It must also be able to absorb the shock of an exploding shell [17:96]."

Bomb shelters are totally passive structures because they protect personnel and equipment from the enemy and have no openings for effectively returning fire. "The most effective shelters are underground cut-and-cover [17:96]."

Obstacles are structures that prevent or hinder enemy forces from advancing to the air base. Antipersonnel obstacles include "wire obstacles constructed with barbed wire and tape...[and] expedient obstacles constructed from locally available material... Antivehicular obstacles are both deliberate and expedient types of obstacles designed to delay or stop the progress of all types of vehicles [17:123]."

Hardening Facilities. Whereas perimeter defense fortifications protect the base defensive forces, other base

facilities must be hardened to protect deployed aircraft, munition storage areas, support personnel, and critical equipment and utilities. "Even small-caliber rifle or automatic weapons fire against many existing air base facilities could produce high numbers of casualties among facility occupants [7:11]." The threat is even greater from mortars, large-caliber projectiles, rockets, and bombs.

Hardening the exterior walls, roofs, windows, and doors can protect facilities from enemy action. Exterior walls can be protected by filling hollow spaces, attaching protective overlays, placing loose soil or sandbags against the walls, erecting revetments, or constructing interior shelters (7:14-19,22,23). Roofs can be protected by adding concrete or sandbag overlays. Windows can be protected by permanently sealing window openings, or by adding a removable protective cover panel. Finally, doorways can be protected with protective panels or revetments, or replaced with blast and penetration resistant doors (7:20-24).

Pavement Surfaces and Support Systems

Non-airfield Pavement Surfaces. Although expedient shelters and other base buildings are required to support the deployed forces, efficient routes of transportation are required to minimize travel time between facilities. Adequate parking areas should also be provided so the roads can remain open to traffic.

Roads and parking areas are quite satisfactory in many

nations. Europe, for instance, has many roads equal to those in the United States. Unfortunately, many other nations have few paved roads, if any at all. For example, roads in desert Arab countries are generally underdeveloped (35:187). Generally, underdeveloped nations are marked by "a lack of investment capital [24:255]." Since local roads are administered and financed by local governments and highways are financed by national governments (25:901), it is reasonable to assume that undeveloped areas lack the investment capital to construct effective road systems. Therefore, forces deployed to undeveloped, third world nations can expect inadequate roads.

Deployed CE forces may find it necessary to expeditiously construct, maintain, and repair the non-airfield pavement surfaces to ensure a totally operational base. Since CE forces can be deployed worldwide, they must be familiar with expedient methods of providing roads and parking areas in both wet and dry areas.

Expedient surfaces in wet, muddy areas "must be structurally strong and spread the load over a wide area of the subgrade [17:247]." Graded and compacted areas without some load-bearing surface are totally inadequate in muddy areas. Three different expedient loadbearing surfaces can be constructed to provide the necessary roads and parking areas in the deployed location. These surfaces are (1) chespalings roads, (2) corduroy roads, and (3) tread roads

(17:250-254). These expedient road surfaces are shown in Appendix B.

In contrast to road surfaces in wet areas which are built to distribute loads over a greater area, expedient road surfaces in dry, sandy areas attempt to stabilize the sand so it can support necessary loads (17:254). Numerous expedient methods can be used to stabilize sand so it can be used for non-airfield pavement surfaces. For example, chicken wire, expanded metal lath, and chain link wire mesh (cyclone fence) can be used to stabilize sand (17:254). Other expedients include lowering tire pressure, stabilizing sand with portland cement or oil, grading the road until firmer soil is found, and placing building rubble in the ruts (43:7.19).

In some instances, airfield landing mats can provide non-airfield pavement surfaces. "Airfield landing mats can be used to form an expedient road surface over either mud or sand [17:255]." In either case, airfield landing mats should be used for non-airfield pavement surfaces only if there are sufficient quantities to meet both the non-airfield surface needs and the airfield bomb damage repair needs.

Airfield Pavements. The flightline area contains some of the most critical facilities on a base. Included are the airfield pavements (i.e., the runways, taxiways, and ramps) and the systems required to support these pavement areas. These supporting systems include the runway/taxiway lighting system and aircraft arresting system. These pavement

facilities and support systems are critical because the flying mission cannot effectively be conducted without them.

During the early 1960s, Air Force strategic planners believed that enemy weapon systems would be aimed at the softer targets, namely, the aircraft (5:2). Aircraft are especially vulnerable on the ground due to "their delicate structure, fuel contents and associate high-explosive ordnance [5:2]."

However, this view has changed with the advent of hardened aircraft shelters and improved aircraft performance and support systems (5:2). Today, airfield pavements are the primary target on airbases (5:3). Therefore, airfield pavements are a major concern for Civil Engineering forces in contingency environments.

In contingency environments, Civil Engineering's airfield pavement work is classified as Rapid Runway Repair (RRR). "Following an enemy attack, the BCE must be capable of rapidly restoring damaged runways, taxiways, aircraft parking areas and other airfield pavements. Consequently, RRR is a priority mission for the Prime BEEF contingency force (CF) teams [8:15]."

Chapter 5 of AFR 93.2 outlines eight major steps for this RRR procedure after all unexploded ordnance has been removed by Explosive Ordinance Disposal personnel. These steps consist of [14:5.2]:

- a. Identifying craters for repair and estab-

- lishing a new temporary runway center line;
- b. Delivering, stockpiling, and placing select fill material;
- c. Cleaning and sweeping the new runway;
- d. Assembling the AM-2 matting;
- e. Positioning AM-2 matting over the crater;
- f. Anchoring AM-2 matting; and
- g. Painting new runway center line.

Since the early 1960s, the objective has been to provide at least a minimum operating strip (MOS). The MOS is "a 50 foot wide, 5,000 foot long area clear of all debris and structurally capable of withstanding the weight of a fully loaded fighter aircraft for the number of passes necessary for launch and recovery of all assigned aircraft. This objective had to be accomplished within a four hour period for any anticipated damage from three 750 - pound bomb craters [5:3]."

AM-2 matting met the RRR requirements for the wartime scenario specified in the early 1960s. However, the Soviet Union has greatly improved its Air Force.

Since 1973, they have phased a new generation of aircraft into the inventory; including improvements to the MIG-21 FISHBED aircraft (the J, K, and L models); and newer aircraft - the Su-17 FITTER C, the MIG-23 FLOGGER and the Su-19 FENCER are fully employed... The FENCER A, an aircraft designed with air-to-ground weapons (against airfields; specifically runways) appears to be the first Soviet fighter designed for ground attack, and was doubled in Frontal aviation capability by the end of 1976 [5:8].

These modernization efforts by the Soviet Union have resulted in a change from a position of defense to one capable of successful offensive action (5:9). Therefore, the current practice of repairing three large craters in four hours with AM-2 matting is no longer realistic (5:13,14).

New, faster methods of repairing craters must be found.

Arresting Systems. During wartime, aircraft often must make emergency landings. Furthermore, the runways themselves may be severely damaged from enemy action. Expedient repair work may not be completed or the MOS may be too short for the emergency landing. In these cases, aircraft arresting systems become crucial for safe landings.

Although many arresting systems exist, "the BAK-12 is the only expeditionary aircraft arresting barrier system. The other arresting systems, the BAK-9, 11, 13 and 14, were designed for permanent installation [42]." In contrast, the BAK-12 can be "installed as an expeditionary semi-permanent, or permanent runway facility or may be used in conjunction with other engaging devices [10:3326]." It can be fixed on-grade to a concrete pad, below grade in a concrete pit, or expeditiously installed with earth anchors in about 100 manhours (1:4.9). Finally, "the BAK-12 can be readily installed anywhere in the world [1:4.9]."

Airfield Lighting. While arresting systems are critical for emergency landings and to ensure landing aircraft do not exceed the MOS, airfield lighting becomes critical for night landings. The need for airfield lighting is especially critical in contingency environments where the MOS may be only 50 feet wide by 5,000 feet long. The surrounding area may be dangerously marred by unrepaired bomb craters.

Both the Harvest Bare and Harvest Eagle kits contain

portable airfield lighting sets that can be installed by Prime BEEF forces (1:4.1). Both kits contain components that are "identical to those items currently being used at both military and civilian airports around the world and are highly reliable [1:4.5,4.6]."

Utility Systems

Electrical Power Production. Electrical power during contingencies is needed to operate the runway lighting system and critical base facilities. A reliable source of power is becoming increasingly important to the Air Force mission as more defense systems and support functions rely on electrical power for their operation. Sources of electrical power become even more critical during contingency situations in which the enemy targets the electrical power sources in an attempt to disrupt the Air Force mission (40:1,2). Electrical power systems are "used during expedient construction and operation of air base facilities for contingency force beddown and expedient post-attack recovery of vital base facilities [40:1]."

Electrical generators are the primary source of electrical power for Air Force operations in contingency environments. Generators also serve as a backup "to provide exigent operation of air base facilities and functions (including surveillance) during commercial electric power disruptions or outages caused by accident, sabotage, vandalism, and/or attack in the CONUS and the overseas

theaters [40:11]." This section examines expedient methods, as they pertain to the installation, repair, and maintenance of electrical generators at Air Force installations during contingencies.

Preparing electrical power can be accomplished by using the generator sets available in the Harvest Bare and Harvest Eagle kits. The generators that make up these kits have been developed after extensive study of the problems encountered with electrical generators during the build-up of the Vietnam conflict (27).

At present, the second generation standard family of generators is still under development, and many of the interim family of generators are still being used. The vast majority of generators in the current Air Force inventory is the first generation standard family. These are the generators included in the Harvest Bare and Harvest Eagle kits. During contingencies, expedient methods would be used to keep the generators found in these kits operational. Expedient methods would also be used on the interim family of generator sets that still exist (32).

Electrical Distribution. Electrical power is useless unless the power can be transmitted from the power source to the facilities requiring electricity. Host nation power and distribution lines should be used whenever possible. However, in many countries such as those in Southwest Asia, standardized power does not exist (1:5.1). "Frequency and voltage may vary from location to location. Their

distribution networks are limited and those that do exist may be deteriorated and unreliable [1:5.1,5.2]."

Therefore, Air Force Civil Engineers may have to provide their own electrical distribution systems. The Harvest Bare deployment kit contains an expedient electrical distribution system. Harvest Bare kits contain both primary and secondary distribution systems to supplement the Harvest Bare generator sets (1:5.2,5.3).

Interior Electrical Wiring. Procedures for wiring the interior of facilities are given in AFM 91.17 and AFP 85.1. These procedures vary little during contingencies. Any variation to these procedures simply adds to the already hazardous conditions with the threat of electrical fires. However, insulated wiring can be expediently mounted on the surfaces of interior walls, ceilings, and floors. Furthermore, expedient methods can be used to determine the required wire size for a specific load when no other method is available (17:351). This method of expediently sizing interior wiring is found in Appendix B.

Water Supply. Water is perhaps the most critical resource required by the human body to stay alive. This is especially true in desert environments where sparse rainfall produces very few rivers and only intermittent streams (1:6.1). If deployed forces do not have adequate sources of potable water, the body's natural cooling system brakes down. Dehydration takes place, followed by incapacitation, heat stroke, and possibly death (1:6.3).

Heat and lack of water will be the greatest threat against combat forces. Casualty stories indicate the problem of water is critical. Fifty percent of the Egyptian army's 20,000 casualties were caused by heatstroke in the six day war in 1967, between Israel and Egypt... During the Kuwait Intervention, British forces suffered dehydration rates of almost ten percent. Water will quickly become a killer. As temperatures rise to 120 to 125 degrees farenheit, such as in an armored personnel carrier or other tracked vehicle, water consumption rates will need to increase. The Surgeon General has stated that a loss of two quarts of body fluid decreases efficiency by 25 percent, and a loss of fluid equal to fifteen percent of the body weight is usually fatal [28:1].

Due to its critical nature, water consumption must be carefully planned during contingencies. Consumers of potable water include individuals, mess operations, and hospitals (1:6.4). Nonpotable water use for laundry operations, construction, and grave registration must also be considered (1:6.4). Finally, demineralized water must be planned for thrust augmentation for many heavy aircraft (1:6.5).

Water Treatment. Fortunately, other than desert areas, water is usually readily available. Also, seawater and brackish water can be used for most nonpotable requirements, although it should be disinfected if it is to come in contact with human skin. Furthermore, seawater and brackish water can be made potable when treated with the reverse osmosis water purification unit (ROWPU). However, water with small amounts of dissolved solids can be purified with the Erdlator (1:6.1,6.2).

Water Storage. Once the water has been located it

should be stored for latter use. Water can be stored in "flexible bladders ranging in sizes up to 50,000 gallon capacity, 1,500 gallon water distribution trucks and 400 gallon distribution trailers, 3,000-gallon onion or stave tanks, 36-gallon lyster bags, and 5-and 10-gallon igloo water coolers [1:6.7]." The bladders can be used to store both potable and nonpotable water. The onion or stave tanks store the brine water from the ROWPUs. The distribution trucks, distribution trailers, and igloo coolers transport water as required. The lyster bags provide water in the billeting and work areas. Considerable water is also stored in the water pipelines, themselves (1:6.7).

Expedient water containers can be constructed from available matter if the conventional storage containers are destroyed from normal wear and tear or by enemy action (11:16). Examples of expedient water containers include cleaned fuel storage cans (11:16,17) and lumber or excavated basins lined with a membrane sheeting (43:5.43-5.45).

Water Distribution. Water must be transported from its source for treatment and storage. Once in storage, the water must be distributed to the deployed forces. Although water trailers can be used to distribute water, they are labor intensive. There is also the potential problem of improperly segregating the storage vessels. If this occurs, nonpotable water may be used for potable purposes and vice versa (34:5.15). Although the containers can be color coded to reduce confusion, pipelines are much more efficient.

Pipes can distribute greater quantities of water to numerous locations in the deployed location.

Pumps. Typically, pumps are used to drive the water through the pipes from the water storage bladders to the user locations. Pumps are classified as either raw water pumps, fire transfer pumps, or potable water booster pumps (1:6.6). Raw water pumps "pump water from remote sources to various water treatment stations and to raw water storage bladders [1:6.6]." The diesel-driven fire transfer pumps are used to fill the fire vehicles. The fire vehicles can be filled from the water source, the raw water bladders, or the potable water bladders (1:6.6). The potable water booster pumps are "used to pressurize the potable water distribution system [1:6.6]."

Water Distribution Problems. Although pipelines are effective in distributing water, problems can occur. For example, surface or near-surface distribution lines collect heat during the day. Also, plastic pipes can degrade from ultraviolet light if left uncovered in hot environments. Finally, pipelines expand and contract and tend to leak during great temperature variations. Desert pipelines often leak due to the wide temperature variation between day and night (34:5.15).

Field Sanitation. In contrast to water which must be acquired, purified and distributed to the deployed forces, waste must be kept away from the deployed forces. "The total weight of wastes of all kinds, including liquid

wastes, produced under field conditions approaches 100 pounds per person per day. If this material is not removed promptly and thoroughly, a bare base installation would soon become unhealthy and unsightly. Prompt and thorough removal of this material in such a manner that will not contaminate local water sources, air, or the land is a must [1:7.1]."

Latrines. During contingencies, human waste must be disposed of to prevent disease and the appearance of vermin. The method of disposal can vary greatly, depending upon where the forces are deployed (1:7.1). Modern sewage systems may not always be available. Furthermore, the Harvest Bare portable chemical toilets and human waste incinerators may not always be in operational condition. Therefore, expedient latrine facilities may have to be constructed.

Garbage Disposal. Garbage is caused by the kitchen and mess activities. Both wet and dry forms of garbage must be removed from the kitchen and mess areas before offensive odors are generated and flies and rats are attracted. The usual practice is to collect the garbage in cans outside the kitchen and then dispose it by burial (20:242).

Since liquid wastes contain particles of food, grease, and soap, it must be treated before it is buried (1:7.3). Treatment involves either soakage pits or grease traps. "Soakage pits act as reservoirs from which water is gradually absorbed by the surrounding ground [1:7.3]."

Grease traps "prevent greases from clogging the soil's ability to absorb the waste water [1:7.3]." Expedient

soakage pits and grease traps can be constructed during contingencies.

Dry garbage is divided into two classes - combustible and noncombustible (1:7.5). Although noncombustible dry garbage can be buried directly, the combustible dry garbage should be burned to reduce its volume. It can be burned in either an open incinerator or an inclined plane incinerator (11:30). The burned garbage can then be buried or placed in a sanitary fill with the noncombustible garbage. Care should be taken to properly bury the garbage. Improper burial of garbage "creates breeding/feeding grounds for all types of disease carriers (rats, flies, etc.) [1:7.5]."

The Sanitary Collection System. Sewage systems carry waste away from the deployed forces to reduce disease and improve the living conditions of the deployed forces (1:7.6). The sewage system at a deployed location is made up of Harvest Bare pipes, couplings, and valves. However, commercial pumps and controls, sewage lagoons, and expediently made items are also used (1:7.6,7.9). The entire system must be capable of handling 14 gallons of sewage per day for each person (1:7.7).

The collection system is made up of "a series of lateral, branch, main, and outfall sewers leading from shelter connections, together with such devices as grease traps, wet-well sumps, and sewage lagoons [1:7.7]." The lateral sewers collect the sewage from the shelter connections and empties it into the branch lines. The

branch lines connect to the mains and the mains bring the sewage to the lagoons.

Liquid Fuels. Liquid fuels are needed to power numerous pieces of equipment required by CE forces during contingencies. Heaters, incinerators, pieces of equipment with internal combustion engines require liquid fuels. Furthermore, any piece of equipment which runs on electrical power relies on liquid fuels since electrical generator engines operate on liquid fuels (1:1.7).

Providing and Storing Liquid Fuels. The most efficient way to provide liquid fuel is to transport the fuel through pipelines from a major storage complex to the deployed forces. However, a fuel pipeline may not always be available. Furthermore, pipeline systems are especially vulnerable to sabotage (45). Since pipelines are usually buried, the most susceptible pipeline facilities and locations are actually "pump stations, input stations, river crossings, intersections with other systems, and centralized computers which remotely control operations [45:iii].\" If damaged, these critical pipeline facilities \"could require up to 6 months or more for repair [45:iii].\"

During contingencies, an alternate procedure of supplying deployed forces with liquid fuel, other than for sortie generation, is flying the fuel to the deployed site in fuel transport planes or helicopters. The fuel can then be off-loaded into fuel transport vehicles and transported to storage facilities. Fuel storage facilities can be

existing steel tanks, deployed fuel bladders, or expediently used storage such as 55-gallon drums (33).

Special Fuel Dispensing Problems. At extremely low arctic temperatures, special problems are encountered which affect fuel dispensing systems. Pumps and other equipment are difficult to start and operate when the temperature drops to -60 degrees F. Fuel bladders and other elastomeric materials become brittle and useless at these low temperatures (30:vi). Therefore, fuel dispensing equipment, batteries, and elastomerics must be developed to withstand the extremely cold temperatures of the arctic (30:viii).

Heating. Liquid fuels provide a primary source of heat for deployed forces during contingencies. However, liquid fuels are not the only sources of heat. In fact, anything that burns can be used to provide heat. No matter what the fuel, an adequate heat source can be critical for deployments to cold regions.

Estimating Heat Requirements. Properly sized heating units are important for conserving fuel. Undersized heaters must operate continuously during long, cold winter deployments. Therefore, the smaller heaters may actually consume more fuel than the larger units. Unfortunately, the larger heaters are more expensive. However, slightly oversized heaters may actually "be beneficial in overcoming heat loss because of doors opening and also for bringing an unused shelter up to the desired temperature more quickly before sensitive equipment is turned on [31:II.5]."

Expedient Heating. Wood is perhaps the best expedient fuel for creating fire and heat. Wood must be fine, dry, and loosely arranged before it will begin to burn (4:289). Once these conditions are met, wood produces an excellent expedient heat source.

Air Conditioning. While heaters are required during cold weather, air conditioning is required when forces are deployed to hot areas of the world. Serious heat related health problems such as heat exhaustion and heat stroke can result if cooling is not provided (19:190; 22:51). Since both health problems are incapacitating, and heat stroke can be fatal, adequate air conditioning can be critical for both individual health and overall mission accomplishment.

Selecting the proper cooling unit is also important for fuel conservation and to ensure adequate dehumidification (31:II.5). Smaller cooling units use less fuel and ensures fuel for cooling during long hot spells. Smaller cooling units also ensure proper dehumidification. A smaller unit "will cool more slowly and, because its capacity is close to the requirement, will cool almost constantly; it therefore will be also constantly dehumidifying the shelter [31:II.5]." Oversized cooling units may cool the shelter more quickly, but it switches off more often. "While in the non-cooling mode, it is not dehumidifying the shelter [31:II.5]."

Summary

This chapter provided a general background to expedient methods. After defining terms closely associated with expedient methods, it presented a brief history of Civil Engineering mobilization and explained the concept of expedient methods and its importance to Civil Engineers. A literature review of expedient methods was then presented. The literature review gave a brief insight to the numerous areas of work in which Civil Engineers utilize expedient methods during contingencies.

The following pages develop these areas of work into a workable guide for performing expedient methods. The final product, found in Appendix B, supplements AFM 88-34 to form a comprehensive expedient methods field manual.

III. Methodology

Chapter Overview

This chapter restates the research objectives identified in Chapter 1 and describes their method of accomplishment. Justification for the research approach and specific aspects of data collection is also presented.

Research Steps for Objective #1

Research Objective #1. The first objective of this thesis was to identify published expedient methods not included in AFM 88-34 but useful to Civil Engineers deployed to contingency environments. The expedient methods considered useful were those that involved the 16 areas of work expected of Civil Engineers during contingencies. These 16 areas of work were categorized into three major groups and redefined as follows:

1. Facilities
 - a. Expedient Shelters
 - b. Expedient Field-fortifications
 - c. Expedient Facility Hardening
2. Pavement Surfaces and Support Systems
 - a. Non-airfield Pavements
 - b. Airfield Pavements
 - c. Aircraft Arresting Systems
 - d. Airfield Lighting Systems
3. Utility Systems

- a. Electrical Power Production
- b. Electrical Distribution
- c. Interior Electrical Wiring
- d. Water Supply
- e. Water Distribution
- f. Field Sanitation
- g. Liquid Fuels
- h. Heating
- i. Air Conditioning

Method of Approach. A literature review of magazine articles, course handouts, pamphlets, regulations, and manuals was used to find published expedient methods useful to Civil Engineers. These published expedient methods were compared to those in AFM 88-34. Any expedient methods not included in AFM 88-34 were used to develop the supplement to AFM 88-34.

Justification of Approach. The literature review was required to find expedient methods that were already available to Civil Engineers. This review served as a base for evaluating the unpublished methods identified in objective #2.

Aspects of Data Collection. All expedient methods that were uncovered by the literature review but already included in AFM 88-34 were disregarded. Those expedient methods that were not found in AFM 88-34 were retained and included in the supplement.

The next step in data collection was to make a list of

key words that related to the topic of expedient methods. This list was, in fact, provided by the School of Civil Engineering at the Air Force Institute of Technology (AFIT), Wright-Patterson AFB OH, at the onset of this research effort (41). The 16 areas of work that Civil Engineers are expected to perform during contingencies provided the necessary key words.

These key words were used to begin the actual literature review effort. A request for unclassified Air Force and Army reports for each of the work areas identified by the key words was submitted to the Defense Technical Information Center (DTIC), Defense Logistics Agency, Cameron Station, Alexandria, VA.

The key words were then used to find appropriate articles listed in the Air University Index to Military Periodicals. Microfiche slides of these articles were located at the AFIT Engineering (EN) Library. The microfiche slides were reviewed to locate data pertinent to this thesis. Articles with no relevant data were immediately discarded. Articles with only a few pages of pertinent data were saved and paper copies of these pages were made. Articles that were needed in their entirety were identified and complete copies were obtained from DTIC.

Other sources of expedient methods information were the course handouts offered by the AFIT School of Civil Engineering in their short course, ENG 485, "Contingency Engineering"; Army field manuals; and Navy Seabee

engineering manuals. All of these sources contained additional, valuable information that was used to complete objective #1.

All sources uncovered by the literature review contained expedient methods that could be applied by Civil Engineers during contingencies. General information of the expedient methods provided by these sources was presented in Chapter 2 of this thesis. The detailed methods were used to complete the supplement to AFM 88-34.

Research Steps for Objective #2

Research Objective #2. The second objective of this thesis was to obtain the unpublished expedient methods actually used by Civil Engineers during past contingencies. Since these expedient methods were developed, used, and found effective during actual contingencies, they would be a valuable source of information for future contingencies. Therefore, these expedient methods would be included in the supplement to AFM 88-34.

Method of Approach. The only practical means of obtaining unpublished expedient methods was by a survey. Those surveyed included all Air Force Civil Engineering officers, enlisted personnel, and civilians stationed in the Continental United States (CONUS). Responses were expected only from those members who performed the Civil Engineering mission in a contingency environment and actually used expedient methods not found in any publication. The

responses in this case contained the detailed, step-by-step procedures for accomplishing the expedient methods. Since the survey was actually a request for expedient methods instructions, the survey could be sent directly to the CONUS Air Force Civil Engineers without the approval required for typical surveys (16:1.3).

Aspects of Data Collection

The first step in collecting the expedient methods instructions was to design the survey cover letter, instructions, and forms. The survey cover letter was critical to this thesis, for an adequate number of pertinent responses depended entirely upon the motivation of the respondents. The author felt that many respondents could be motivated directly by stressing the benefits that their inputs would have on the less experienced Civil Engineering personnel. However, other respondents had to be motivated by their Base Civil Engineers (BCEs). Therefore, the survey forms were sent directly to each BCE with a clear and concise cover letter. The cover letter explained the importance of this thesis and requested their assistance and support. The BCE could then direct their branch chiefs to complete the survey forms and to solicit responses from other military and civilian personnel who have had any contingency experience.

The BCE letter contained another letter to the branch chiefs which provided concise instructions for properly

completing the survey forms. The survey instructions stated the purpose of the survey, defined the terms "expedient methods" and "contingencies," and identified the survey respondents.

To ensure pertinent expedient methods procedures from the respondents, the survey forms were made as simple as possible. This was extremely important since the respondents had to write detailed procedures instead of the simple responses typical of most surveys.

The survey forms contained a completed sample to demonstrate the proper way of completing the forms. The survey forms asked each respondent to enter expedient methods procedures along with the respondent's name, rank, and phone number. This biographical information provided a means to contact the respondents for clarification of their procedures. Also, by providing their names, the respondents received full credit for their expedient methods when these procedures were published in the new field manual.

The survey forms also required the respondents to state the time, place, and situation that the expedient methods procedures were used if this information was unclassified. This information provided historical realism to the procedures and would give future readers the means to compare their contingency situation with those provided by the respondents.

The second step was to test the survey before sending the survey package to the BCEs to eliminate any ambiguity

that may have existed in the cover letter, survey instructions, or survey forms. Twenty-two Civil Engineering graduate students enrolled in the Graduate Engineering Management Program at the AFIT were selected to perform the test survey. Responses to the test survey revealed no need for improving the survey cover letter, instructions, and survey forms.

The third and final step was to send the survey package (i.e., the cover letter, survey instruction letter to the branch chiefs, and approximately 80 survey forms) to the BCEs at each CONUS Air Force Base. A copy of the cover letter, instructions letter, and survey form was placed in Appendix A of this thesis for reference. The responses to the survey provided expedient methods actually used during contingencies. This information was then assembled with the information found from the literature review to form the supplement to AFM 88-34.

Research Steps for Objective #3

Research Objective #3. The third objective of this thesis was to design the supplement to AFM 88-34 from the information obtained from objectives #1 and #2.

Method of Approach. The supplement was kept in the same basic format of AFM 88-34 so the pages could be inserted without impairing the effectiveness of the manual. The supplement was also kept clear and concise so the information could be easily located and used during

contingencies.

Aspects of Supplement Design. The first step in designing the supplement to AFM 88-34 was to discard duplicate expedient methods as discussed in the Methods of Approach section. The remaining expedient methods were then grouped into similar categories. These categories were identified by the 16 key words discussed previously. Expedient methods that did not fall in any of these categories were grouped in a category labeled "Miscellaneous Expedient Methods." These 17 categories formed the body of the supplement to AFM 88-34 and can be found in Appendix B of this thesis.

The next step was to design the instructions for inserting the pages of the supplement into AFM 88-34. This was accomplished by locating sections in AFM 88-34 that paralleled each of the 17 categories of the supplement. The pages of each category were then placed in the appropriate section of AFM 88-34. Care was taken that the inserted pages did not interrupt the logical presentation of AFM 88-34.

The instructions were then written. The instructions direct the reader to insert a given page of the supplement before or behind a given page in AFM 88-34. The final step was to construct a revised Table of Contents for AFM 88-34 to account for the inserted pages of the supplement. This Table of Contents is also found in Appendix B.

IV. Results and Recommendations

Chapter Overview

This chapter gives the results for each of the research objectives discussed in the first two chapters. Recommendations based on these results are presented to improve the comprehensive expedient methods field manual developed in the thesis.

Research Results

Results of Research Objective #1. The literature review disclosed 41 published sources that were pertinent to this thesis. These sources were cited in both the main body of this thesis and in the Appendices. Fourteen sources contained expedient methods instructions that were not published in AFM 88-34. These sources were used to develop the supplement to AFM 88-34.

Results of Research Objective #2. All 84 CONUS Air Force bases were surveyed to obtain previously unpublished expedient methods instructions. Of these bases, 18 submitted responses. These responses contained a total of 65 expedient methods, 22 of which were never before published. These unpublished expedient methods were added to those discovered in the literature review to form the supplement to AFM 88-34.

Results of Research Objective #3. The actual supplement to AFM 88-34 was then developed. This supplement can be

found in Appendix B, along with instructions for inserting the pages into AFM 88-34.

Recommendations

Although this thesis provided 70 additional expedient methods to supplement AFM 88-34, it also uncovered areas in which expedient methods are lacking. These areas are listed below:

1. Expedient repair of aircraft arresting systems
2. Expedient wiring of facilities
3. Expedient plumbing techniques
4. Expedient liquid fuels distribution systems
5. Expedient air conditioning systems

Therefore, it is recommended that additional research be conducted to uncover and/or develop expedient methods in these areas. Additional expedient methods can be uncovered by additional surveys and a more extensive literature review. A survey should be conducted for each of the areas to which information is missing. Each survey should be sent directly to those Air Force Civil Engineers whose wartime duties would include expedient methods in the area of concern. Additional information could be found by surveying Civil Engineering personnel attending the AFIT short courses, stationed overseas, in the Air National Guard, and in the other branches of the military. Retired Civil Engineers should also be surveyed.

Additional expedient methods can also be uncovered by

conducting a second literature review. This second literature should include Air Force trip reports and other published documents not researched in this thesis. The literature review should focus only on those areas which are weak in expedient methods.

If the additional surveys and literature review fails to uncover sufficient expedient methods for all of the areas presented above, it is recommended that research be conducted to develop expedient methods for the remaining weak areas. The Engineering and Services Laboratory at the Air Force Engineering and Services Center (AFESC), Tyndall AFB FL or Civil Engineering graduate students at the Air Force Institute of Technology, Wright-Patterson AFB OH would be best qualified to conduct this research.

A copy of of this thesis has been sent to the Directorate of Engineering and Services (HQ USAF/LEEE) since the O-2 to AFM 88-34 identifies LEE as the office of primary responsibility for any changes made to the manual. This office can then revise AFM 88-34 by including the supplemental information found in Appendix B. This revised AFM 88-34 should then be made available to all Air Force Civil Engineers. Also, any follow-on research efforts should send the results to HQ USAF/LEEE.

Appendix A: Survey Package



DEPARTMENT OF THE AIR FORCE
AIR FORCE INSTITUTE OF TECHNOLOGY (AFIT)
WRIGHT-PATTERSON AIR FORCE BASE, OH 45433

REPLY TO
ATTN OF LS

SUBJECT: Expedient Methods Field Manual

TO

1. One of our graduate students, Captain Roy V. Bousquet, is developing a new field manual on expedient methods. The manual will contain actual methods of performing quick and temporary forms of construction, maintenance, and repair that have proved useful for CE during past contingencies. In addition to combining the numerous published sources on expedient methods, including AFM 88-34, the comprehensive manual will include previously unpublished techniques in expedient methods.
2. Many civilian and military personnel have performed their CE mission in wartime, during military exercises, or after natural disasters. Unfortunately, many of the innovative techniques used during these crises were never recorded. We want to gather this wealth of information to help younger officers and enlisted personnel who have never operated in a contingency environment. This information would also be useful in your expedient methods training program, providing realistic, "hands-on" contingency training. The new manual should be a useful guide in this training.
3. Please sign the attached letter and send copies of the letter and some survey forms to your branch chiefs. Your branch chiefs most likely possess the information needed. They can also find other experienced personnel who have actually used expedient methods during contingencies. Please have these personnel complete the enclosed forms and return them to your administrative office for mailing. A return envelope is included.
4. I realize that your people are very busy with their day-to-day duties. Many will not be willing to take the time to draw sketches and write brief directions that explain their expedient method experiences. However, the information that they possess will be valuable for many other Air Force Civil Engineers. Your support would be greatly appreciated.

Larry L. Smith
LARRY L. SMITH, Colonel, USAF
Dean
School of Systems and Logistics

- 2 Atch
1. Letter for Branches
2. Survey Forms

AIR FORCE—A GREAT WAY OF LIFE

REPLY TO
ATTN OF:
SUBJECT: Expedient Methods Field Manual
TO:

1. We have a chance to help write a manual of expedient methods to help us in future contingencies. Expedient methods are quick and temporary forms of construction, maintenance, and repair that are performed during contingencies to keep a base operational. A graduate student at the Air Force Institute of Technology (AFIT) is developing a new, comprehensive field manual on expedient methods. This manual will assist in our expedient methods training as well as providing a valuable source of information for our less experienced officers and enlisted personnel who have never operated in a contingency environment.

2. If you have ever been in an actual contingency such as a war, military exercise, or natural disaster, you probably have experience in using expedient methods. You may have used expedient methods during base build-up (providing electrical power, sanitation, shelter, etc.), for expedient maintenance/repair of existing facilities, or for making substitute tools. The procedures you used would be valuable additions to the new expedient methods manual.

3. Please take the time to fill out the four sections of the following form. Give copies of the form and this cover letter to anybody else in your branch who has information that can be added to the manual. Then return all the forms within 2 weeks to your Admin Office for mailing. You will receive full credit for any expedient methods procedure that you provide.

Thank you very much.

- 2 Atch
1. Survey Form
2. Example Sketch

SURVEY FORM

XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
SECTION 1- BIOGRAPHICAL INFORMATION:

NAME/RANK: _____
JOB TITLE: _____
CURRENT BASE: _____
AV PHONE NO: _____

XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
SECTION 2- BACKGROUND INFORMATION:

BASE/COUNTRY/YEAR WHERE EXPEDIENT METHOD WAS USED
(if unclassified): _____
EXAMPLE: _____

PHU-CAT / VIETNAM / 1967

WHAT WORK DID YOU DO USING EXPEDIENT METHODS?:

EXAMPLE:

SET UP TEMPORARY SHOWER UNITS
UNTIL PERMANENT UNITS COULD
BE CONSTRUCTED

XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
SECTION 3- STEP-BY-STEP PROCEDURE (if sketch on back side is
not self-explanatory:)

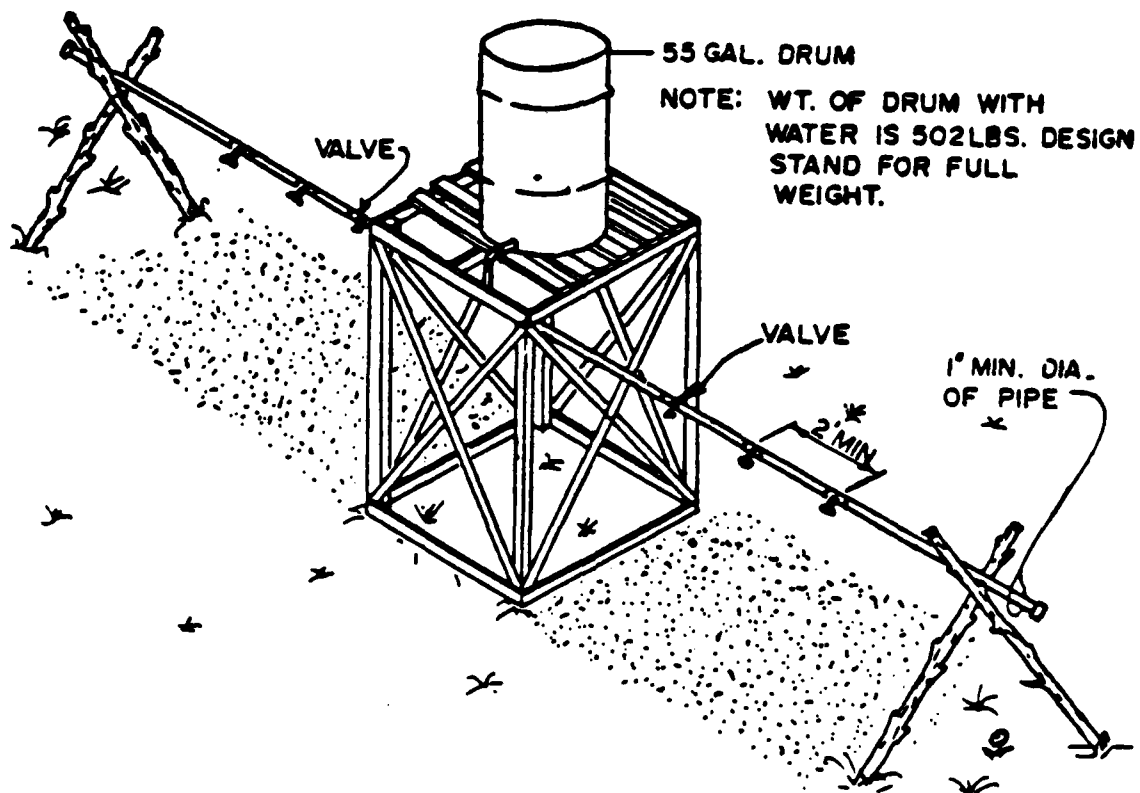
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SECTION 4 - SKETCH OF EXPEDIENT METHODS:

EXAMPLE SKETCH

"EXPEDIENT SHOWER UNIT"

Submitted by TSGT John E. Doe

As used in Vietnam, 1967



Appendix B: Supplement to AFM 88-34

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Instructions for Inserting Pages into AFM 88-34

1. Insert pages 61 and 62 after page 12-25 in AFM 88-34.
2. Insert pages 63 through 67 after page 6-26 in AFM 88-34.
3. Create a new chapter in AFM 88-34 entitled "Fortifications." Locate this new chapter between existing chapters 12 and 13. Insert pages 68 through 86 in this new chapter.
4. Insert pages 87 and 88 after page 1-3 in AFM 88-34.
5. Create a new chapter in AFM 88-34 entitled "Airfield Pavements and Support Systems." Locate this new chapter before the current Chapter 1. Insert pages 89 through 101 in this new chapter.
6. Insert pages 102 through 106 before page 9-1 in AFM 88-34.
7. Insert pages 107 through 112 after page 9-B in AFM 88-34.
8. Insert pages 113 and 114 after page 9-33 in AFM 88-34.
9. Insert pages 115 and 116 before page 9-1 in AFM 88-34 but after the pages inserted in step 6.
10. Insert page 117 after page 9-4 in AFM 88-34.
11. Insert pages 118 through 120 after page 5-21 in AFM 88-34.
12. Insert page 121 after page 5-7 in AFM 88-34.

13. Insert pages 122 through 126 after page 5-21 in AFM 88-34 and behind the pages inserted in step 11.
14. Insert page 127 before page 4-1 in AFM 88-34.
15. Insert pages 128 through 130 after page 4-2 in AFM 88-34.
16. Insert pages 131 and 132 after page 4-4 in AFM 88-34.
17. Insert page 133 after page 1-2 in AFM 88-34.
18. Insert pages 134 through 136 after page 8-1 in AFM 88-34.
19. Insert page 137 after page 13-6 in AFM 88-34.
20. Insert pages 138 and 139 before page 13-1 in AFM 88-34.
- 21., Insert pages 140 through 142 after page 11-1 in AFM 88-34.

Supplemental Expedient Methods

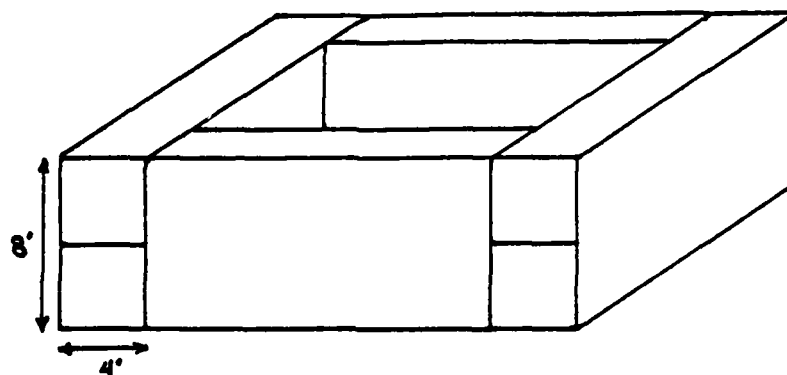


Figure 1. Expedient Shelter: Revetment Command Post

As Used in Ben Hoe, Vietnam

Submitted by MSgt Daniel Bermudez

Use 8 Republic Revetment sections to form the command post walls. Use 2"x4"s and plywood or just tree limbs tied together with rope for the roof.

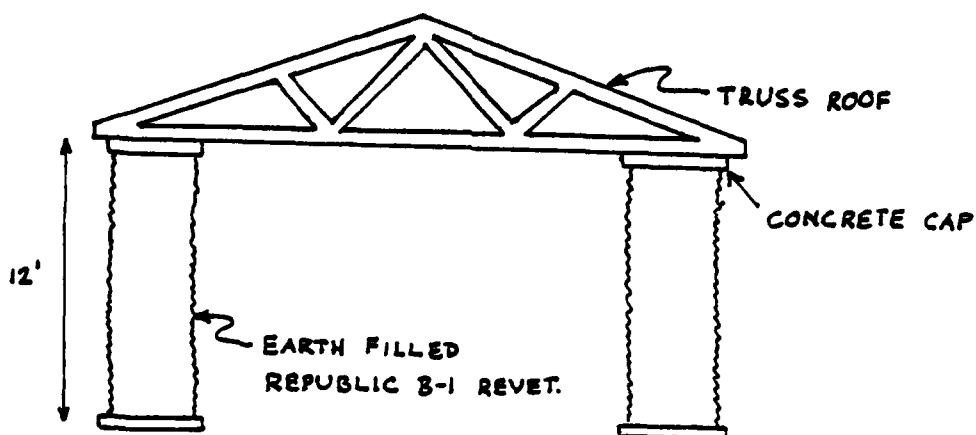


Figure 2. Expedient Shelter: "Singapore" Shelter

As Used in Korea

Submitted by Capt James T. Ryburn

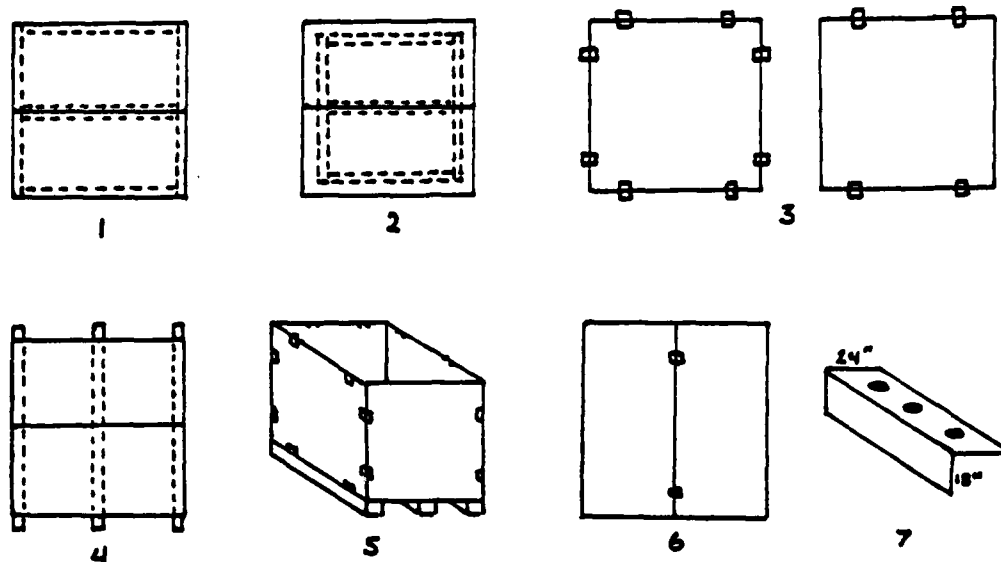


Figure 3. Expedient Shelter: Making a Portable Building
As Used in Project "Bright Star"

Submitted by SSgt William J. Ferris

- Step 1. Frame 2 pieces of plywood with 2"x4" to make a 6'x6' wall. Make 2 of these.
- Step 2. Frame 2 more 6'x6' walls. Allow for joining 4 walls.
- Step 3. Attach 2 hinges on each of the 4 sides on 2 walls, and 2 hinges on the top & bottom of the other walls.
- Step 4. Nail 2 pieces of 3'x6' plywood to the 4"x4"s to make a floor.
- Step 5. Connect walls to each other and to the floor.
- Step 6. Connect 2 pieces of 3'2"x6'2" plywood with hinges to form a 6'4"x6'2" roof. Attach roof to top hinges. Cut holes for windows and door. Make door from 4'x8' plywood sheet.
- Step 7. If used as a latrine, the back 2' of floor must be removed and a bench seat can be installed.

NOTE: To disassemble, pull hinge pins, fold roof, and put shelter sections on a pallet.

MATERIALS: 2 pieces of 3'2"x6'2"x3/4" plywood
10 pieces of 3'x6'x3/4" plywood
1 additional sheet of 3/4" plywood
10 - 2x4s, 6' long
26 - 4" hinges (butt)
3 - 4x4s, 6'2" long

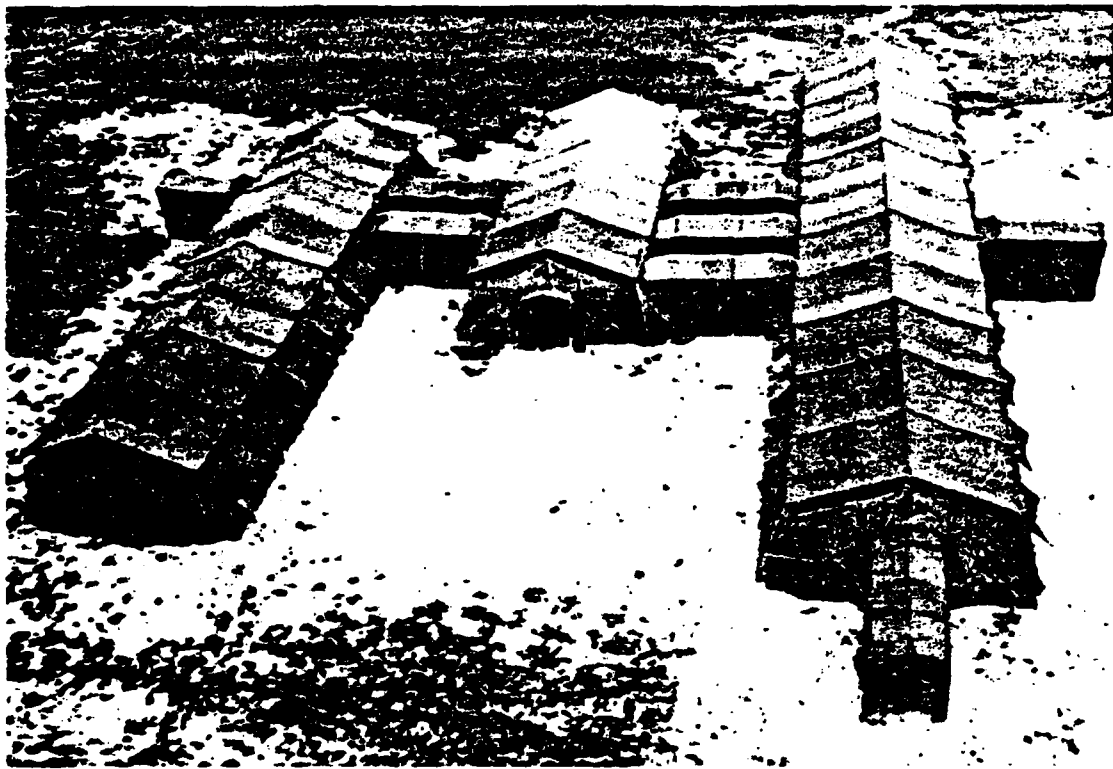


Figure 4. Expedient Shelter: TEMPER Complex

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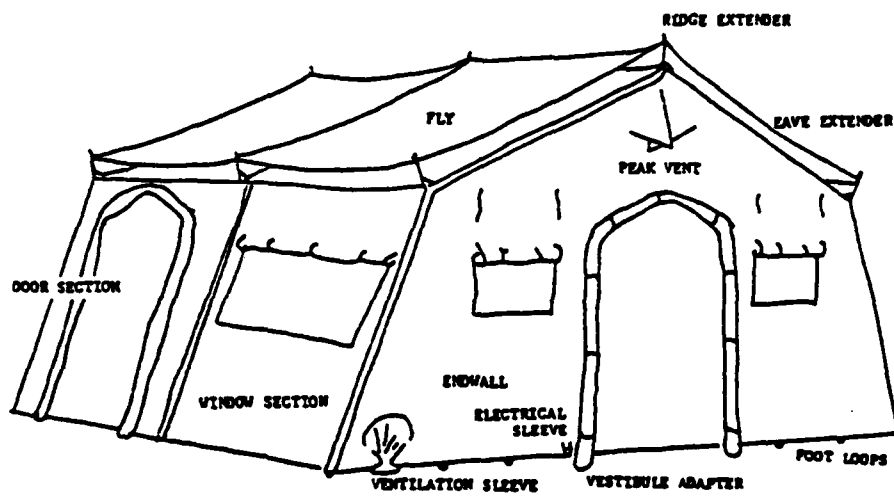


Figure 5. TEMPER Coverings

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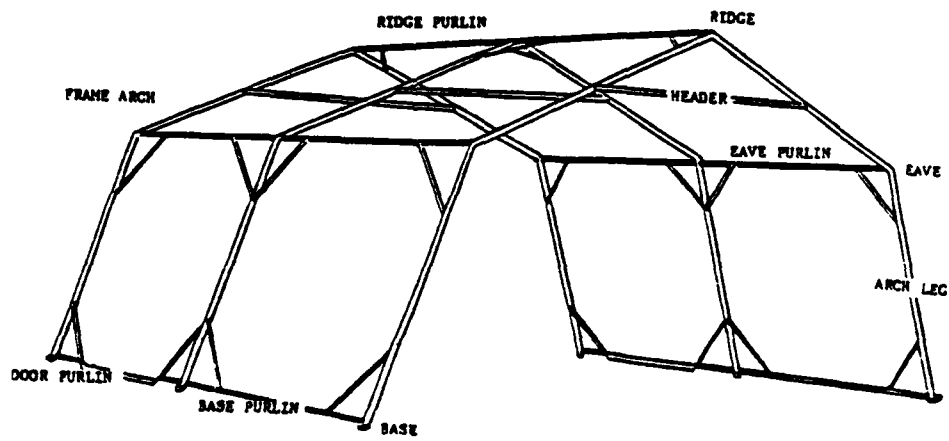
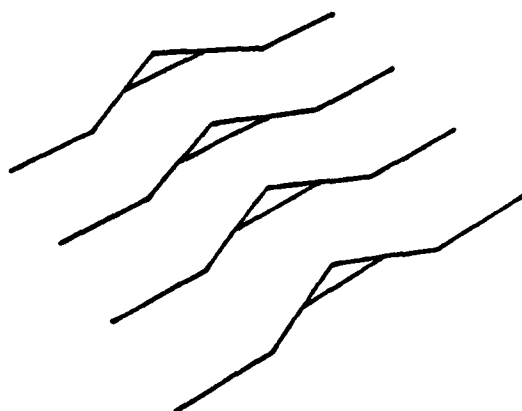
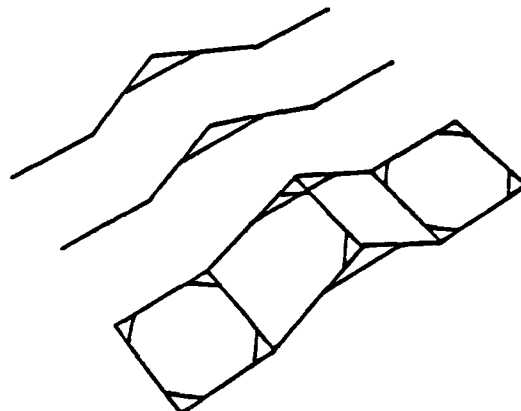


Figure 6. TEMPER Frame

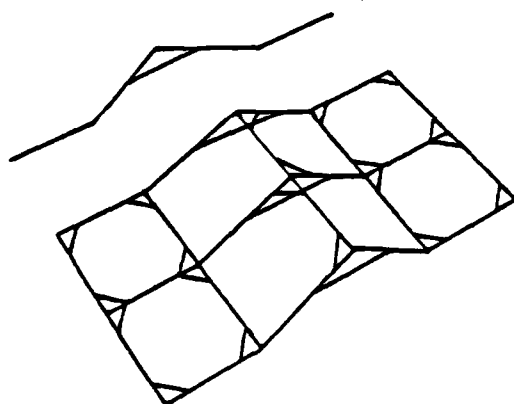
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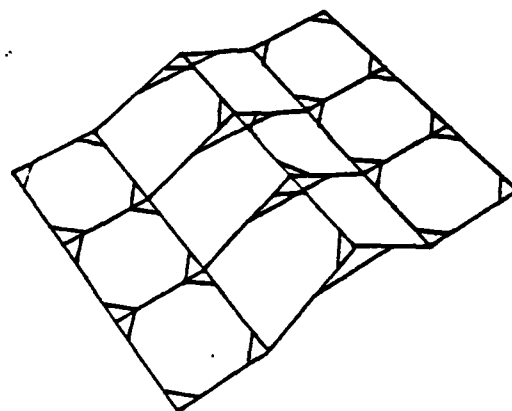
1- FRAMES LAID PARALLEL



2- ONE SECTION WITH ALL FIVE PURLINS



3- TWO SECTIONS WITH PURLINS



4- THREE SECTIONS WITH PURLINS

Figure 7. Steps in Assembling TEMPER Frames

Adapted from 44:25

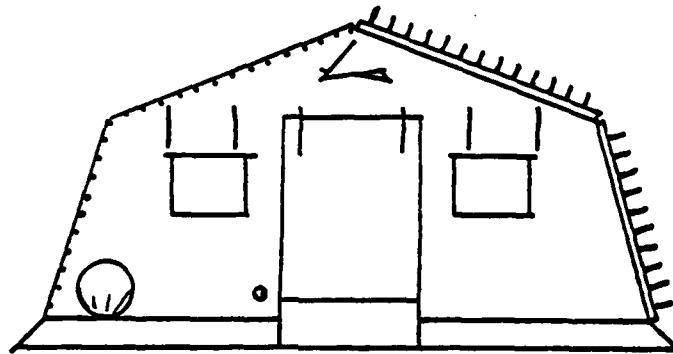


Figure 8. TEMPER Endwall Fabric

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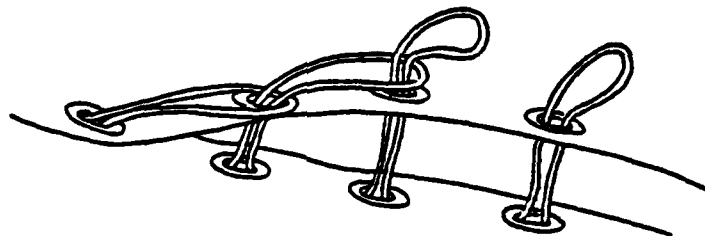


Figure 9. TEMPER Lacing Procedure

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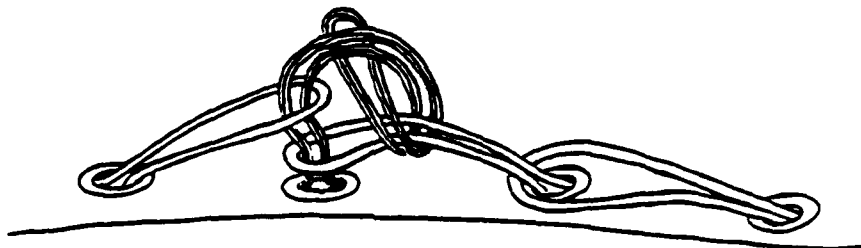


Figure 10. TEMPER Lacing Tie Off Procedure

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TABLE I

Parts Required to Assemble the TEMPER

The TEMPER tent is erected in lengths of 8 ft. To erect a two section tent of 16'x20' floor area, you would need the following parts:

FRAME:	3 Arches
	3 Headers
	10 Purlins
	6 Eave Extenders
	3 Ridge Extenders
COVERINGS:	2 Roof Sections
	1 16' Fly
	2 End Sections
	2 End Section Liners
	1 Endwall Plenum
COMPONENTS	26 Steel Pins
	10 Wooden Stakes.

To add one section to a two section tent:

FRAME:	1 Arch
	1 Header
	5 Purlins
	2 Eave Extenders
	1 Ridge Extender
COVERINGS:	1 Roof Section
	1 8' Fly
	1 Liner Section
	1 16' Plenum
COMPONENTS:	6 Steel Pins
	2 Wooden Guy Line Stakes

Adapted from 44:19

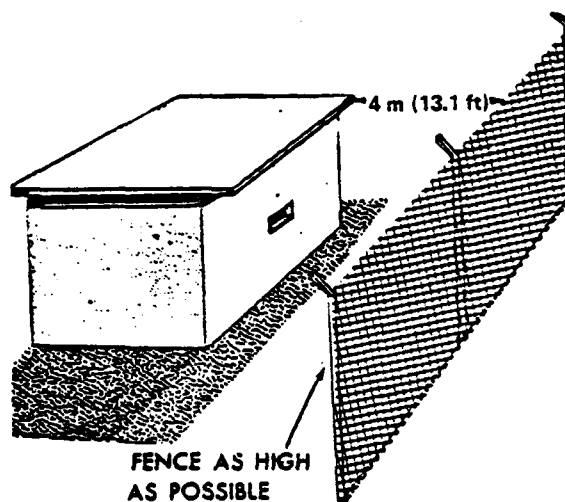
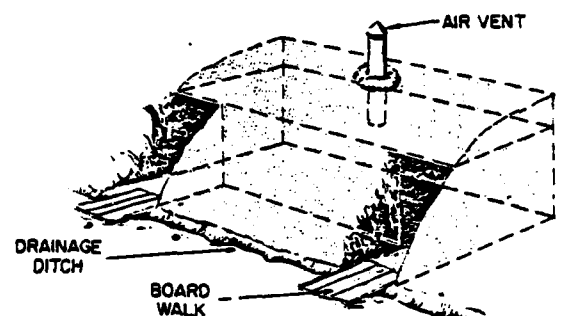
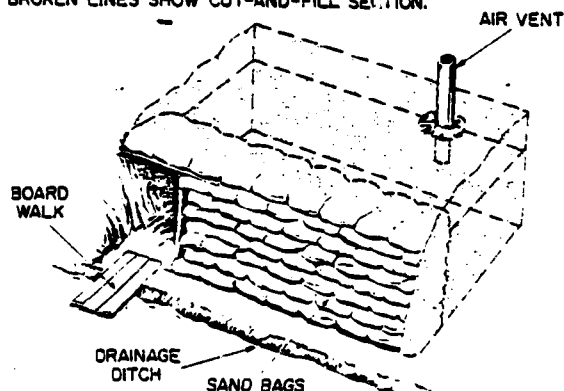


Figure 11. Fortifications: Fence Standoff

Reprinted from 18:3.12



CUT-AND-COVER SHELTER IN A HILLSIDE (BAFFLE WALL OF ENTRANCE CAMOUFLAGE OMITTED) SHADED AREA AND BROKEN LINES SHOW CUT-AND-FILL SECTION.



CUT-AND-COVER SHELTER IN A CUT BANK SHOWING SAND-BAGGED OUTER WALL. SHADED AREA AND BROKEN LINES SHOW AREA OF CUT-AND-FILL.

Figure 12. Fortifications: Cut-and-cover Shelter

Reprinted from 18:3.12

TABLE II

Minimum Thickness of Protective Material
Required to Resist Penetration

No Standoff - Material in Inches

Types of ammo	Soil		Sand		Clay		Soil cement (BC)	C	T	A	S
	W	D	W	D	W	D					
.30 cal ball	36	24	36	24	44	30	18	9	60	2.6	1.3
.50 cal ball	54	36	45	30	80	54	18	9	120	4.4	2.2
57-mm recoil- less rifle	18	12	18	12	36	24	20	10	20	9.0	5.0
82-mm recoil- less rifle	40	27	41	27	80	54	42	22	48	21.0	12.5
90-mm recoil- less rifle	60	40	63	42	120	80	66	33	75	32.2	19.5
107-mm recoil- less rifle	72	48	70	48	144	96	84	42	88	40.0	22.5
60-mm mortar	72	48	45	30	100	64	20	10	20	2.8	1.0
81-mm mortar	90	60	63	42	136	90	26	13	27	3.7	1.3
120-mm mortar	103	70	70	48	180	120	32	16	36	4.7	1.7

1/4" Steel or 1/2" Timber Standoff

.30 cal ball	18	12	18	12	22	15	9	6	30	1.3	0.6
.50 cal ball	27	18	26	15	40	27	9	6	60	2.2	1.1
57-mm recoil- less rifle	9	6	9	6	18	12	10	6	10	4.5	2.5
82-mm recoil- less rifle	20	13	21	13	40	27	21	11	24	10.5	6.3
90-mm recoil- less rifle	30	20	30	21	59	40	33	17	38	16.0	9.8
107-mm recoil- less rifle	36	24	35	24	71	48	42	21	44	20.0	11.3
60-mm mortar	36	24	22	15	50	32	10	5	10	1.4	0.5
81-mm mortar	45	30	31	21	66	45	13	7	14	1.9	0.6
120-mm mortar	52	35	35	24	90	60	16	8	18	2.4	0.8

"W" = wet
 "D" = dry
 "BC" = bituminous concrete
 "C" = concrete
 "T" = timber
 "A" = aluminum
 "S" = steel

Adapted from 19:110

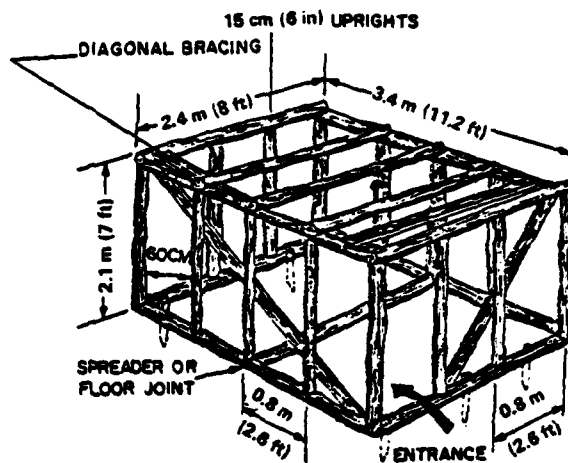


TABLE III

Size of Roof Supports

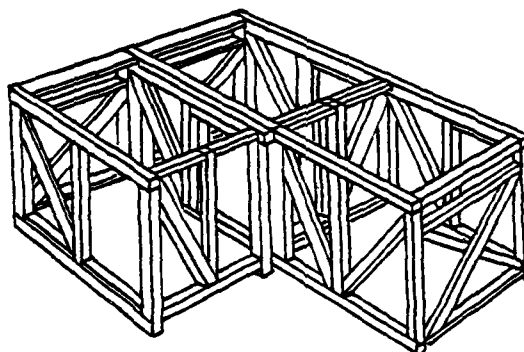
Size of timber (diam.) Maximum span when used to support 18" of earth

4 in.	4 ft.
5 in.	5 ft.
6 in.	7 ft.
7 in.	9 ft.
8 in.	11 ft.
9 in.	13 ft.

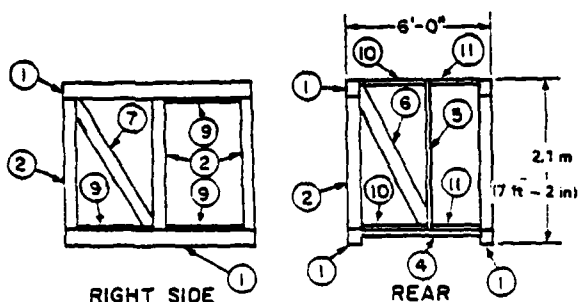
Figure 13. Fortifications: Log Framed Shelter

Adapted from 18:3.6

Reprinted from 18:3.6



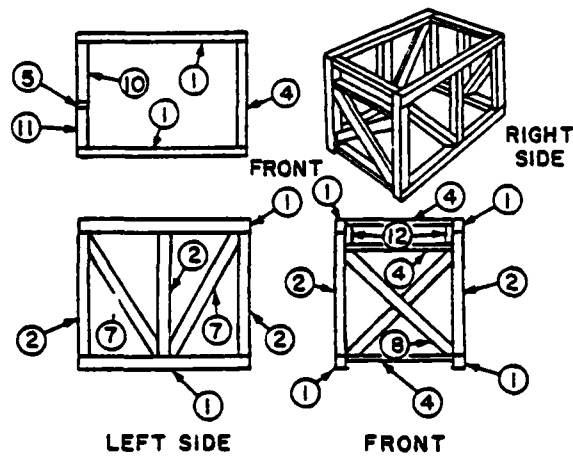
① TYPICAL CONNECTION OF THREE SECTIONS



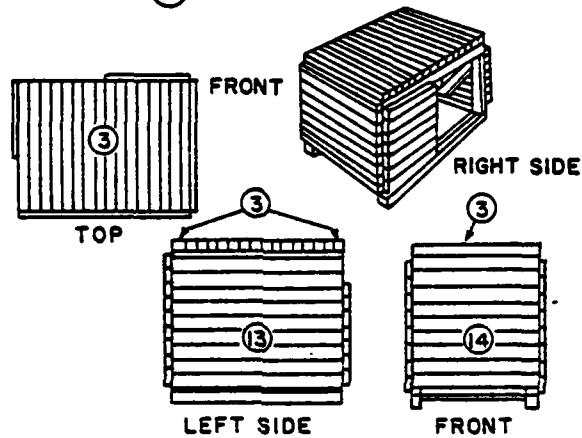
② FRAMING DETAILS

Figure 14. Fortifications: Sectional Shelters

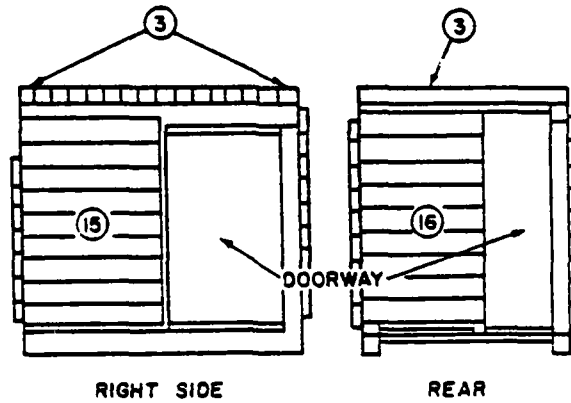
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③ FRAMING DETAILS



④ SHEATHING DETAILS



⑤ SHEATHING DETAILS

Figure 14 - continued

Reprinted from 18:3.7

TABLE IV

Bill of Materials for One 6'x8' Sectional Shelter With
Post, Cap and Stringer Construction - Dimensional Timber

No.	Nomenclature	Material size	Quantities				
		Rough size	Roof	Front	Right	Left	Rear
1	Cap or sill	6"x8"x8'0"	-	-	2	2	-
2	Post	6"x6"x5'10"	-	-	3	3	-
3	Stringer **	6"x6"x6'0"	16	-	-	-	-
4	Spreader	3"x6"x5'0"	-	2	-	-	1
5	Post, door	3"x6"x6'6"	-	-	-	-	1
6	Brace	* 3"x6"x7'0"	-	-	-	-	1
7	Brace	* 3"x6"x6'10"	-	-	1	2	-
8	Brace	* 3"x6"x8'0"	-	2	-	-	-
9	Spreader	2"x6"x3'3"	-	-	3	-	-
10	Spreader	2"x6"x2'9"	-	-	-	-	2
11	Spreader	2"x6"x2'0"	-	-	-	-	2
12	Scab	3"x6"x2'0"	-	-	-	-	-
13	Siding	3"xRWx8'0"	-	-	-	41	1/3SF
14	Siding	3"xRWx6'0"	-	36SF	-	-	-
15	Siding	3"xRWx4'0"	-	-	24SF	-	-
16	Siding	3"xRWx3'6"	-	-	-	-	21SF
17	Roll roofing	100 sq ft roll	6	-	-	-	-
18	Driftpin	1/2"x14"	32	-	6	6	-
19	Nails	60d	-	8 lb	8 lb	8 lb	8 lb

* Allowance for double out ends of braces is included in overall length as shown under rough size.

** Laminated wood roof may be substituted if desired.

Adapted from 18:3.8

TABLE V

Comparison of Rectangular and Round Timber

Size or rectangular timber	Size or round timber required to equal (in inches)
6x6	7
6x8	8
8x8	10
8x10	11
10x10	12
10x12	13
12x12	14

Adapted from 18:3.8

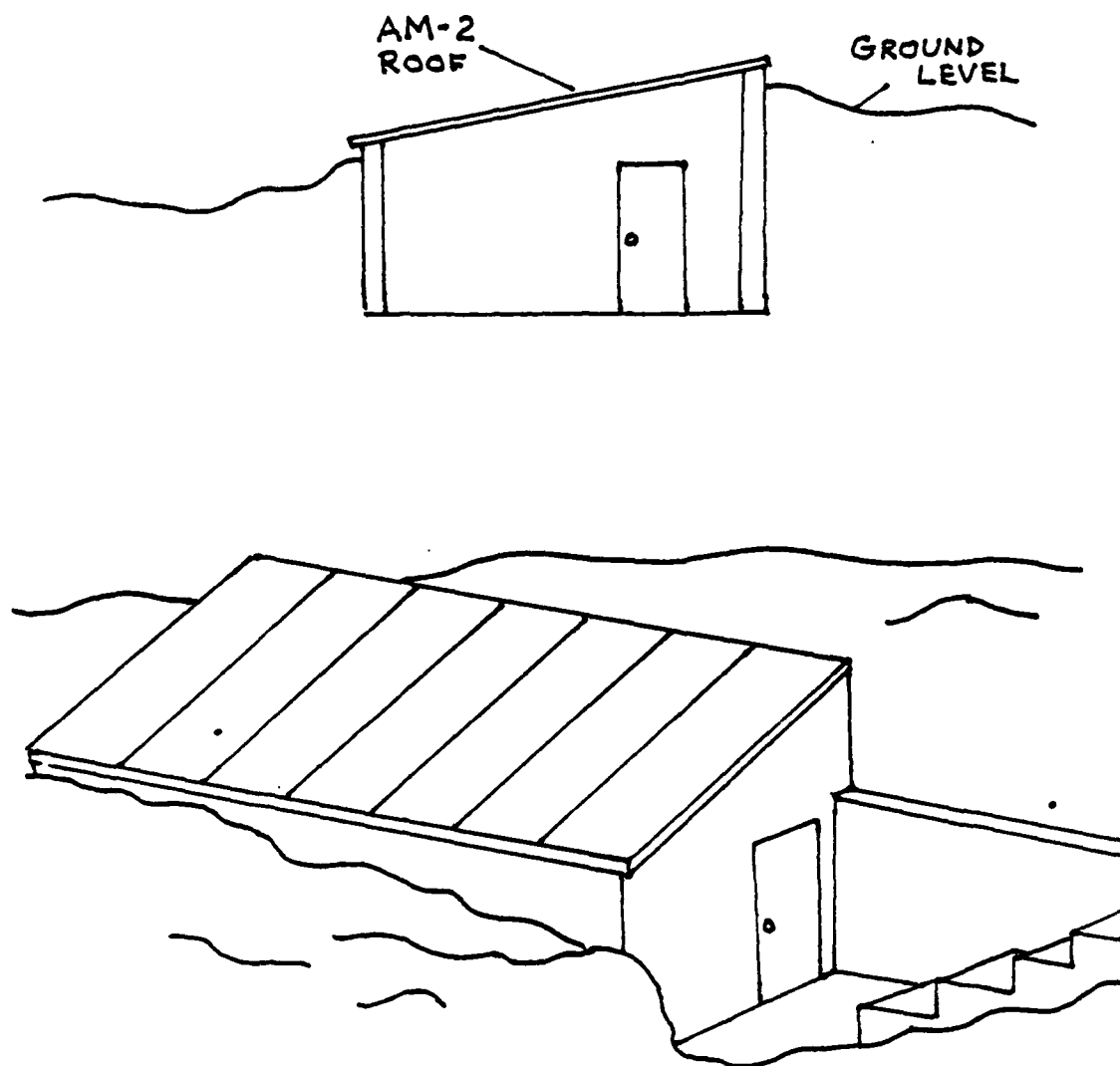


Figure 15. Fortifications: Underground Command Bunker
As Used During an AFLC Inspection
Submitted by 1Lt Jared Astin

TABLE VI

**Material and Labor Requirements for 300-Meter (984-foot)
Sections of Various Barbed Wire Entanglements**

Type of entanglement	Pickets				Barbed wire No. of 400 m. 41.5 kg reels	No. of concertinas	Staples	Kg of materials per lin m of entanglement	Lb of materials per lin m of entanglement	Man-hours to erect 300 m of entanglement
	Extra long	Long	Medium	Short						
Double-apron, 4- and 2- pace		100		200	14-15 (19)			4.6 (3.5)	10 (7.7)	59
Double-apron, 6- and 3- pace		66		132	13-14 (18)			3.6 (2.6)	8 (5.7)	49
High wire (less guy wires)		198			17-19 (24)			5.3 (4.0)	11.6 (8.8)	79
Low wire, 4- and 2-pace 4-strand fence		100	100	200	11 (15)			3.6 (2.8)	7.9 (6.1)	49
Double expedient concertina		101		4	5- 6 (7)			2.2 (1.8)	4.8 (3.9)	20
Triple expedient concertina		101		4	3	100	295	6.9	15.1	40
Triple standard concertina	51	101		7	4	148	295	10.4	22.8	99
Triple standard concertina		160		4	3 (4)	59	317	7.9 (5.4)	17.3 (11.8)	30

¹ Lower number of reels applies when screw pickets are used; high number when U-shaped pickets are used. Add difference between the two to the higher number when wood pickets are used.

² Average weight when any issue metal pickets are used.

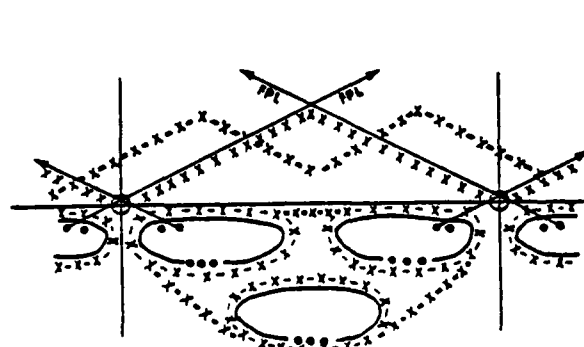
³ Man-hours are based on the use of screw pickets. With the exception of the triple-standard concertinas, add 20 percent to the man-hours when driven pickets are used. With experienced troops, reduce man-hours by one-third. Increase man-hours by 50 percent for nightwork.

⁴ Based on concertinas being made up in rear areas and ready for issue. Once expedient concertina opens to 19.7 ft length, as compared with 15 meters for a standard concertina; it requires 302 feet of standard barbed wire, also small quantities of No. 16 smooth wire for ties.

⁵ Number of 984 ft, 14.5 kg barbed tape carrying cases required if barbed tape is used in place of barbed wire.

⁶ Kgs of materials required per linear meter of entanglement if barbed tape is used in place of barbed wire and barbed tape concertina is used in place of standard barbed wire concertina.

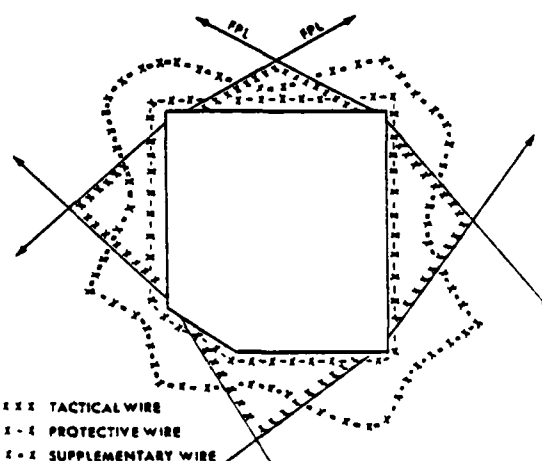
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XXXXXXX TACTICAL WIRE
X-X-X-X-X PROTECTIVE WIRE
-X-X-X-X SUPPLEMENTARY WIRE

**Figure 16. Obstacles:
Classification of Wire by Use**

Reprinted from 19:124



XXXXX TACTICAL WIRE
X-X-X PROTECTIVE WIRE
X-X-X SUPPLEMENTARY WIRE

**Figure 17. Obstacles:
Perimeter Defense Wire**

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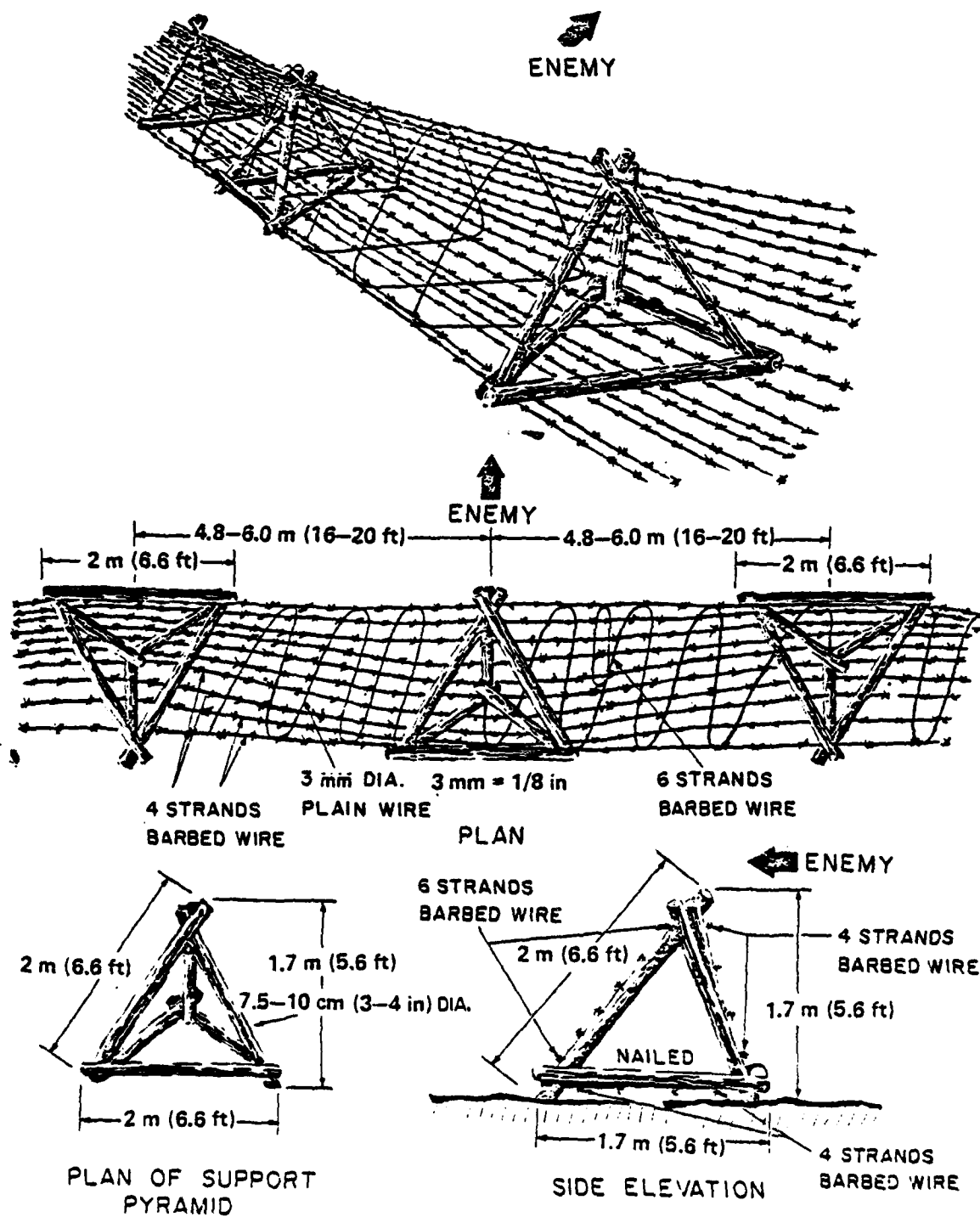


Figure 18. Obstacles: Lapland Fence

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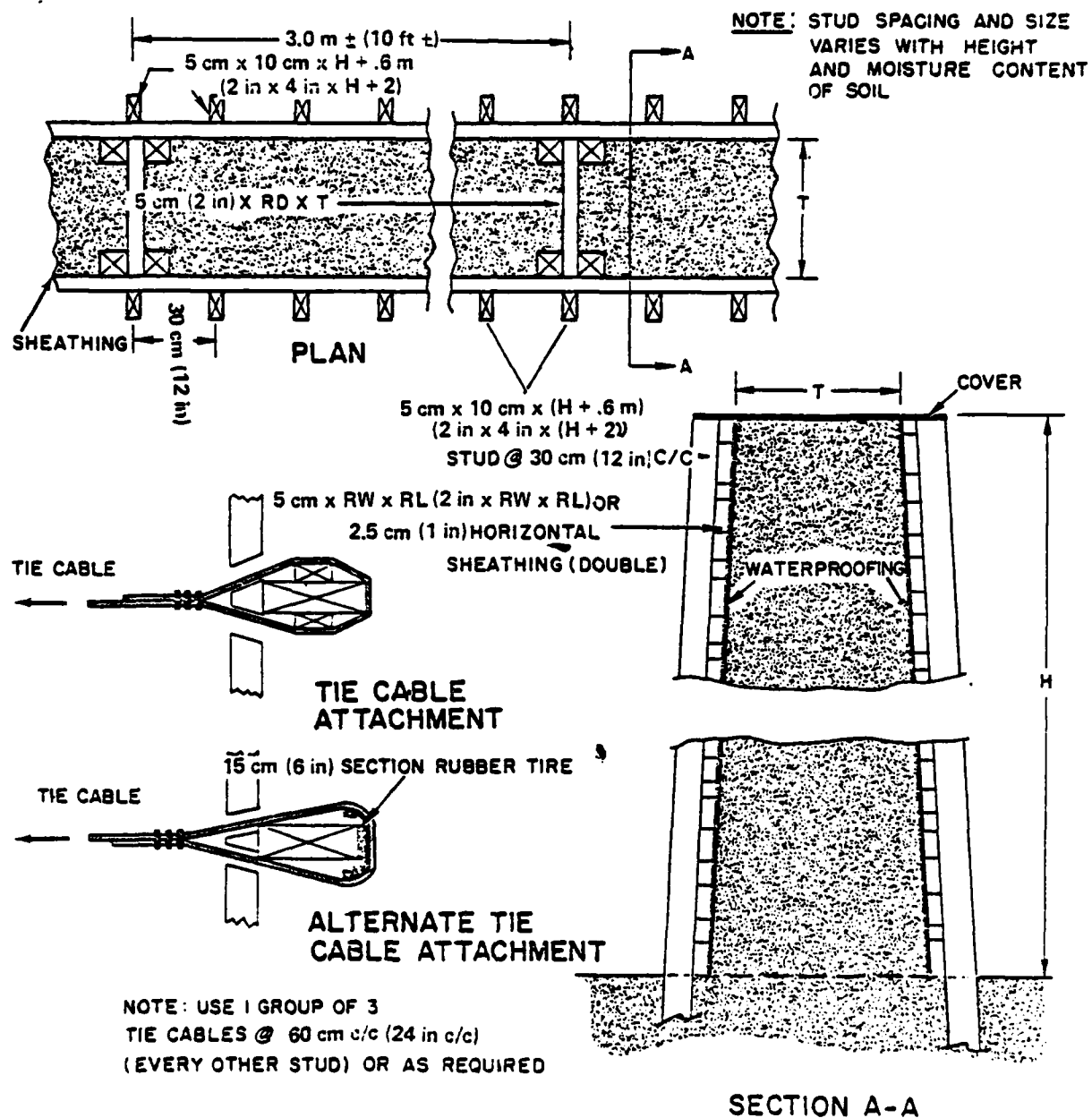


Figure 19. Hardening: Dimensional Timber
(Soil Bin) Revetment

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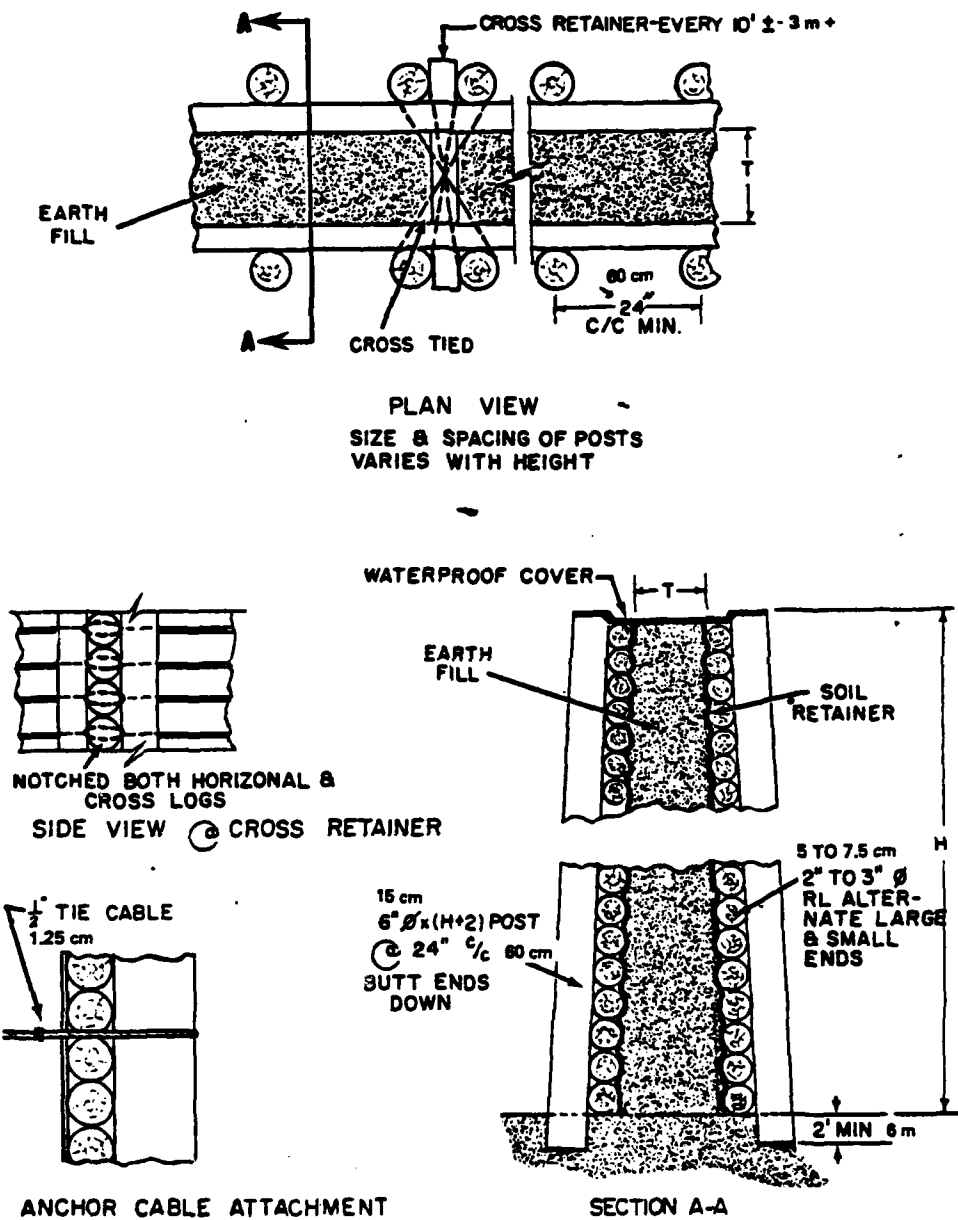


Figure 20. Hardening: Log Bulkhead (Soil Bin) Revetment

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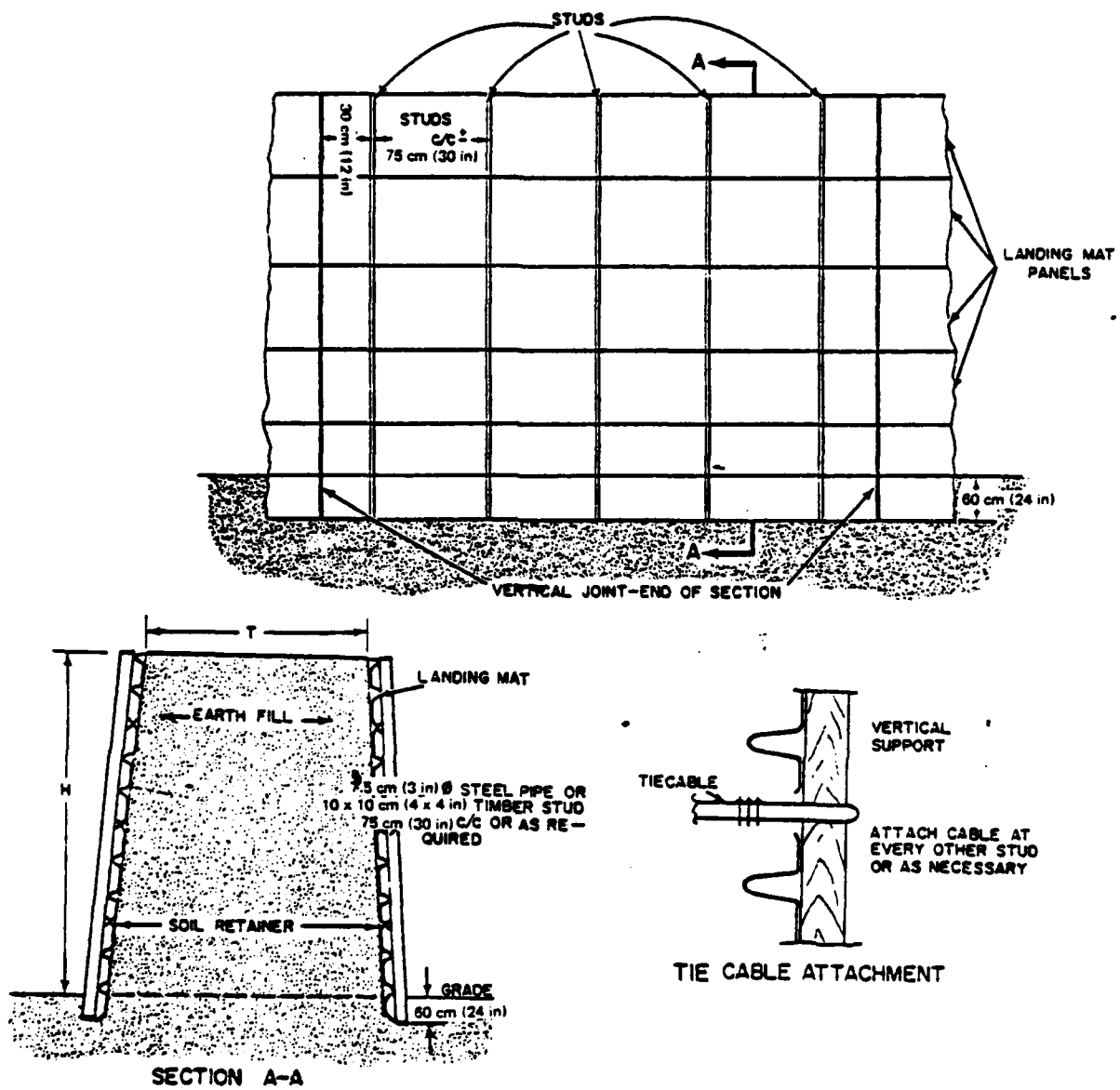


Figure 21. Hardening: Landing Mat Bulkhead (Soil Bin) Revetment

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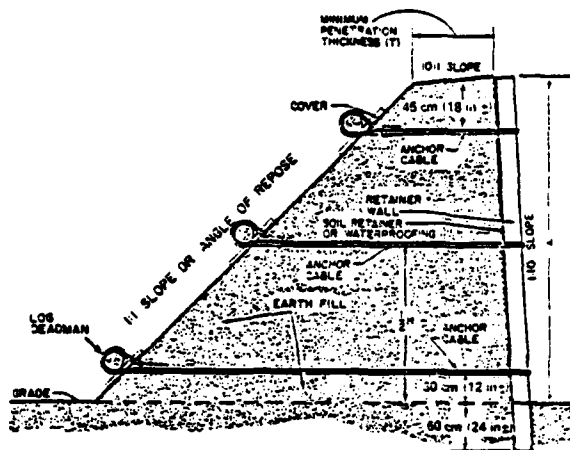
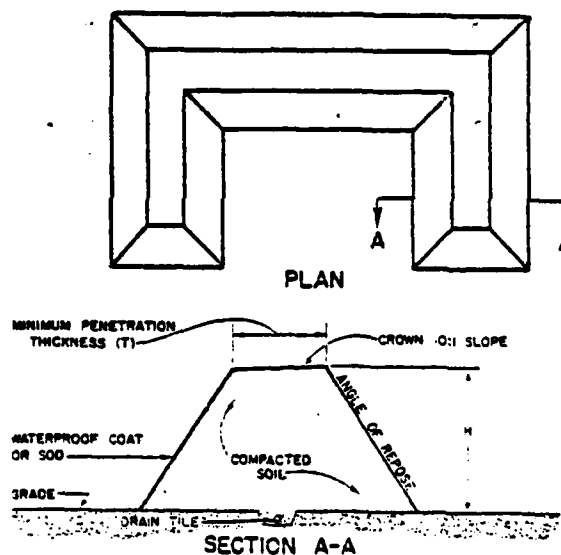


Figure 22. Hardening: Gravity Revetment

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NOTE:

WATERPROOFING MAY BE ASPHALT CUTBACK OR CEMENT SLURRY. TRAFFIC ON THE REVETMENT MUST BE PROHIBITED IN ORDER TO PRESERVE THE WATERPROOF COATING.

Figure 23. Hardening: Earth Revetment

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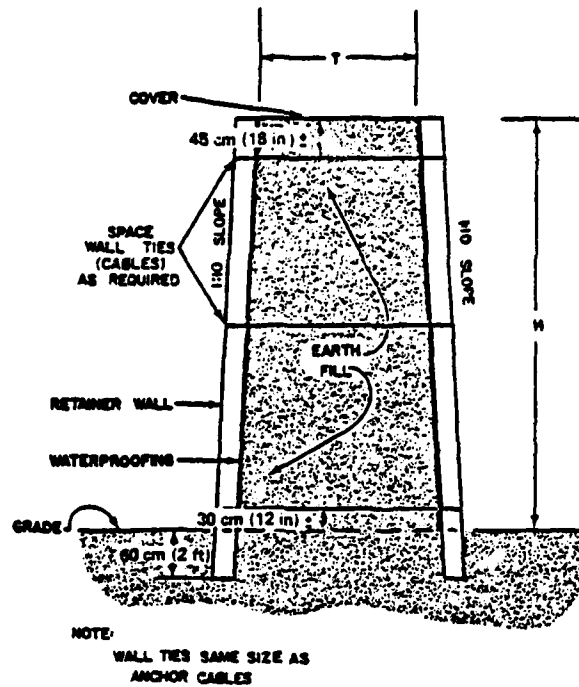


Figure 24. Hardening: Bulkhead Revetment

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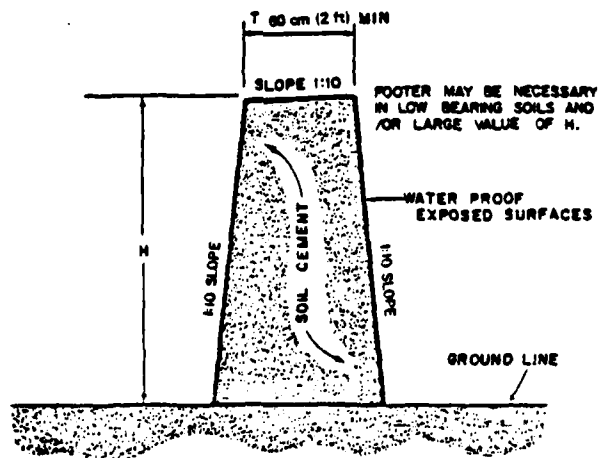


Figure 25. Hardening: Freestanding Wall,
Soil-cement Revetment

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SYSTEMS AND LOGISTICS R V BOUSQUET SEP 84

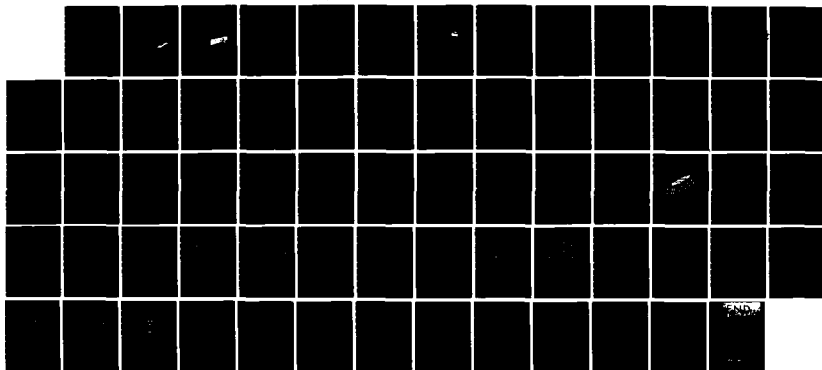
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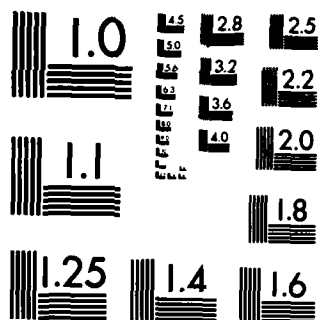
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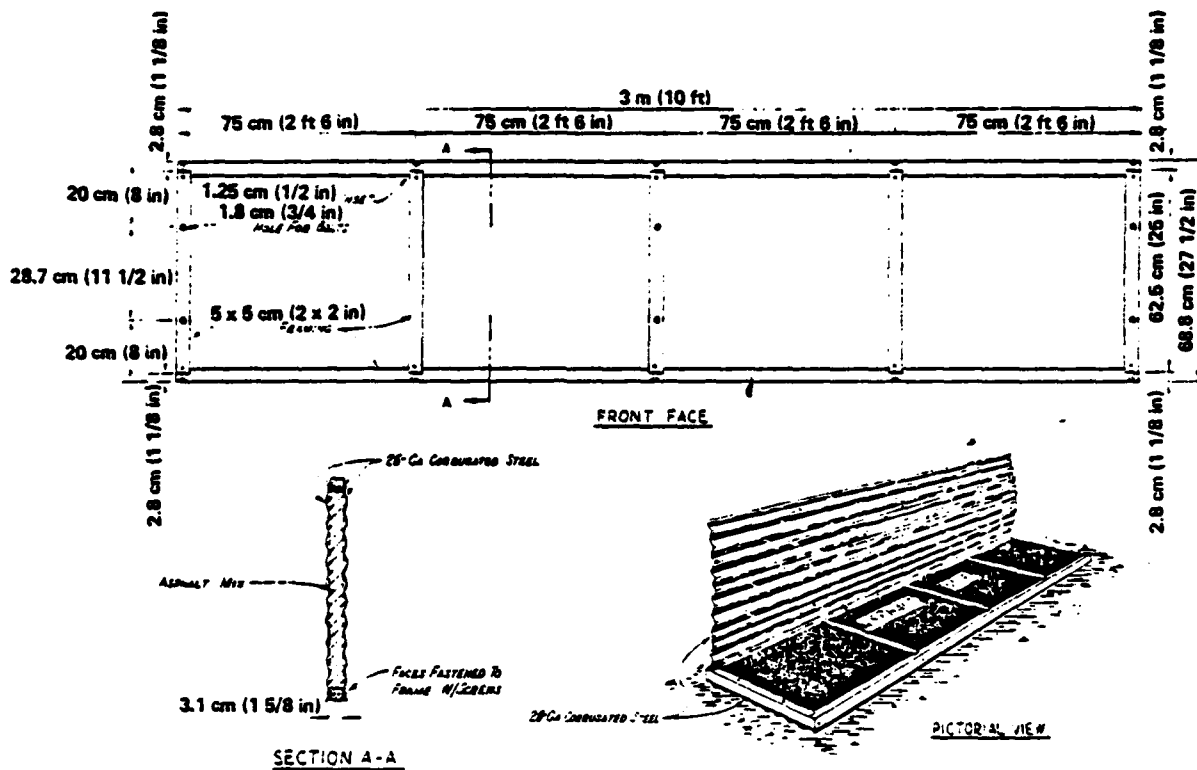


Figure 27. Hardening: Plastic Armor Panel
(Double Corrugated Metal)

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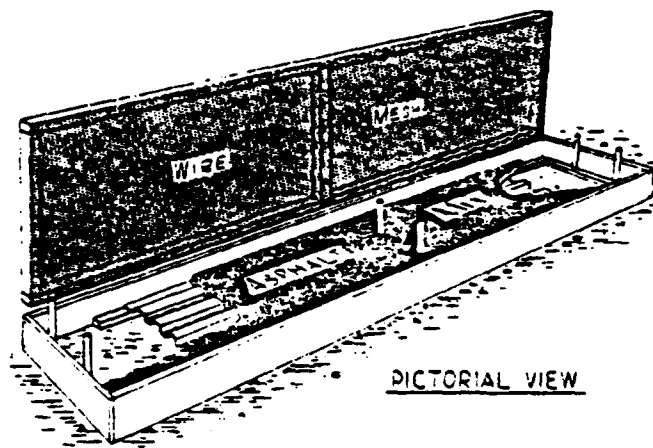
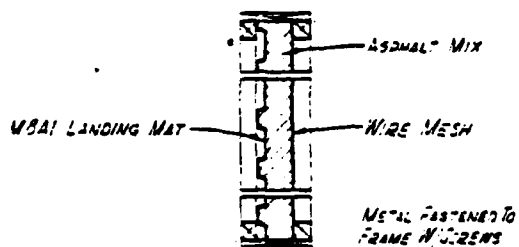
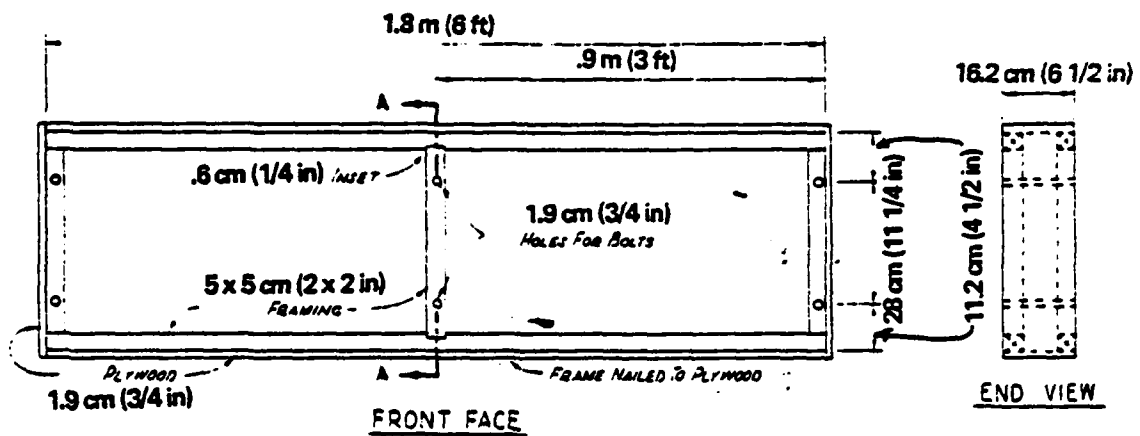


Figure 28. Hardening: Plastic Armor Panel
(MBA1 Mat With Wire Mesh)

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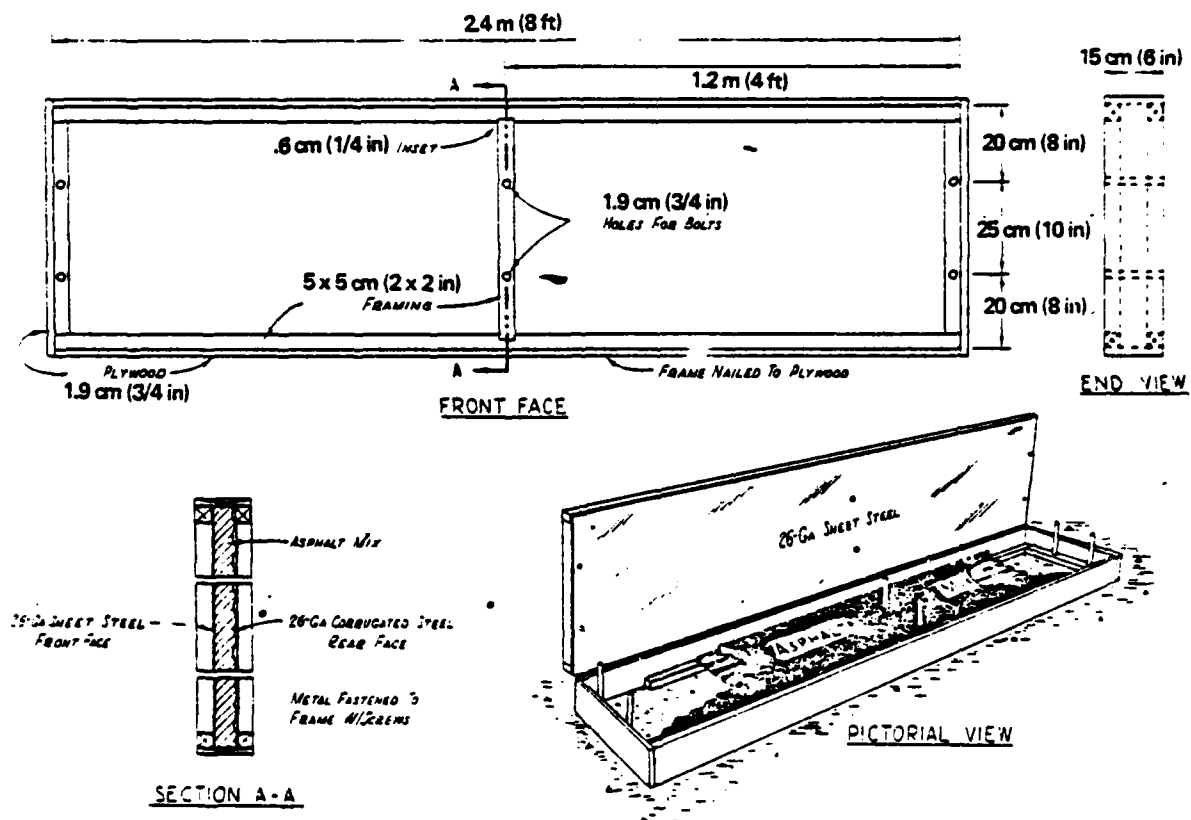


Figure 29. Hardening: Plastic Armor Panel
(Corrugated and Sheet Metal with Plywood)

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TABLE VII
Hot Asphalt Mixes for Revetment Construction

Sieve size *	Percent used	Percent passing indicated sieve sizes									
		1	1/2	3/4	1 1/2	4	10	20	40	60	200
A. Mix 1—Coarse Mix ^b :											
3/4-1 1/2.....	22.2	22.2	21.8	1.5	0.0						
1 1/2-3 1/8.....	22.2	22.2	22.2	21.8	4.9	0.0					
3 1/8-4.....	22.2	22.2	22.2	22.2	22.0	2.0	0.0				
LSD.....	33.4	33.4	33.4	33.4	33.4	33.4	33.4	33.3	33.0	31.6	25.3
Blend.....	100.0	100.0	99.6	78.9	60.3	35.4	33.4	33.3	33.0	31.6	25.3
B. Mix 2—Sand Mix ^b :											
Sand.....	86.0	86.0	86.0	86.0	86.0	86.0	85.1	83.0	66.2	10.3	4.7
LSD.....	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	13.8	13.2	10.3
Blend.....	100.0	100.0	100.0	100.0	100.0	100.0	99.1	97.0	80.0	24.0	15.5
C. Mix 3—G11A Well Graded Mix ^b :											
3/4-1 1/2.....	11.6	11.6	11.4	0.8	0.0						
1 1/2-3 1/8.....	7.3	7.3	7.3	7.2	1.6	0.1					
3 1/8-4.....	15.9	15.9	15.9	15.9	15.3	1.4					
4-10.....	16.3	16.3	16.3	16.3	16.3	16.7	1.6	0.3	0.2	0.2	0.2
10-20.....	12.5	12.5	12.5	12.5	12.5	12.5	12.5	1.3	0.1	0.0	
20-40.....	10.5	10.5	10.5	10.5	10.5	10.5	10.5	3.7	1.1	0.1	0.1
40-60.....	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	1.4	0.3
TVS.....	14.6	14.6	14.6	14.6	14.6	14.6	14.6	14.4	13.3	10.7	1.9
LSD.....	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.5	2.1
Blend.....	100.0	100.0	99.2	39.1	32.6	66.3	50.0	36.0	26.0	14.9	4.5

* Sizes 1, 1/2, 3/4, and 1 1/2 are in inches; all others are standard sieve sizes. LSD and TVS are limestone dust and Tennessee Valley sand, respectively.
^b Mix 1 contained Alabama limestone aggregate and 7.5 percent asphalt binder; Mix 2 contained Cook's Bayou sand and 7.5 percent asphalt binder; Mix 3 contained Alabama limestone and Tennessee Valley sand and 3.3 percent asphalt binder. The binder used in all three mixes was 55-100 penetration asphalt.

Reprinted from 18:E.16

TABLE VIII

Field Expedient Mixes for Revetment Construction

Mix designation	Binder	Aggregate																
1-A, rapid-cure asphalt mix	8.5 percent asphalt (percentage of total aggregate weight); RC-2 rapid cure (70 percent asphalt content); binder mixed cold.	Same as hot Mix 1: Limestone dust filler, 33.4 percent; Alabama limestone, 66.6 percent. Gradation of Alabama Limestone <table><tr><th>Sieve size</th><th>Percent passing</th></tr><tr><td>3/4 inch</td><td>100</td></tr><tr><td>1/2 inch</td><td>66</td></tr><tr><td>3/8 inch</td><td>33</td></tr><tr><td>No. 4</td><td>0</td></tr></table>	Sieve size	Percent passing	3/4 inch	100	1/2 inch	66	3/8 inch	33	No. 4	0						
Sieve size	Percent passing																	
3/4 inch	100																	
1/2 inch	66																	
3/8 inch	33																	
No. 4	0																	
1-B, hot-cold mix	7.5 percent 85-100 penetration asphalt, binder mixed hot.	Same as hot Mix 1: Total aggregate soaked with 2.2 percent (percentage of total aggregate weight) diesel fuel prior to mixing with binder.																
1-C, Peneprime mix	6.5 percent Peneprime (60 percent asphalt content); binder mixed cold	Same as hot Mix 1																
No. 4, commercial hot-cold mix.	6 percent AC-3 cutback asphalt, binder mixed hot.	10 percent fine river sand; 30 percent concrete sand; 60 percent No. 37 Birmingham slag. Gradation of No. 37 Birmingham Slag <table><tr><th>Sieve size</th><th>Percent passing</th></tr><tr><td>1/2 inch</td><td>100</td></tr><tr><td>3/8 inch</td><td>99</td></tr><tr><td>No. 4</td><td>90</td></tr><tr><td>No. 10</td><td>48</td></tr><tr><td>No. 40</td><td>24</td></tr><tr><td>No. 100</td><td>8</td></tr><tr><td>No. 200</td><td>2</td></tr></table> Aggregate sprayed with kerosene, then mixed with hot asphalt.	Sieve size	Percent passing	1/2 inch	100	3/8 inch	99	No. 4	90	No. 10	48	No. 40	24	No. 100	8	No. 200	2
Sieve size	Percent passing																	
1/2 inch	100																	
3/8 inch	99																	
No. 4	90																	
No. 10	48																	
No. 40	24																	
No. 100	8																	
No. 200	2																	

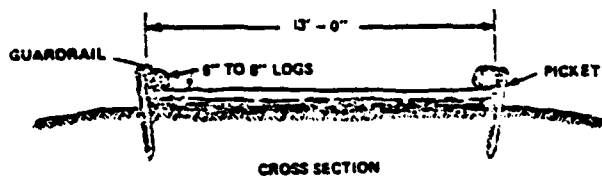
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TABLE IX
Concrete Mixes

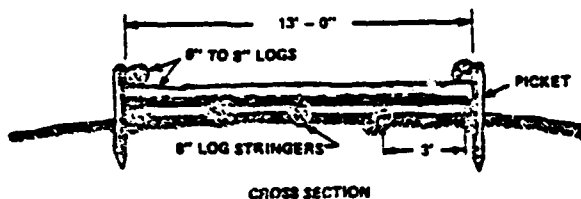
	Mix 5 (Standard 3,000-psi mix)	Mix 6 (sand grout mix)
Water ratio (weight of water/weight of cement)	0.78	0.56
Density, pcf	153.3	140.4
28-day unconfined compressive strength, psi	2,580	2,100
Aggregate	43.2 percent limestone sand 56.8 percent coarse Alabama limestone.*	100 percent Cook's Bayou sand

* Limestone comprised equal portions by weight as follows: 1/4- to 1/2-inch, 1/2- to 3/4-inch, and 3/4-inch to No. 4 sieve sizes.

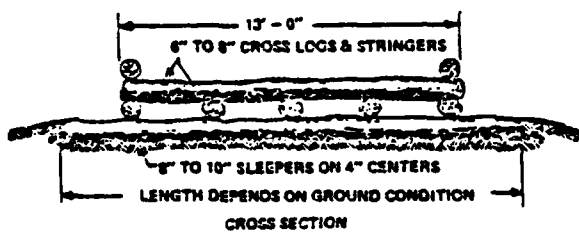
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A. STANDARD CORDUROY



B. CORDUROY WITH STRINGERS



C. HEAVY CORDUROY

Figure 30. Non-airfield Pavements: Corduroy Roads

Reprinted from 15:252

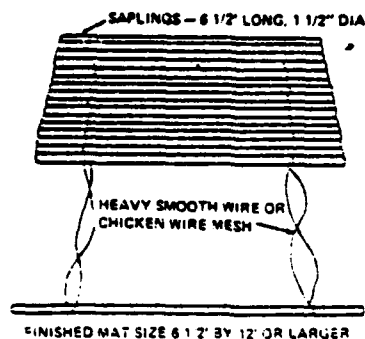
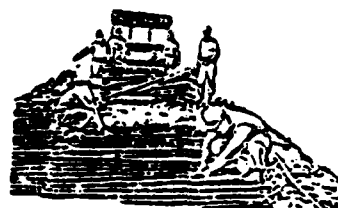


Figure 31. Non-airfield Pavements: Chespalong Road

Reprinted from 15:250

Vehicular Transportation in Sandy Areas. Additional expedients for driving over sandy areas are given below

[43:7.19,7.20]:

1. Use lighter traffic loads and reduce tire pressures. A general rule of thumb is to lower tire pressure so that tire deflection is increased by 50 percent.

2. Sand stabilization using portland cement is a well-established method for constructing pavement base layers.

3. Mix available local ground or soils with the sand to improve trafficability.

4. If a firmer material lies at shallow depths, keep blading loose sands off the roadway.

5. Place building rubble in the ruts.

6. Use crude oil, if available, for stabilizing the sand.

Airfield Pavement Repair. The following procedures should be followed when using polymer-concrete (PC) for repairing spalls on airfield pavements (26:180):

1. Spall Repairs: The In-line Mixing System

- a. Remove any standing water that may be present.
- b. Place 50:50, sand-gravel mixture in the repair until it is level with the pavement surface.
- c. Push an in-line mixing gun into the surface and fill the spall with the polymer mixture.
- d. Add sand and polymethyl methacrylate (PMMA) to the surface and strike off until it is level with the pavement surface.

2. Spall Repairs: The Modified Concrete Method

- a. Remove any standing water that may be present.
- b. Fill the spall with PC; some vibration or rodding may be necessary to completely fill the voids.
- c. Strike off level with the pavement surface.

Airfield Lighting. Some airfield lighting expedients are given below (12:88):

1. Use bean bag lights.
2. Use kerosene smudge pots.
3. Light fixtures can be mounted on stakes placed at the shoulders of the runway surface.
4. Single conductor airfield lighting cable can be run along the ground and used to connect the isolation transformers in series with the C-3 regulator.
5. The MB-17 or EMU-15 generators can be used to power the C-3.

TABLE X

Aircraft Characteristics - Dimensions in British (Feet)

ARCAFT DESIGNATION	WINGSPAN	LENGTH	HEIGHT	VERTICAL CLEARANCE	TREAD #	WHEEL # BASE	PIVOT POINT	TURNING RADIUS	CONTROLLING GEAR	180° TURN DIAMETER	AFR 93-5 GROUP INDEX
C-123K	110.0	76.2	34.5	18.0	150.0	288.0	15.3	29.0	Nose	70.0	1
O-2A	38.0	29.2	9.4		98.0						2
P-4C	38.6	58.3	16.4	6.0	215.0	279.0	8.9	24.8	Nose	57.7	2
RF-4C	38.4	63.0	16.4	6.0	215.0	279.0	8.9	24.8	Nose	76.7	2
P-40	38.4	63.0	16.4	6.0	215.0	279.0	8.9	24.8	Nose	57.7	2
P-40E/G	38.4	63.0	16.4	6.0	215.0	279.0	8.9	24.8	Nose	76.8	2
P-5E	28.0	48.2	13.4	38.8	150.0	204.0	31.3	37.0	Nose	73.9	2
P-5F	28.0	51.7	13.2	32.3	150.0	254.0	26.5	43.0	Nose	85.7	2
A-7D	38.73	46.13	16.06	15.50	113.9	188.18	4.75	10.24	Nose	58.0	2
A-7K	38.72	48.69	16.30	15.50	113.9	188.18	4.75	10.24	Nose	58.0	2
A-10	57.48	53.33	14.66	60.0	206.6	212.8	14.5	22.2	Nose	87.0	2
OV-10A	40.0	39.7	15.1		178.0			22.7	Nose	72.0	2
C-12A	54.5	43.8	15.0	14.5	206.0	180.0	12.7	19.5	Main	79.7	2
F-14	64.1	61.98	16.0		192.0	276.5					2
F-15A/B	42.8	63.8	18.8	12.0	107.0	210.0	25.0	25.0	Nose	83.0	2
F-15C/D	42.8	63.8	18.8	12.0	107.0	210.0			Nose		2
F-16A/B	32.8	49.6	16.7	18.4	93.0	158.0	21.5	25.0	Nose	78.0	2

GIVEN IN INCHES NOTE: REFERENCE FIGURES 1 THRU 10, FOR GENERAL AIRCRAFT CONFIGURATION

Reprinted from 36:10

TABLE X - Continued

Aircraft Characteristics - Dimensions in British (Feet)

ARCAFT DESIGNATION	WINGSPAN	LENGTH	HEIGHT	VERTICAL # CLEARANCE	TREAD #	WHEEL # BASE	PIVOT POINT	TURNING RADIUS	CONTROLLING GEAR	180° TURN DIAMETER	AFR 93-5 GROUP INDEX
T-33A	38.9	37.8	11.7	20.0	105.0	169.9	10.4	19.9	Main	78.6	2
A-37B	38.3	31.8	9.5		164.0	94.0		14.1	Nose		2
OA-37	38.3	31.8	9.5		164.0	94.0		14.1	Nose	63.1	2
T-37B	33.6	29.3	9.2	6.0	168.0	93.0	6.9	10.5	Nose	48.9	2
T-38	25.3	46.4	12.9	39.0	129.0	233.4	15.3	31.0	Nose	66.0	2
T-39A/B	44.4	43.8	16.0	30.0	86.0	174.0	20.7	25.3	Nose	87.0	2
EB-57	122.5	68.3	20.5		169.0	171.0		24.0	Main		2
P-100	38.8	57.6	16.2	31.0	152.4	176.0	21.1	24.9	Nose	84.3	2
P-101B	39.7	66.9	17.25	34.0	239.0	257.0	25.3	32.8	Nose	92.0	2
P-104G	21.9	54.8	13.5	18.0	106.0	181.0	32.3	35.6	Nose	96.2	2
P-105D	34.9	67.5	19.7	29.0	207.0	253.0	25.2	32.8	Nose	100.0	2
P-105F/G	34.9	69.9	20.5	29.0	207.0	285.0	27.6	36.0	Nose	103.6	2
P-106A/B	38.3	70.8	20.3	12.0	184.0	290.0	7.6	25.4	Nose	93.6	2
F-111A	63.0	75.5	17.1	14.0	120.0	288.0	28.7	23.6	Nose	120.3	3
F-111D	63.0	75.5	17.1	14.0	120.0	288.0	28.7	23.6	Nose	120.3	3
F-111E	63.0	75.5	17.1	14.0	120.0	288.0	28.7	23.6	Nose	120.3	3
F-111F	63.0	75.5	17.1	14.0	120.0	288.0	28.7	23.6	Nose	120.3	3

GIVEN IN INCHES NOTE: REFERENCE FIGURES 1 THRU 10 FOR GENERAL AIRCRAFT CONFIGURATION

Reprinted from 36:11

TABLE X - Continued

Aircraft Characteristics - Dimensions in British (Feet)

ARCAFT DESIGNATION	WINGSPAN	LENGTH	HEIGHT	VERTICAL # CLEARANCE	THREAD #	WHEEL # BASE	PIVOT POINT	TURNING RADIUS	CONTROLLING GEAR	180° TURN DIAMETER	AFR 93-5 GROUP INDEX
FB-111A	70.0	75.7	17.4	14.0	120.0	288.0	28.7	23.7	Nose	127.3	3
EF-111A	63.0	75.5	17.1	14.0	120.0	288.0	28.7	23.6	Nose	120.3	3
C-130B	132.6	97.8	38.5		171.0	388.0	19.2	37.0	Nose	170.0	4
C-130E	132.6	97.8	38.4		171.0	388.0	19.2	37.0	Nose	170.0	4
C-130H	132.6	97.5	37.9		171.0	388.0	19.2	37.0	Nose	170.0	4
AC-130A/H	132.6				172.0	388.0	19.2	37.0	Nose	170.0	4
LC-130E	132.6				172.0	388.0	19.2	37.0	Nose	170.0	4
HC-130H	132.6	111.9	38.4		172.0	388.0	19.2	37.0	Nose	170.0	4
C-7A	95.6	72.6	31.8	21.0	277.0	251.0	11.6	29.0	Nose	59.4	5
C-9A	93.3	119.3	27.5	35.0	197.0	638.0	18.1	54.0	Nose	128.2	5
C-9C	93.3	119.3	27.5	35.0	197.0	638.0	18.1	54.0	Nose	128.2	5
LC-9-30	93.3	133.5	28.0		198.0	731.0	9.1	141.3			5
C-24	117.5	94.5	27.9	13.0	296.0		27.7	40.0	Outer	172.9	5
C-140A	51.7	60.5	20.5		148.0	248.0		26.0	Nose		5
T-41A	93.0	100.0	37.0	22.0	206.0	447.0	9.8	56.7	Nose	115.0	6
B-737-200	93.0	100.0	37.0		206.0	447.0	9.8	57.7		115.0	6
B-727	108.0	153.6	34.0		225.0	763.0	10.7			161.0	7

■ GIVEN IN INCHES NOTE: REFERENCE FIGURES 1 THRU 10 FOR GENERAL AIRCRAFT CONFIGURATION

Reprinted from 36:12

TABLE X - Continued

Aircraft Characteristics - Dimensions in British (Feet)

AIRCRAFT DESIGNATION	WINGSPAN	LENGTH	HEIGHT	VERTICAL # CLEARANCE	TREAD #	WHEEL # BASE	PIVOT POINT	TURNING RADIUS	CONTROLLING GEAR	180° TURN DIAMETER	AFR 93-5 GROUP INDEX
E-3A	145.8	152.9	41.8	40.0	265.0	708.0	45.6	23.5	Nose	288.0	8
C-135A	130.8	134.5	41.7	31.0	265.0	548.0	45.7	65.0	Nose	228.0	8
C-135B/C/E	130.8	134.5	41.7	26.0	265.0	548.0	45.7	65.0	Nose	228.0	8
EC-135A/G/L	130.8	134.5	41.7	31.0	265.0	548.0	45.7	65.0	Nose	228.0	8
EC-135B/E	130.8	141.5	41.7	26.0	265.0	548.0	45.7	65.0	Nose	228.0	8
EC-135C/J	130.8	136.2	41.7	24.0	265.0	548.0	45.7	65.0	Nose	228.0	8
EC-135H/K/P	130.8	134.5	41.7	26.0	265.0	548.0	45.7	65.0	Nose	228.0	8
EC-135N	130.8	141.5	41.7	31.0	265.0	548.0	45.7	65.0	Nose	228.0	8
KC-135A/D/Q	130.8	136.2	41.7	31.0	265.0	548.0	45.7	65.0	Nose	228.0	8
KC-135E	130.8	136.2	41.7	26.0	265.0	548.0	45.7	65.0	Nose	228.0	8
KC-135R	136.2	136.2	41.7	22.0	265.0	548.0	45.7	65.0	Nose	288.0	8
KC-135T/W	130.8	140.0	41.7	26.0	265.0	548.0	45.7	65.0	Nose	228.0	8
KC-135U	135.1	136.0	41.7	24.0	265.0	548.0	45.7	65.0	Nose	228.0	8
KC-135V	130.8	140.5	41.7	24.0	265.0	548.0	45.7	65.0	Nose	228.0	8
KC-135B	134.5	141.5	41.7	26.0	265.0	548.0	45.7	65.0	Nose	228.0	8
C-137B	130.8	144.5	41.3	27.0	265.0	628.0	45.7	62.0	Nose	210.0	8
C-137C	145.8	152.9	41.8	31.0	265.0	708.0	45.7	69.0	Nose	230.0	8
A-119D	147.1	175.9	54.2		172.0	732.0					8

■ GIVEN IN INCHES NOTE: REFERENCE FIGURES 1 THRU 10 FOR GENERAL AIRCRAFT CONFIGURATION

Reprinted from 36:13

TABLE X - Continued
Aircraft Characteristics - Dimensions in British (Feet)

AIRCRAFT DESIGNATION	WINGSPAN	LENGTH	HEIGHT	VERTICAL # CLEARANCE	TREAD #	WHEEL # BASE	PIVOT POINT	TURNING RADIUS	CONTROLLING GEAR	180° TURN DIAMETER	AFR 93-5 GROUP INDEX
B-707-120	145.8	152.9	42.4		265.0	708.0	34.5				8
B-707-320	145.9	152.9	52.4		265.0	708.0	34.5				8
B-18	136.68	151.08	33.6	51.27	174.0	677.75					9
C-141A	160.0	145.0	39.3	8.0	210.0	636.0	38.3	63.5	Nose	226	9
C-141B	160.0	168.3	39.3	8.0	210.0	796.0	38.3	76.5	Nose	240	9
C-5	222.7	247.8	65.1	12.0	432.0	980.0	46.0	72.5	Nose	189.5	10
DC-10-10	155.3	181.4	57.5	34.0	420.0	869.0	39.0	121.6			11
DC-10-30	165.3	181.4	57.6	35.0	420.0	869.0	37.1	125.2			11
DC-10-40	165.3	182.4	58.1	35.0	420.0	869.0	29.5	125.2			11
KC-10A	165.3	182.3	58.1	35.0	416.0	869.0	37.1	125.2			11
L-1011	155.3	177.8	55.3		432.0	840.0	38.8	242.5			11
E-4A	195.67	231.83	63.42	33.0	434.0	1008.0	32.0	14.0	Nose	292	12
E-4B	195.67	321.34	63.42	33.0	434.0	1008.0	32.0	14.0	Nose	292	12
L-500	155.3	164.2	55.3		432.0	840.0	38.8	242.5			11
B-247	195.7	231.3	63.4		434.0	1008.0	47.0	75.0		312	12
B-52D	185.0	156.6	48.3	21.6	136.0	597.0	39.0	114.0	Outer	264.6	13
B-53G	185.0	162.0	40.7	44.5	136.0	597.0	39.0	114.0	Outer	264.6	13

GIVEN IN INCHES NOTE: REFERENCE FIGURES 1 THRU 10 FOR GENERAL AIRCRAFT CONFIGURATION

Reprinted from 36:14

Aircraft Characteristics - Dimensions in British (Feet)

[illegible]

■ GIVEN IN INCHES

Reprinted from 36:15

TABLE XI

Aircraft Characteristics -
Gross Weights * and Performance ** in British Units

AIRCRAFT DESIGNATION	BASIC EMPTY WEIGHT	BASIC MISSION T/O	MAXIMUM TAKE-OFF	BASIC MISSION LANDING	MAXIMUM LANDING	TAKE-OFF DISTANCE	TAKE-OFF (50')	LANDING DISTANCE	LANDING (50')
C-123K	35.37	60.0	60.0	37.4	60.0	1810	2802	1539	2446
O-2A	3.26	4.85	4.85	3.73	4.85	1055	1680	480	1170
F-4C	31.8	58.0	58.0	36.8	46.0	3520	4850	3520	5430
AP-4C	29.5	52.8	58.0	33.6	46.0	3220	3970	2430	3490
F-4D	31.8	58.0	58.0	36.8	46.0	3760	5840	3760	5670
F-4E/D	31.9	53.8	58.0	37.8	46.0	3780	5880	3780	5690
F-5E	9.7	15.8	24.7	11.9	21.8	2160	2900	2425	4100
F-5F	10.5	16.0	25.2	12.1	25.2	2110	3270	2415	3860
A-7D	21.8	38.984	42.0	23.777	37.088	6250	9200	3950	5405
A-7K	21.856	38.984	42.0	23.777	37.088	6250	9200	3950	5405
A-10	25.0	47.3	50.0	27.1	50.0	4000	4850	1500	3200
OV-10A	8.03	10.53	14.40	8.78	14.40	1050	1450	660	1090
C-12A	7.8	12.5	12.5	12.5	12.5	2200	2950	1150	2000
F-14	39.31	58.54	74.35	51.83		1200		1600	
F-15A/B	27.5	50.0	54.0	34.0	39.0	2500	3500	3600	4400
F-15C/D	28.2	52.0	59.4						
F-16A/B	16.37	31.8	35.4	21.12	27.500	3225	5000	3200	4590

* IN KIPS
** IN FEET

Reprinted from 36:16

TABLE XI - Continued

Aircraft Characteristics -
Gross Weights * and Performance ** in British Units

AIRCRAFT DESIGNATION	BASIC EMPTY WEIGHT	BASIC MISSION T/O	MAXIMUM TAKE-OFF	BASIC MISSION LANDING	MAXIMUM LANDING	TAKE-OFF DISTANCE	TAKE-OFF (50')	LANDING DISTANCE	LANDING (50')
T-33A	9.1	16.3	16.3	12.2	16.3	3800	6000	3200	4200
A-37B	6.5	12.0	14.0	5.2	14.0	1590	3000	2000	4000
OA-37	6.5	12.0	14.0	5.1	14.0	1590	3000	2000	4000
T-37B	4.2	6.6	6.6	5.0	6.0	1500	2250	1450	2800
T-38	7.1	12.1	12.1	8.1	12.1	2800	4000	3400	5000
T-39A/B	10.0	18.7	18.7	13.2	17.5	2750	4050	1700	2800
EB-57	37.0	63.0	63.0	42.6	63.0	5000	6200	2350	3100
F-100	23.0	36.8	41.5	25.3	41.5	4500	6800	4300	5990
F-101B	28.8	45.5	52.4	33.6	35.5	2600	3400	6110	7250
F-104G	14.4	22.0	25.2	16.2	25.2	3200	5100	2500	4800
F-105D	28.2	44.3	52.8	31.1	52.8	4200	5700	2500	4000
F-105F/G	29.1	45.1	54.6	32.0	54.6	4370	6070	2800	4300
F-106A/B	24.9	35.2	39.6	28.4	36.8	4300	6200	4800	6200
F-111A	48.4	92.7	100.0	51.6	82.5	4600	5630	1480	2380
F-111D	49.7	82.4	100.0	51.2	82.5	2490	3250	1480	2400
F-111E	49.4	93.7	100.0	52.6	82.5	4700	5750	1500	2410
F-111F	51.0	93.1	100.0	53.0	82.5	3350	4540	1590	2430

* IN KIPS
** IN FEET

Reprinted from 36:17

TABLE XI - Continued

Aircraft Characteristics -
Gross Weights & Performance in British Units

AIRCRAFT DESIGNATION	BASIC EMPTY WEIGHT	BASIC MISSION T/O	MAXIMUM TAKE-OFF	BASIC MISSION LANDING	MAXIMUM LANDING	TAKE-OFF DISTANCE	TAKE-OFF (50')	LANDING DISTANCE	LANDING (50')
FB-111A	49.6	110.1	119.2	53.2	109.0	5280	6600	1720	2740
BF-111A	53.4	72.8	87.5	58.7	80.0	3250	4100	1770	2800
C-130B	72.3	135.0	135.0	119	135.0	2750	4100	1875	3320
C-130E	72.0	152.4	175.0	133.3	175.0	3690	5410	2980	4650
C-130H	75.3		175.0						
HC-130H	81.8	147.9	175.0	91.3	175.0	3230	4430	1846	2922
C-7A	18.5	28.5	28.5	27.1	28.5	1390	1765	825	1770
C-9A	62.2	108.0	108.0	92.5	99.0	4380	5360	1756	2690
C-9C	57.2	85.3	110.0	92.5	110.0	4380	5530	1756	4680
DC-9	61.8		121.0		110.0		6850		4880
C-54	38.7	62.0	82.5	82.5	82.5	915	1615	1158	2012
C-140A	21.5	40.5	40.5	26.1	30.0	3670	5150	2050	2980
T-43A	60.5	98.0	115.0		103.0	4400	6800	3900	4400
B-737	60.5	115.5	125.0		103.0		6800		4400
B-727	101.5		209.5		154.0		10300		4690
E-3A	195.0	325.0	325.0	250.0	325.0	8400	11300	4950	8150
DC-8			358.0		245.0				
C-135A	109.0	270.0	301.6	200.0	297.0	10600	14750	3800	5700

IN KIPS
IN FEET

Reprinted from 36:18

TABLE XI - Continued

Aircraft Characteristics -
Gross Weights & Performance in British Units

AIRCRAFT DESIGNATION	BASIC EMPTY WEIGHT	BASIC MISSION T/O	MAXIMUM TAKE-OFF	BASIC MISSION LANDING	MAXIMUM LANDING	TAKE-OFF DISTANCE	TAKE-OFF (50)	LANDING DISTANCE	LANDING (50)
C-135B	116.8	274.0	301.6	200.0	297.0	9700	13100	4000	6100
C-135C	121.0	274.0	301.6	132.0	297.0	9700	13100	2500	4300
C-135E	123.0	274.0	301.6	134.0	297.0	9500	13200	2400	4200
EC-135A	119.3	297.0	301.6	132.6	297.0	13500	18500	2800	4400
EC-135B/E	116.0	299.0	301.6	128.8	297.0	11700	16200	2400	4200
EC-135C	135.6	299.0	301.6	149.9	297.0	11400	15900	2600	4300
EC-135G	122.8	297.0	301.6	136.1	297.0	13500	18400	3000	4700
EC-135H	139.4	299.0	301.6	155.6	297.0	11700	16600	2700	4600
EC-135J	138.1	299.0	301.6	157.1	297.0	11400	15900	2700	4400
EC-135K	123.4	299.0	301.6	134.4	297.0	11700	16350	2300	4100
EC-135L	112.8	297.0	301.6	124.4	297.0	13500	18400	2500	4000
EC-135N	124.0	297.0	301.6	136.8	297.0	13500	18400	3000	4700
EC-135P	134.1	299.0	301.6	148.5	297.0	11700	16400	2600	4400
MC-135A	104.3	297.0	301.6	115.3	297.0	13500	18400	2200	3700
MC-135D	107.6	297.0	301.6	118.6	297.0	13500	18400	2400	3900
MC-135E	112.1	299.0	301.6	123.1	297.0	11700	16200	2300	4100
MC-135Q	105.5	297.0	301.6	116.5	297.0	13500	18400	2300	3800

✱ IN KIPS
✱ IN FEET

Reprinted from 36:19

TABLE XI - Continued

Aircraft Characteristics -
Gross Weights & and Performance ## in British Units

AIRCRAFT DESIGNATION	BASIC EMPTY WEIGHT	BASIC MISSION T/O	MAXIMUM TAKE-OFF	BASIC MISSION LANDING	MAXIMUM LANDING	TAKE-OFF DISTANCE	TAKE-OFF (50')	LANDING DISTANCE	LANDING (50')
KC-135R	117.0	319.7	322.5	128.0	297.0	10300	14800	2200	5300
RC-135M	130.1	299.0	301.6	146.1	297.0	11650	16200	2600	4400
RC-135S	141.6	299.0	301.6	157.0	297.0	11650	16250	2700	4600
RC-135T	110.1	299.0	301.6	121.1	297.0	11700	16800	2200	3900
RC-135U	150.6	299.0	301.6	167.4	297.0	11500	16200	2900	4700
RC-135V	139.0	299.0	301.6	153.3	297.0	11500	16100	2700	4500
RC-135W	141.0	299.0	301.6	157.0	297.0	11650	16300	2700	4600
WC-135B	117.0	299.0	301.6	128.7	297.0	11700	16100	2400	4200
C-137B	135.6	258.0	260.0	180.0	190.0	8100	8860	3100	6500
C-137C	151.7	326.0	336.0	205.5	247.0	10550	11950	2000	5400
A-300	197.8		363.7		295.4		9845		
B-707-120	146.4		258.0		207.0				
B-707-120	146.4		333.6		247.0		10020		6250
B-1B	189.0		477.0						
C-141A	136.9	271.03	323.1	239.175	323.1	3400	4050	1925	3600
C-141B	218.7	323.1	344.9	257.5	323.0				
C-5	324.3	706.6	769.0	641.0	728.0	7200	8600	2420	3900

IN KIPS
IN FEET

Reprinted from 36:20

Aircraft Characteristics - Gross Weights * and Performance ** in British Units

[illegible]

Reprinted from 36:21

Electrical Power Safety Measures. The following electrical power safety measures should be followed during contingencies:

1. The generator should be thoroughly inspected prior to installation. The power production personnel should "look for broken or loose electrical and hose connections, loose bolts and cap screws, and see that the ground plate is properly grounded [3:10]."

2. Once the generator is installed, the wiring diagrams should be checked to make sure all connections are correct (3:10).

3. The load cable should also be checked to make sure it is sized properly, since an undersized cable is a fire hazard (3:10,11).

4. The generator ground should be carefully inspected because expedience has shown "that by far the most prevalent fault to which generators are subjected is a short-circuit to ground [29:4490]."

5. For additional power, generators can be set in parallel. However, it is not recommended to parallel generators of 100KW or less unless absolutely necessary, since they are not designed for parallel operation. It is sager to use a single smaller unit for each facility (3:12,13).

Derating Generators. Generators are rated under the standard conditions of zero to 2,000 feet above sea level and an 80 degrees Fahrenheit (F) ambient temperature. Generators must be derated when used in areas that vary from these standard conditions. The following guidelines should be followed when derating generators (32):

Gas-turbine Generators: Derated 5-1/2% for every 10 degrees F above 80 degrees F, and 4-1/2% for every 1,000 ft above 2,000 feet.

Diesel & Gasoline Generators: Derated 1% every 10 degrees F above 80 degrees F, and 2 to 3% for every 1,000 feet above 2,000 feet.

Dormant Generators. Generators perform more efficiently when allowed to operate over long periods of time (6:22,23). Therefore, standby generators, if left dormant for any length of time, may not start properly when power is interrupted. Power production personnel must exercise the standby generators once a month to ensure that the generators will perform when needed.

Generators in Hot Climates. When installing generators in tropical climates, the following precautions should be made (3:14,15):

1. The cooling systems must be cleaned and flushed at regular intervals and the coolant level checked frequently.
2. Soft water and rust inhibitors can be used in the radiator to prevent rust and scale.
3. The radiator fan motor should be checked frequently, as should the thermostats.

Generators in Cold Climates. When installing generators

in extremely low temperatures, difficulties may arise in lubrication, electrical stability, and overall maintenance. To reduce these problems, the following precautions can be used (3:13,14):

1. Remove the moisture from the equipment that may cause condensation, since moisture may corrode or damage the equipment when it is energized.

2. Check the specific gravity of the storage batteries so they will not freeze.

3. Apply cold weather lubricants or graphite to rotating points (winterizing kits may or may not be available).

4. When the generators are shut down for any length of time in subzero temperatures (degrees F), drain the hot engine and fill the crankcase to the low level with SAE 10W oil. Run the engine without any electrical load. When the engine is warmed up, put regular oil back in.

5. Prevent water from entering the fuel lines, since it will turn to ice and clog the lines. This can be prevented by keeping the fuel tank full. Also, flush the cooling system and check all hoses, lines and fittings regularly for tightness and serviceability.

6. Since wires become brittle in extreme cold, touch them as little as possible. When installing new wire, warm it up before bending or twisting it.

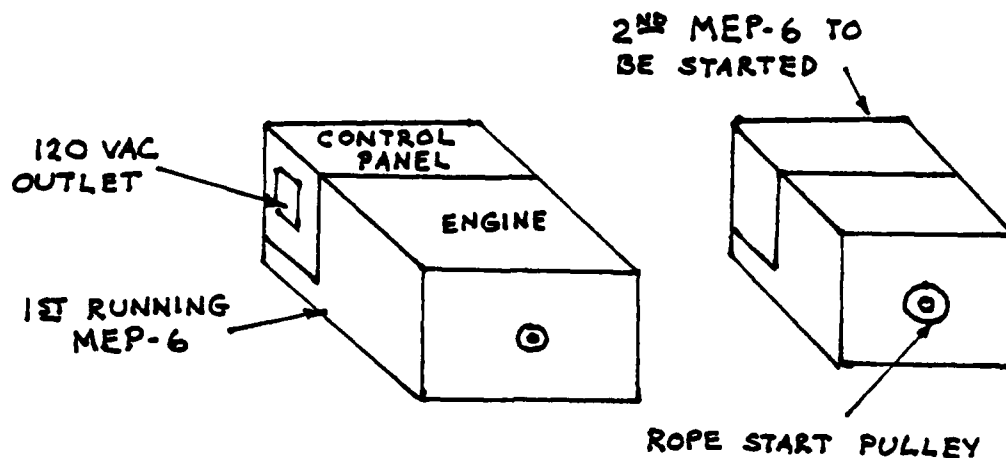


Figure 32. Electrical Power: Quick Start Method
for MEP-6 Portable Generators

As Used at Homestead AFB

Submitted by TSgt Dennis L. Becchelli

1. Using a rope, start one MEP-16 generator to give a 120 volt source of AC power.
2. Obtain a 1/2" portable electrical drill, a 1/2" drive - 1/2" socket, and a 5" long - 1/2" drive extension from the mobility team kit.
3. Place the socket on the rope pulley bolt head of the second MEP-16 to be started.
4. Start the second MEP-16 with the drill. CAUTION: Due to the high torque of the drill, a firm grip is required to prevent injury and/or damage to the bolt head. The second generator should start within one minute after starting the drill.

Guidelines for Expedient Electrical Distribution Lines.
The following guidelines should be followed when providing electrical power distribution lines in contingencies:

1. Areas with a high ambient temperature have reduced current carrying ability because the heat buildup in the wires cannot effectively dissipate into the surrounding atmosphere. Therefore, cables must be derated at temperatures greater than 86 degrees F (1:5.4).

2. Cables should be protected from direct sunlight by burying the primary distribution lines at least 18 inches and secondary lines at least 8 inches, limiting loads during the hottest part of the day, using high temperature rated insulation, and not using cables above their rated current (1:5.4; 34:4.5).

3. Low voltage distribution cables, wired directly into the generator's output terminals, can be run short distances on top of the ground to provide the necessary power. When distribution transformers become available, the system can be made more efficient by converting to high voltage [12:83].

4. Distribution cables can be placed in trenches carrying water and sanitary pipelines to save time and energy (1: 5.4).

5. Electrical devices should be covered with weatherproof enclosures whenever possible to provide more environmental protection (1:5.5).

6. Transformers can be protected in desert climates by using extra creep bushings and by cleaning oil and other contamination from the bushings (34:4.11).

7. Electrical grounding is critical for systems of 25 ohms or less for generators, CCCs, transformers, and shelters (1:5.5). Therefore, all personnel concerned with power distribution must be aware of the potential problems of grounding in areas of poor soil conductivity and be careful around electrical systems (34:4.13).

8. In an emergency installation, time is the important factor. It may be necessary to use trees, pilings, four-by-fours or other temporary line supports to complete the installation [3:11].

TABLE XII

American/German Wire Gage Size Conversions
for Insulated Wire at 25 Degrees C Ambient

American Wire Gage (AWG) Size	Conductor Area Sq. mm	Next Standard German Size Sq. mm	Up to Three Conductors in Conduit		Multi- Conductor		Separate Conductor	
			Amp- acity	Fuse Size	Amp- acity	Fuse Size	Amp- acity	Fuse Size
			A	A	A	A	A	A
18	0.82	1.	12	10	16	16	20	20
16	1.13	1.5	16	16	20	20	25	25
14	2.08	2.5	21	20	27	25	34	36
12	3.31	4.	27	25	36	26	45	50
10	5.26	6.	36	36	47	50	57	63
8	8.37	10.	48	50	65	63	78	80
6	13.30	16.	65	63	87	80	104	100
4	21.15	25.	88	80	115	100	137	125
2	33.62	35.	110	100	143	125	168	160
0	53.52	50.	140	125	178	160	210	200
00	67.43	70.	170	160	220	224	260	250
000	85.01	96.	210	200	265	250	310	300
0000	170.21	120.	260	250	310	300	365	355

Adapted from 9:1112

TABLE XIII

Wire Ampacity: Load Capacity of Insulated Conductors

Nominal cross-section (square mm)	Permitted permanent load capacity in A					
	Group 1		Group 2		Group 3	
	Cu	Al	Cu	Al	Cu	Al
0.75	-	-	13	-	16	-
1	12	-	16	-	20	-
1.5	16	-	20	-	25	-
2.5	21	16	27	21	34	27
4	27	21	36	29	45	35
6	35	27	47	37	57	45
10	48	38	65	51	78	61
16	65	51	87	68	104	82
25	88	69	115	90	137	107
35	110	86	143	112	168	132
50	140	110	178	140	210	165
70	175	-	220	173	260	205
95	210	-	265	210	310	245
120	250	-	310	245	365	285
150	-	-	355	280	415	330
185	-	-	405	320	475	375
240	-	-	480	380	560	440

Group classification:

Group 1: One or more single-core conductors laid in a conduit (e.g., NYA)

Group 2: Multiple-core conductors, (e.g., sheathed conductors, conduit wires, lead sheath conductors, flat conductors, movable conductors)

Group 3: Single-core conductors with spacing of at least their own diameter, laid in free air, also single-conductor wiring in switch and distribution equipment, and bus bar distributions.

The values apply to an ambient temperature of 25 degrees C. Permissible loadings for temperatures between 25 and 55 degrees C are given below:

Ambient temperature up to Degrees C 30 35 40 45 50 55

Permissible loading:

with rubber insulation	%	92	85	75	65	53	38
with plastic insulation	%	94	88	82	75	67	58

Adapted from 9:2113

TABLE XIV
Fuse or Circuit Breaker Protection

Nominal copper conductor (square mm)	Nominal rating of overload protection device		
	Group 1 (A)	Group 2 (A)	Group 3 (A)
0.75	-	10	16
1	10	16	20
1.5	16	20	25
2.5	20	25	35
4	25	35	50
6	35	50	63
10	50	63	80
16	63	80	100
25	80	100	125
35	100	125	160
50	125	160	200
70	160	224	250
95	200	250	300
120	250	300	355
150	-	355	425
185	-	355	425
240	-	425	500

For ambient temperatures above 25 degrees C, the nominal rating of the protective device must be reduced by the percentage given Table XII; the next lower nominal current rating to that of the overload device should be used.

Adapted from 9:2113

TABLE XV

Power Cable Loading for Air-suspended Cables at 30 Degrees C

 Three-core cable	 Three-core cable with single-core sheaths	 Single-core cables, laid up together				
Nom- inal cross section	PROTODUR cable			PROTOTHEN		
						
	0.6/1 kV	3.5/6 kV	5.8/10 kV	5.8/10 to 17.3/30 kV		5.8/10 kV
	Current rating in A					
sq. mm	Cu	Al	Cu	Al	Cu	Al
1.5	18	-	-	-	-	-
2.5	25	-	-	-	-	-
4	34	26	-	-	-	-
6	43	34	-	-	-	-
10	60	46	-	-	-	-
16	80	62	-	-	-	-
25	106	83	105	82	135	165
35	132	102	130	100	165	200
50	160	124	155	120	195	240
70	202	158	195	155	245	295
95	244	191	240	185	295	360
120	283	221	275	215	340	410
150	325	253	315	245	385	465
185	372	289	360	285	440	530
240	437	340	430	335	520	630
300	500	391	490	385	590	710

Adapted from 9:2114

TABLE XVI

Reduction Factors for Air-suspended Cables

Deviating Ambient Temperatures:

Ambient temperature degree C	25	30	35	40	45	50
PROTODUR cable up to 5.8/10kV	1.06	1.0	.94	.87	.79	.71
PROTOTHEN Y cable up to 17.3/30kV	1.06	1.0	.94	.87	.79	.71
PROTOTHEN X cable up to 17.3/30kV	1.04	1.0	.96	.91	.87	.82

Bunching:

Number or 3-core cables per trench	1	2	3	6	9
Laid side by side:					
touching	0.95	0.84	0.80	0.75	0.73
spacing (1 to 2 cable diameters)	0.95	0.90	0.88	0.85	0.84
Laid one above the other:					
touching	0.95	0.78	0.73	0.68	0.66
spacing (1 cable diameter)	1.00	0.93	0.90	0.87	0.86

Adapted from 9:2114

TABLE XVII

Electrical Parameters for Long-span Overhead Lines

Nominal voltage	kV	20		30		60		110		220		380	
		35	150	150	150	240	240	185	300	435	435	Layout 4x240	Layout 2x564
Nominal cross-section (Al)	sq. mm												
Cable diameter	mm	3.1	17.1	17.1	17.1	21.9	21.9	19	24.5	28.8	2x21.9	4x21.9	2x32
Limit, thermal loading	MVA	5	16	24	24	67	67	100	140	350	490	1700	1380
Effective resistance at 20 degrees C	ohms/km	0.87	0.20	0.20	0.20	0.13	0.13	0.16	0.10	0.17	0.062	0.031	0.027
Inductive resistance at 50 degrees C	ohms/km	0.39	0.34	0.35	0.35	0.37	0.37	0.41	0.38	0.4	0.32	0.26	0.30
Mutual capacitance	nF/km	9.7	11.2	10.9	10.9	10.3	9.3	9.3	10	9.4	11.5	14.4	12.1
Capacitance to earth	nF/km	3.4	3.6	3.7	3.7	4.0	4.0	4.0	4.2	4.8	6.3	6.5	5.7
Charging power	kVA/km	1.2	1.4	3.1	3.1	12	35	35	38	145	175	650	550
Earth leakage current	A/km	0.04	0.04	0.06	0.06	0.13	0.13	0.25	0.25	(.58)	(.76)	(1.35)	(1.18)
Characteristic impedance	ohms	360	310	320	320	340	340	375	350	365	300	240	280
Surge impedance loading	MVA					11	11	32	35	135	160	600	515

Adapted from 9:2114

General guidelines for using 60 HZ electrical equipment on 50 HZ power sources are given below:

Resistive Loads. Incandescent lighting, electric ranges, ovens, and other equipment which convert electric energy directly to heat energy perform equally well on either 50 HZ or 60 HZ source frequency... [However], lamps will not burn as brightly, ovens will not be as hot, etc [9:2109].

Static Induction Devices. Distribution transformers, electric discharge lighting ballasts, series lighting current regulators, and other static inductive equipment induce magnetic energy fields in iron as part of normal operation... [The magnetic flux density] is directly proportional to the volts/hertz ratio of the power source... If equipment designed for 60 HZ operation is to be connected to a 50 HZ power source, the voltage must be reduced proportionately to maintain the volts/hertz ratio at the design point [9:2109].

Induction Motors. Induction motors rated for 60 HZ operation will run at about 5/6 of rated speed when connected to a 50 HZ source... Motor current varies inversely with both source frequency and voltage. As the 50 HZ source voltage is reduced, motor current heating the windings increases while iron loss heating decreases. No amount of voltage reduction can compensate for both heating effects simultaneously. However, induction motors rated [at] 120V, 60HZ will operate successfully at about 110V, 50 HZ if the speed reduction can be tolerated [9:2110].

Remedies to three major electrical problems are given below [9:2110]:

A. INCREASED MOTOR HEATING DUE TO SATURATION OF IRON

REMEDY: Motor geometry establishes a design volts/hertz ratio. If the motor is to be operated at less than design frequency then the voltage must be reduced proportionately (5/6) to maintain the volts/hertz ratio at or below the design limit.

B. REDUCED MOTOR SHAFT SPEED

REMEDY: Shaft speed is a function of source frequency and motor configuration. The coupling to the driven load often involves belts, pulleys, chains, or gears. A change in drive ratios could correct the speed. However, many loads operate adequately at 5/6 of design speed.

C. INCREASED HEAT BUILD-UP DUE TO REDUCED INTERNAL AIR-FLOW

REMEDY: Motor heating is attributed to several factors: Iron losses, frictional losses, and copper losses. In 50 HZ design voltage, iron losses will remain about equal. Frictional losses will be slightly reduced due to decreased shaft speed. Copper losses vary roughly as the square of the load torque. Hence the 50-HZ HP rating of the motor is limited to about 5/6 of the 60-HZ HP rating. Otherwise, heat build-up would accelerate aging of motor insulation and possibly cause burnout.

An expedient method of installing temporary tent lighting and electrical outlets was developed during a training exercise at Holloman AFB NM and submitted by TSgt Mark Gunter. This method is presented below:

1. Use a pre-wired, wall mount, power outlet connected to the generator units.

2. Connect the pre-wired 50 ft or 100 ft interconnecting cable sets to energize the portable power boxes.

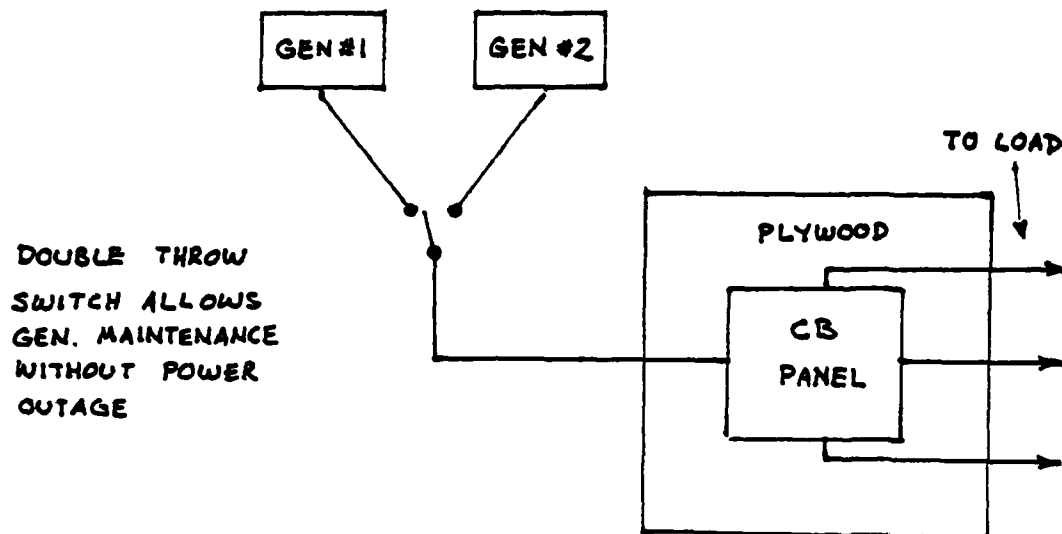
3. These power boxes provide power for the pre-wired, interconnecting stringer light cables.

4. Each spider box contains enough outlets to supply each tent with at least two power receptacles.

5. All equipment is assembled by using the twist type plugs on the cables.

6. All cables, boxes, light systems, etc. can be stored in a large wooden container and labeled "For Prime BEEF Only."

BEST METHOD



ALTERNATE METHOD - ONLY IF CB IS NOT AVAILABLE



Figure 33. Electrical Distribution: Power Panels
As Used in Egypt to Connect Power to Tents, Lights, & Pumps
Submitted by CMSgt Jimmy Chestnutt

The following expedient methods can be used to determine the required wire size for a specific load when no other method is available (15:351):

1. Convert electrical load into amperes by using one of the following equations:
 - a. Amperes = Total watts to be serviced / voltage
 - b. Amperes = Voltage / resistance (ohms)
 - c. Amperes = 745.7 x Horsepower / voltage
2. Using the calculated amperage and length of wire required, use Table XVII or XVIII to determine the wire size needed.

TABLE XVIII

Wire Sizes for 110-Volt Single Phase Circuits

10—ALUMINUM WIRE
12—COPPER WIRE

FOR 110V CIRCUIT		DISTANCE TO LOAD IN FEET									
WIRE SIZE	50	75	100	125	150	200	250	300	400	500	
15	10	10	10	10	10	10	10	10	10	10	10
20	10	10	10	10	10	10	10	10	10	10	10
25	10	10	10	10	10	10	10	10	10	10	10
30	10	10	10	10	10	10	10	10	10	10	10
40	10	10	10	10	10	10	10	10	10	10	10
50	10	10	10	10	10	10	10	10	10	10	10
60	10	10	10	10	10	10	10	10	10	10	10
70	10	10	10	10	10	10	10	10	10	10	10
80	10	10	10	10	10	10	10	10	10	10	10
90	10	10	10	10	10	10	10	10	10	10	10
100	10	10	10	10	10	10	10	10	10	10	10

Reprinted from 15:353

TABLE XIX

Wire Sizes for 220-Volt Three Phase Circuits

10—ALUMINUM WIRE
12—COPPER WIRE

FOR 220V CIRCUIT		DISTANCE TO LOAD IN FEET									
WIRE SIZE	100	200	300	400	500	600	700	800	900	1000	
15	10	10	10	10	10	10	10	10	10	10	10
20	10	10	10	10	10	10	10	10	10	10	10
25	10	10	10	10	10	10	10	10	10	10	10
30	10	10	10	10	10	10	10	10	10	10	10
40	10	10	10	10	10	10	10	10	10	10	10
50	10	10	10	10	10	10	10	10	10	10	10
60	10	10	10	10	10	10	10	10	10	10	10
70	10	10	10	10	10	10	10	10	10	10	10
80	10	10	10	10	10	10	10	10	10	10	10
90	10	10	10	10	10	10	10	10	10	10	10
100	10	10	10	10	10	10	10	10	10	10	10

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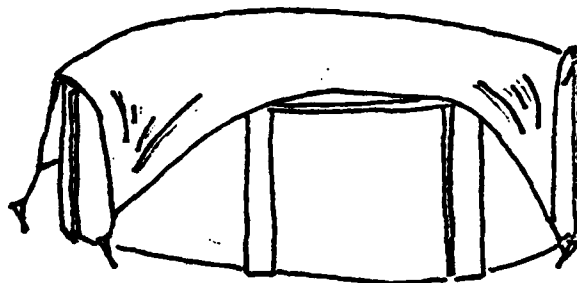


Figure 34. Water Storage: Rubber Tank With Protective Tarp
As Used in Vietnam 1966-1967

Submitted by MSgt James D. Carroll

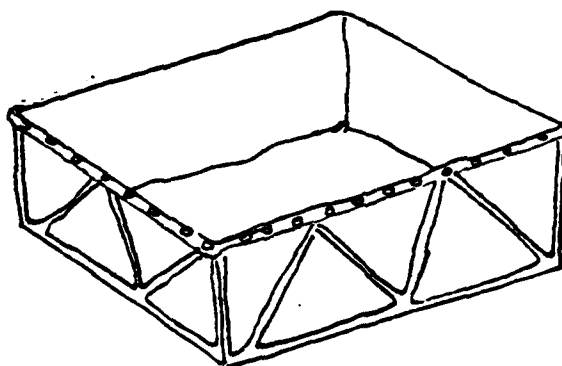
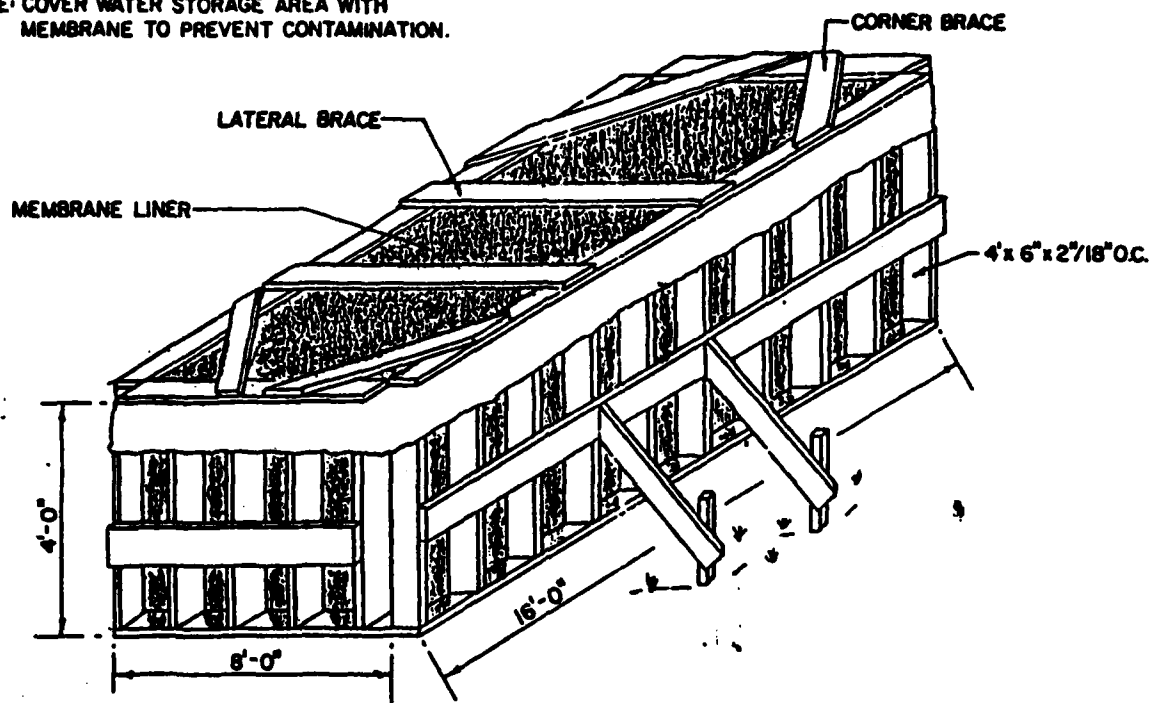


Figure 35. Water Storage: Tarp Lining in Aluminum/Wood Frame
As Used in Vietnam, 1966-1967

Submitted by MSgt James D. Carroll

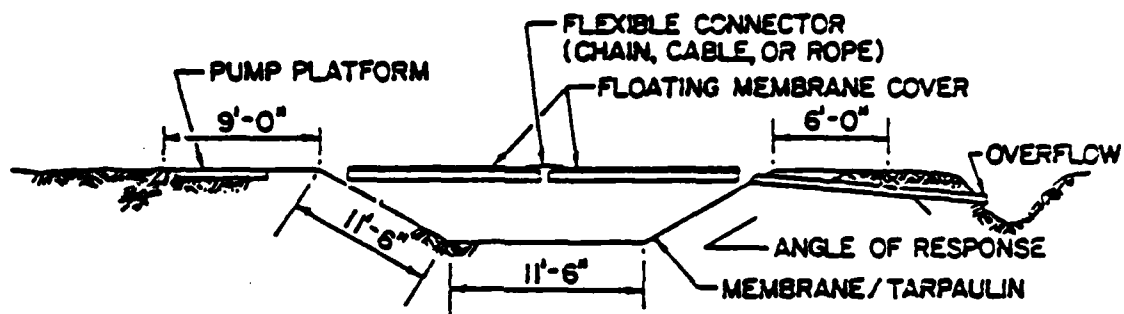
NOTE: COVER WATER STORAGE AREA WITH
MEMBRANE TO PREVENT CONTAMINATION.



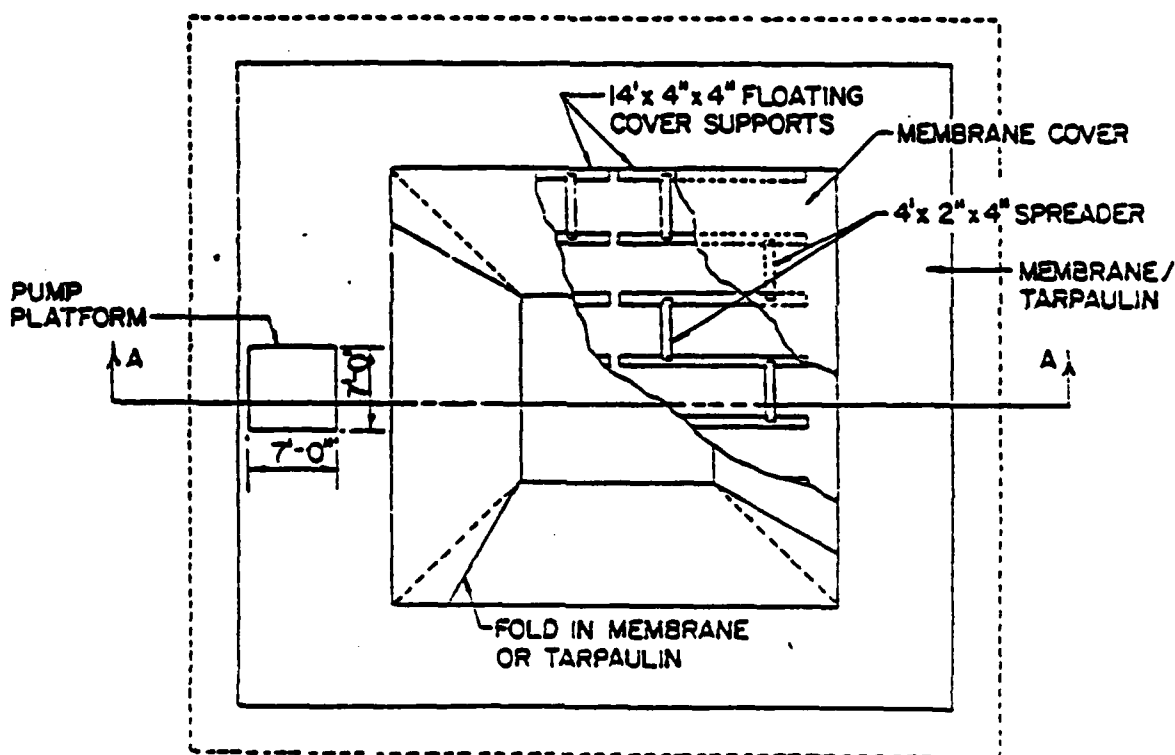
3500 GAL CAPACITY

Figure 36. Water Storage: Wood Framed Container

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SECTION A-A



PLAN

Figure 37. Water Storage: Basin Container

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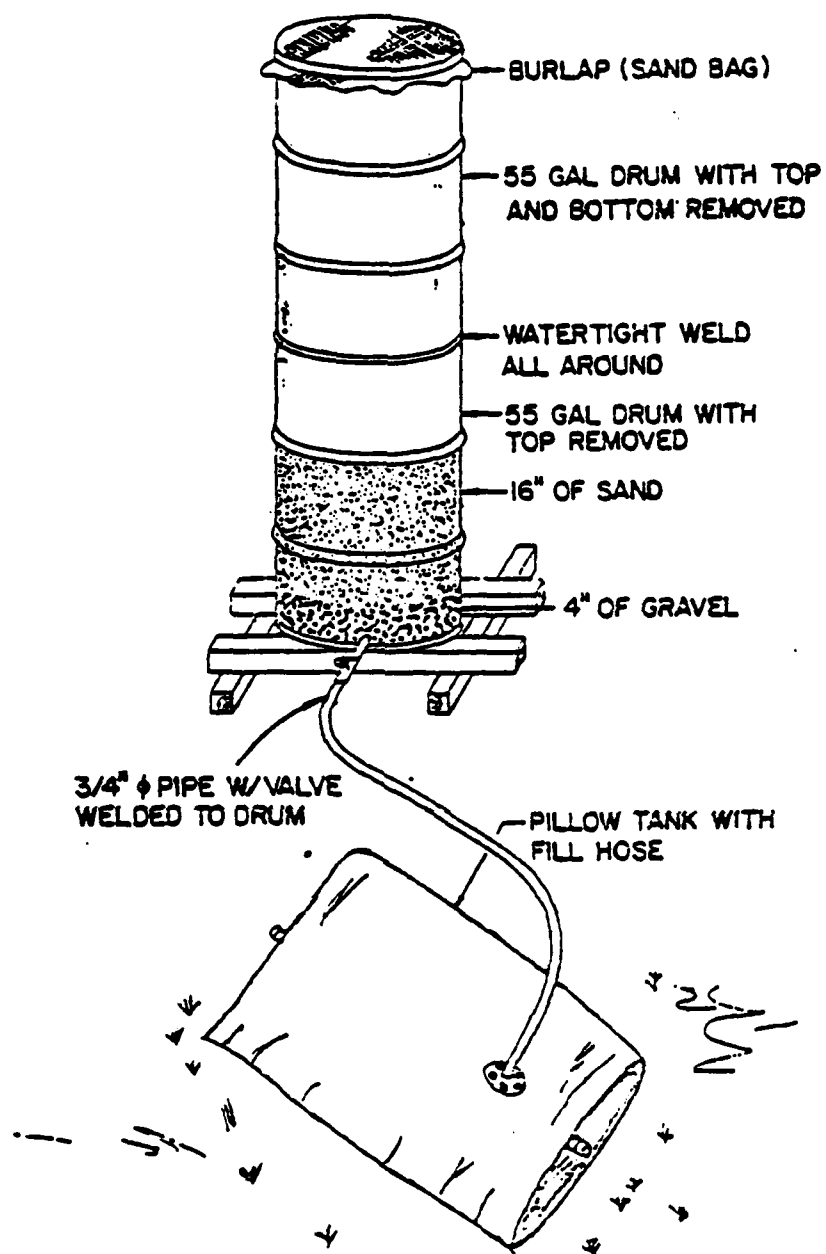


Figure 38. Water Purification: Sand Filter

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TABLE XX

Water Borne Disease

DISEASE	CAUSATIVE ORGANISMS	INCUBATION PERIOD	IMMUNITY	PREVENTIVE TREATMENT	SYMPTOMS
1. Typhoid	Bacillus Typhosus Eberthella Typhus	10 to 14 avg 7 to 25	Yes Vaccine	Field Cl ₂	a) High fever. (4 weeks) b) Rose colored skin eruptions c) Loose bowel movements d) Enlargement of Spleen
2. Paratyphoid	Bacillus Paratyphosus	7 to 10 avg 4 to 14	Yes Vaccine	Field Cl ₂	Similar to Typhoid
3. Bacillary Dysentary	Bacillus Shigella	2 to 3 days	None	Field Cl ₂	a) Frequent bloody mucous filled bowel movements b) Vomiting c) Cramps and pains
4. Amoebic Dysentary	Erdamoeba histolytica	10 days to several months	None	Resistant to Cl ₂ Drying kills cyst Diatomite Filter	a) Similar to Bacillary Dysentary b) Lesions in colon c) Eats blood corpuscles
5. Cholera	Vibro Comma (Comma shaped bacillus or Vibrio)	2 days avg 2 hours to 6 days	Vaccins (3 to 6 mo) Survival (3 to 6 mo)	Field Cl ₂	a) Profuse painless diarrhea b) Dehydration of soft body tissue c) Muscular cramps d) Rapid collapse followed by subnormal temperature and severe prostration
6. Schistosomiasis	Cercariae of Schistosomes	2 days	None	Resists Cl ₂ Diatomite Filter Remove fresh water snails	a) Cough, general pains b) Fever c) Anemia d) Nausea e) Diarrhea f) Painful, bloody urination g) Bloating of the abdomen h) Liver enlarges i) Ulceration (Cancer) j) Tissues thicken k) Constipation l) Muscles stiffen m) Liver shrinks n) Spleen enlarges

Reprinted from 16:12

TABLE XXI

Poisons in Water

Poison	Symbol	Detection	Poisonous effect in water	Treatment	Remarks
Blister gases Nitrogen mustard	HN	Mustard test, Arsenic test	Highly poisonous	Remove by A.C.*	Readily soluble in water. Requires several days to decompose in water. Water containing nitrogen mustard is odorless and tasteless.
Lewisite	L	Arsenic test, Chlorine demand test	Highly poisonous	Remove by A.C.	Quite soluble in water. Decomposes rapidly in water but remains poisonous.
Ethylchlorarsine	ED	Chlorine demand test	Highly poisonous	Remove by A.C.	Quite soluble in water. Decomposes rapidly in water but remains poisonous.
Mustard	H	Mustard test	Fairly poisonous	Remove by A.C.	Fairly soluble, but harmless several hours after decomposition.
Choking gases Chloropicrin	PS	Taste and odor	May be poisonous	May be removed by A.C. but with difficulty	Gives water objectionable taste and odor.
Phosgene	CG	Low pH	Harmless	None necessary	Soluble in water. Decomposes into harmless products.
Diphosgene	DP	Low pH	Harmless	None necessary	Soluble in water. Decomposes into harmless products.
Tear gases Chloroacetophenone	CN	Taste and odor	May be poisonous	Remove by A.C.	Only slightly soluble. Gives water objectionable taste and odor.
Brombenzylcyanide	BBC	Taste and odor	May be poisonous	Remove by A.C.	Only slightly soluble. Gives water objectionable taste and odor.
Vomiting gases Adamsite	DM	Arsenic test	May be poisonous	Remove by A.C.	Slightly soluble in water.
Diphenylchlorarsine	DA	Arsenic test	May be poisonous	Remove by A.C.	Slightly soluble in water.
Blood poisons Cyanogen chloride	CC	Cyanogen chloride test	Highly poisonous	Reduced by aeration, A.C. and chlorination	Decomposes slowly in water.
Nerve gases	G-agents	G-agent test	Highly poisonous	Hydrolysis by soda ash followed by coagulation	Variable rate of decomposition in water.
Physiologically active organic substances Organic arsenicals		Chlorine demand test Arsenic test	Poisonous	Generally removed by A.C.	NOTE: A.C. Activated Carbon
Inorganic arsenic compounds Cyanides		Arsenic test Cyanide test	Poisonous	Generally removed by A.C. Not removed by A.C.	
			Poisonous	Treat with soluble iron salts and coagulate	
Heavy metal salts		Heavy metal test	Slightly poisonous	Not removed by A.C.	Not removed by A.C.
Bone and fish oil		Taste and odor	Poisonous	Large amounts of A.C.	

Reprinted from 16:13

Water Distribution. The expansion and contraction of pipes in hot climates causes leaks. This problem can be reduced by the following methods (34:5.15):

1. Painting pipelines a light color reflects heat and provides better camouflage in some areas.

2. Storing pipes in shady areas and burying distribution lines prevents degradation of plastic pipes.

3. Full-time maintenance crews or burying pipelines at least 18 inches also reduces leaks in hot areas.

FIELD EXPEDIENT WATER DISTRIBUTOR

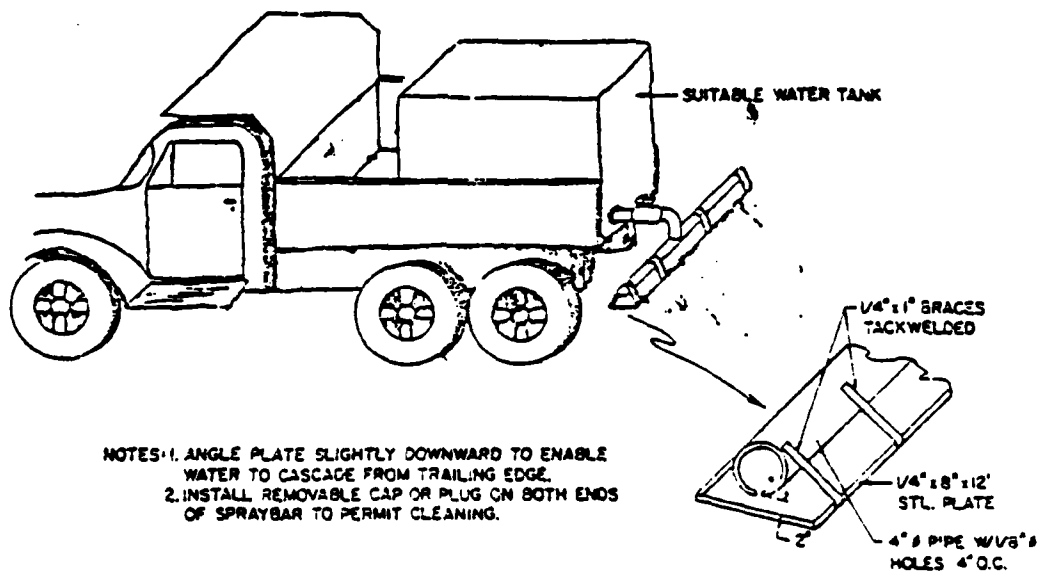
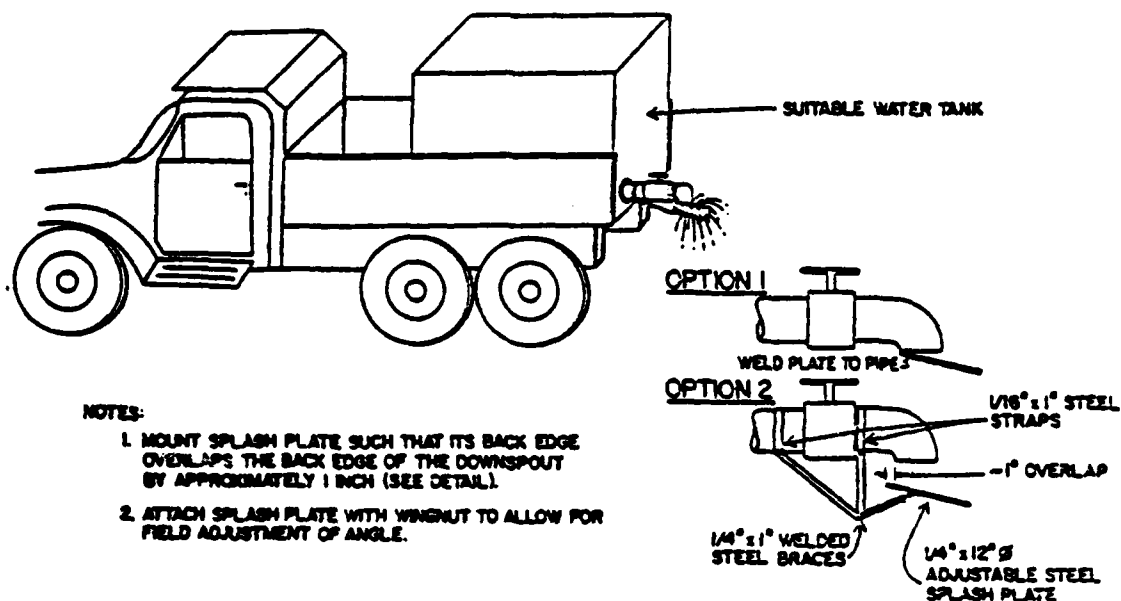


Figure 39. Water Distribution: Vehicular Transport

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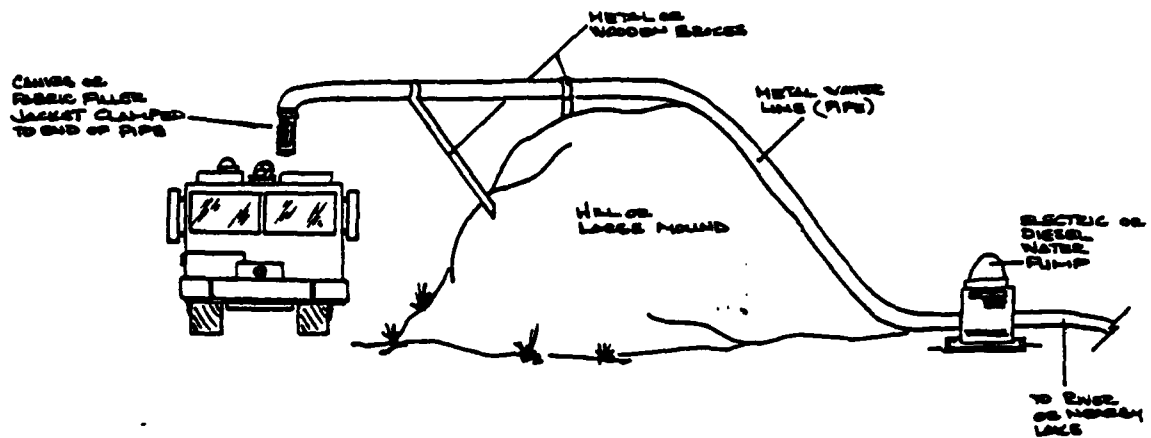


Figure 40. Water Distribution: Quick Crash Truck
 As Used in Bien Hoa AB, Vietnam 1964-1965
 Submitted by Fire Chief A. W. Baumgardner

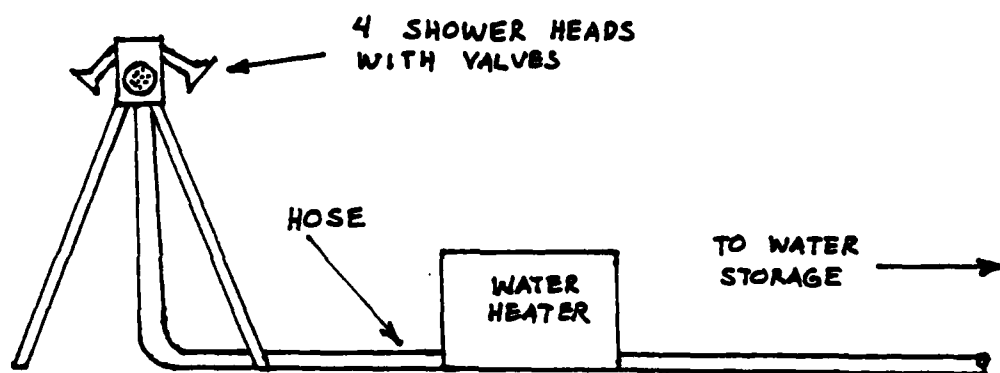


Figure 41. Sanitation: Shower Unit
As Used in Cairo West, Egypt 1980
Submitted by SSgt Tod C. Peabody

Hot Shower Unit. A temporary hot shower unit was used during the "Jack Frost Exercise" in Alaska in January 1979. Temperatures averaged 45 degrees F during this exercise. This expedient hot shower, submitted by CMSgt Donald L. Neels, can be constructed by following the guidelines given below.

1. Construct a plywood shower box with a 4'x8' base, 8'x8' back wall, 4'x8' end walls, and a 2'-high x 8'-long front wall. This box is used only to collect water to prevent flooding the tent floor area. This box can be drained by bucket from a hose attached to the base of one end wall. Also, construct a duct board resting on 4"x4" boards so occupants will not stand in water.

2. Install two 2x4s with 16 penny nails driven approximately 1 ft apart to hang clothes. These 2x4s can be tied with rope to vertical tent poles.

3. Drill a 1-1/4" hole through each end wall, centered and approximately 8" down. Connect 3 sections of 3-ft long, 3/4" galvanized pipe as follows: (1) At the end of one section, install a 3/4"x3/4"x1/2" tee; (2) install a second section of 3/4" pipe and install a second 3/4"x3/4"x1/2" tee; (3) install the third section of pipe and install a 3/4" cap on the end of this section; (4) on the branch side of the two tees, install a 1/2"x2" nipple, 1/2" valve, 1/2"x2" nipple and showerhead; (5) place this completed shower fixture into one hole of the shower end wall and pull it back into the other end hole until the unit is self hanging; and (6) connect one end of a garden hose onto the exposed threading of the pipe and the other end of the hose to a submersible pump.

4. Fill a 32-gallon water can with water.

5. Insert a field unit immersion heater.

6. Insert a low pressure submersible pump with a garden hose attached.

7. Heat the water to the desired temperature of approximately 130 degrees F. The operator can monitor the water temperature with a refrigerator

type thermometer and probe, and controll the temperature by adjusting the fuel to the heater.

8. When the desired water temperature is reached, the operator can connect the plug from the water pump to the power source and add water to the storage can to control any overheat condition.

9. Two men can shower at a time to conserve water. Approximately 2 gallons per man is sufficient. Showering the Navy style (i.e., wetdown, shut off water, soap, scrub, and then rinse) is suggested to conserve water.

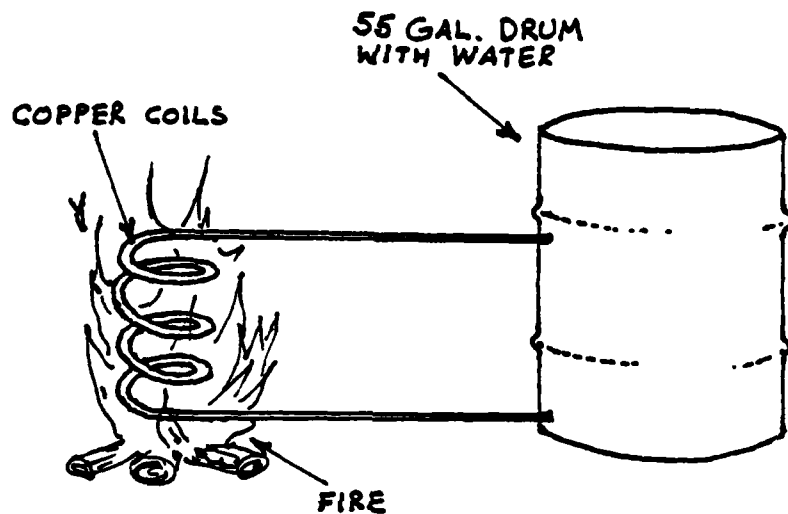


Figure 42. Sanitation: Hot Water Heater

As Used in Boy Scouts

Submitted by A1C Keith Runquist

Attach both ends of some copper tubing to a 55-gallon drum. Fill the drum up with water. Make some coils in the tubing and place the coils over a fire. The fire heats the water in the coils and in the drum.

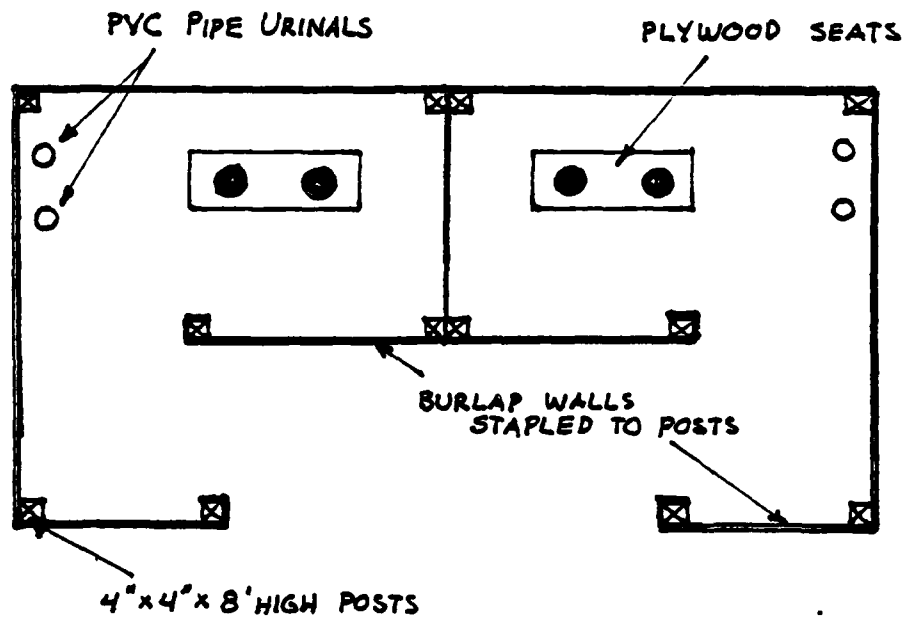


Figure 43. Sanitation: Outdoor Latrine

As Used in Oman, 1982

Submitted by Capt James C. Konyha

Use a few posts and burlap to form the walls in a maze effect. The top is left open.

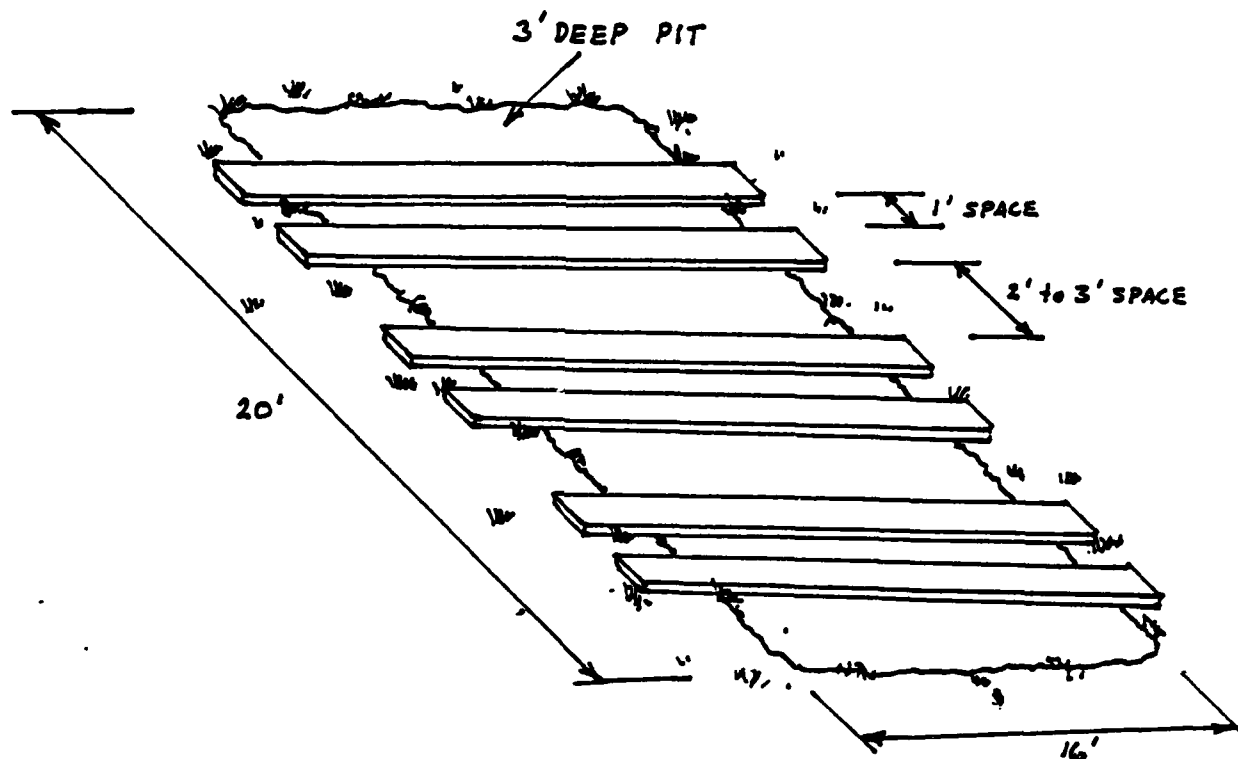
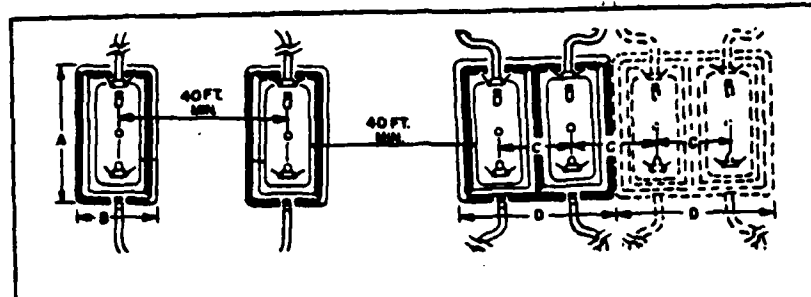


Figure 44. Sanitation: Straddle Pit Latrine
As Used at Eglin, Tyndall, and Bergstrom AFBs

Submitted by TSgt James G. Caraway

1. Use a backhoe to dig a 20' Lx16' Wx3' D hole.
2. Lay six 2"x8"x20' planks across the width of the hole to form three walks as shown in the figure.
3. Two feet at each end of the planking should lay firmly on the ground for stability.

TABLE XXII
Typical Fuel Tank Layout



Capacity	Form Dimensions			Tank Dimensions			C	D	Weight Dry (Approximate)
	A	B		Empty		Full			
Gallons	Length Ft. in.	Width Ft. in.	Height Ft. in.	Length Ft. in.	Width Ft. in.	Height Ft. in.	Width Ft.	Height Ft.	Pounds
500	11 0	12 0	3 6	7 0	8 0	2 6	12	24	60
750	12 0	12 0	3 6	8 0	8 0	3 0	12	24	58
900	15 2	12 0	3 6	11 1	8 0	2 6	12	24	65
1500	14 0	14 0	3 6	10 0	10 0	3 3	14	28	70
2000	16 0	16 0	3 6	12 0	12 0	3 7	18	32	95
3000	17 0	17 0	3 6	13 0	13 0	4 0	17	34	120
3000	23 7	14 8	3 6	19 7	10 0	3 0	14	28	130
4000	18 0	18 0	3 6	14 0	14 0	4 3	18	36	135
6000	19 0	19 0	3 6	15 0	15 0	4 4	19	38	150
6000	20 0	20 0	3 6	16 0	16 0	4 6	20	40	170
8000	29 4	16 0	3 6	25 4	12 0	4 0	16	32	185
7500	22 0	22 0	3 6	18 0	18 0	4 9	22	44	200
10,000	28 0	28 0	3 6	22 0	22 0	4 0	26	52	280
10,000	46 0	18 0	3 6	42 0	12 0	4 0	18	32	290
12,000	54 0	18 0	4 0	50 0	12 0	4 0	18	32	325
15,000	28 0	28 0	4 0	24 0	24 0	5 0	28	56	350
20,000	32 0	28 0	4 0	28 0	24 0	5 2	28	56	400
25,000	34 0	28 0	4 0	34 0	24 0	5 6	28	56	480
40,000	54 0	28 0	4 0	50 0	24 0	5 6	28	56	760
50,000	60 0	28 0	4 0	65 0	24 0	5 7	30	56	960
50,000	66 0	28 0	4 0	65 0	24 0	5 7	30	56	1400
75,000	63 0	28 0	5 0	66 0	24 0	6 0	30	56	1300
80,000	100 0	42 0	5 0	96 0	24 0	6 0	30	56	1410
100,000	60 0	42 0	5 0	76 0	42 0	5 6	48	84	1950
210,000	102 0	62 0	6 0	96 0	48 0	6 0	54	102	2850

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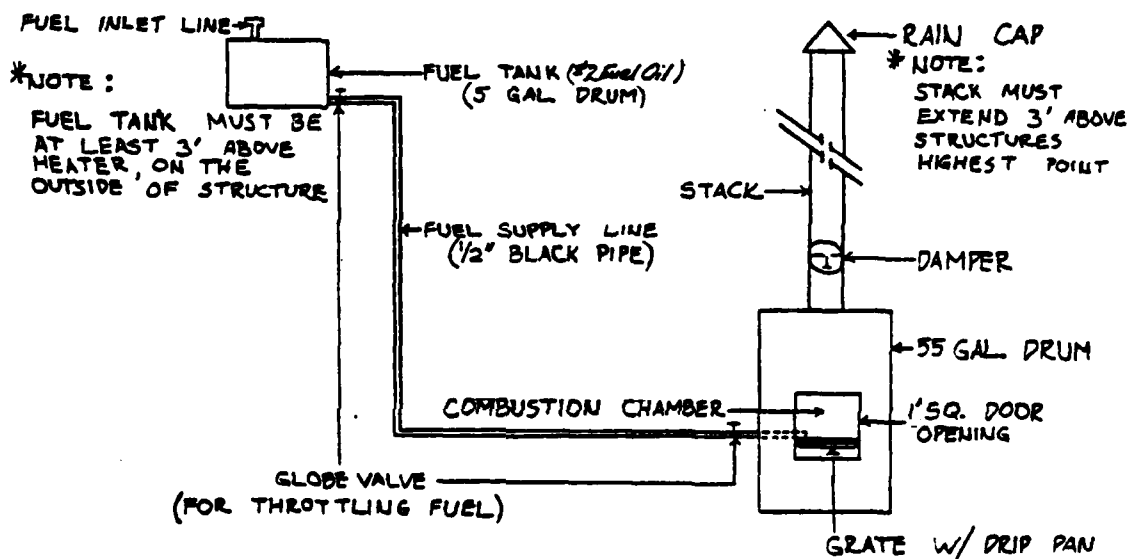


Figure 45. Heating: Semi-permanent Heating Unit

As Used in Vietnam, 1969

Submitted by MSgt Donald Tuttle

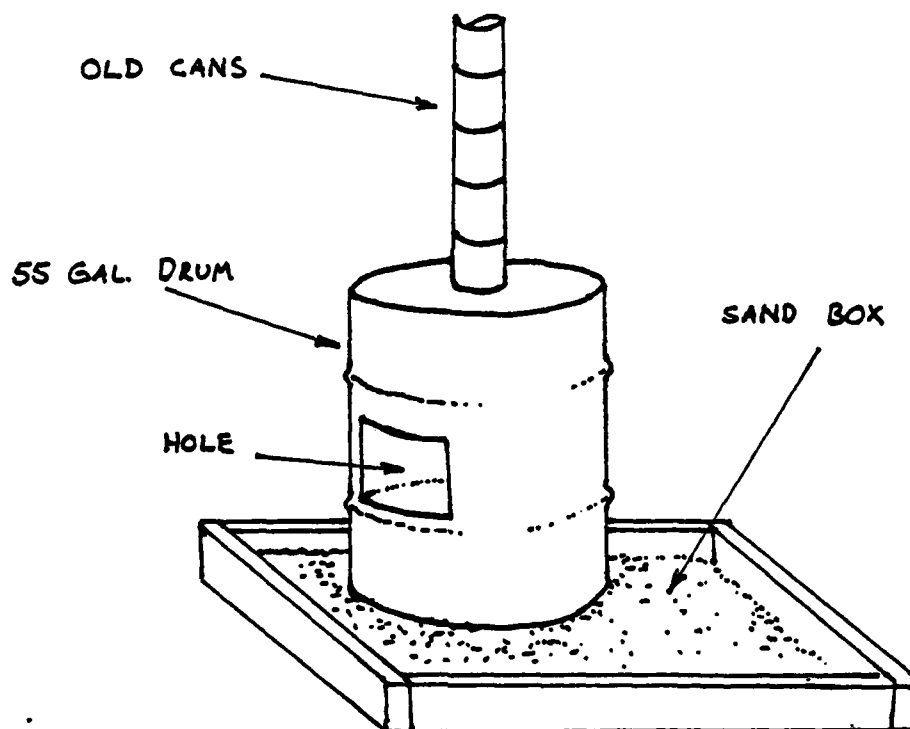


Figure 46. Heating: Tent Heater

Submitted by SSgt Lawrence W. Hopkins

1. Construct a sand box.
2. Place a 55-gallon steel drum in the sand box.
3. Cut a hole in a 55-gallon drum in the top and in the side.
4. Remove both ends from old coffee cans or fruit cans.
5. Stack these cans to form a smoke stack and place into the hole on the top of the drum.
6. Place wood in the hole on the side of the drum for fuel.

ASBESTOS/PERMATEX
PLUG COOKED IN

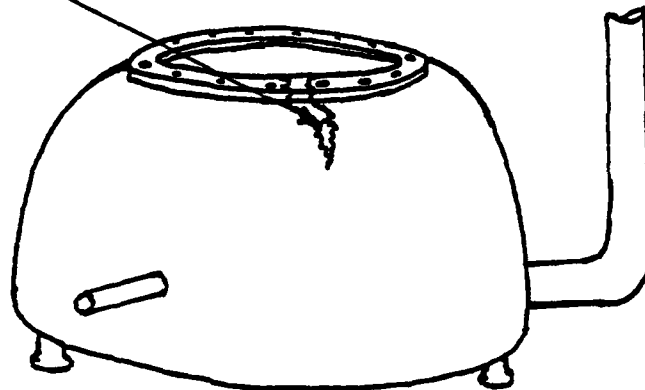
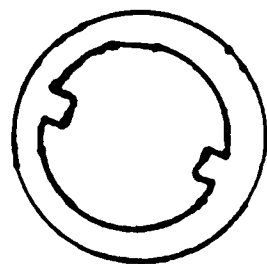


Figure 47. Heating: Expedient Repair of Turbine Block

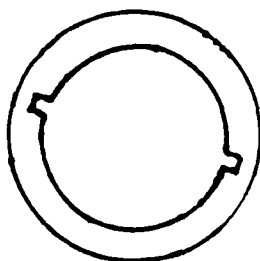
As Used on a Ship's Engine Room, 1954

Submitted by Mr. Troy W. Franklin

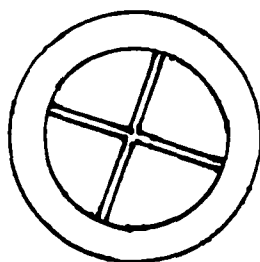
1. Saw into the housing where the steam cut is located.
2. Mix powdered asbestos and permatex and pack into the cut.
3. Reinstall the nozzle block and cook the mixture with the steam.
4. Test before using.



KNURLED TYPE



SLOTTED TYPE



CROSSPIECE TYPE

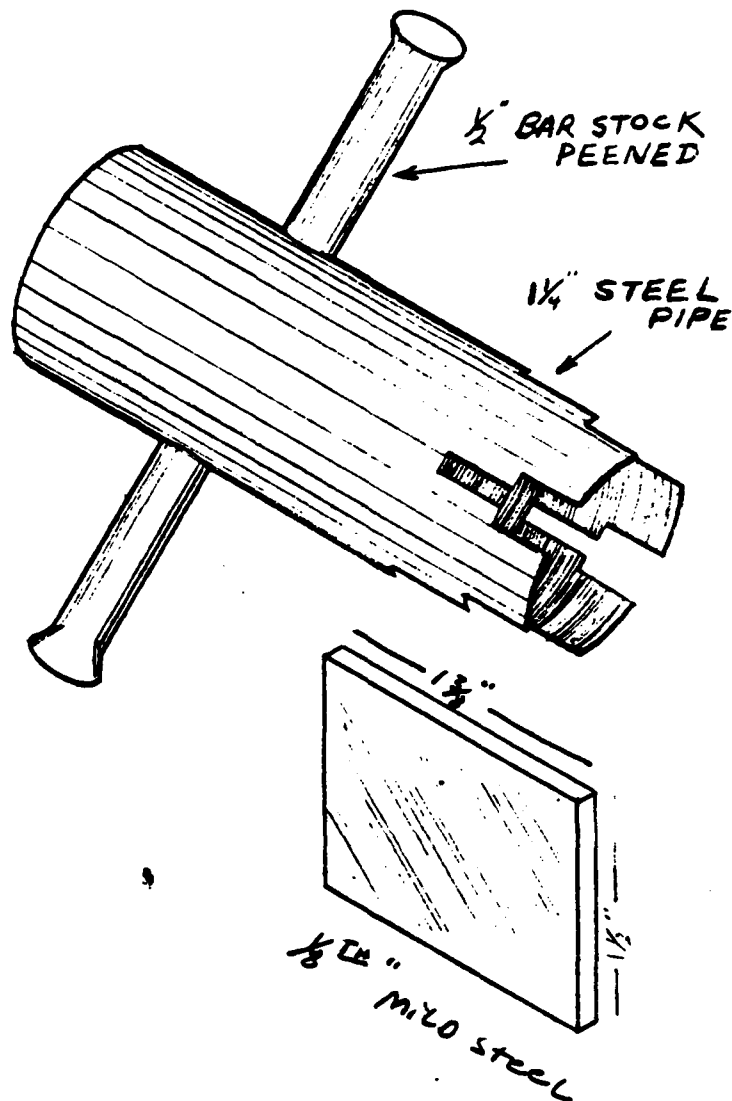


Figure 48. Tools: Improvised Spud Wrench

As Used in Phu-Cat, Vietnam 1967

Submitted by MSgt Richard L. Meade

Wrench can be made of appropriate sized steel pipe/conduit. 1-1/4" pipe is fairly standard for commodes and maintenance service sinks. The 1/8" plate is required so the wrench will remove slotted spuds. It will also remove spuds with knurls and P/O plugs with cross pieces.

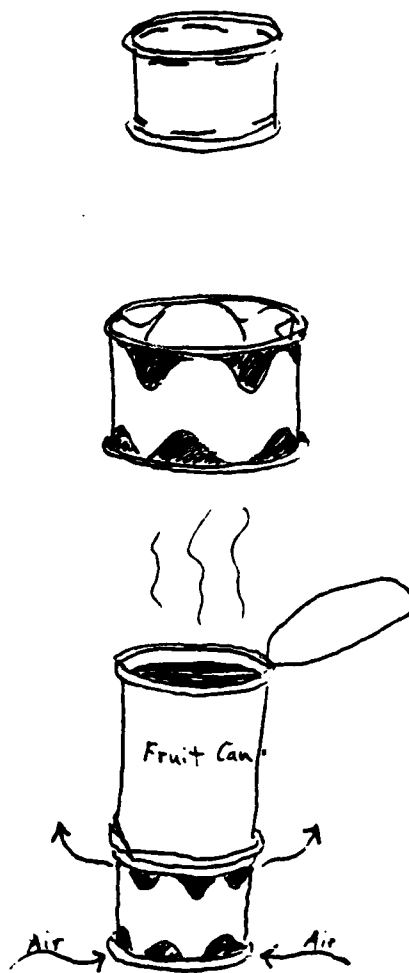


Figure 49. Tools: Portable Stove

Submitted by Mr. Richard Wilson

To make a portable stove to heat C Rations, use a medium size cracker can. Cut slits around the top and bottom of the can on the outside. Push in the sides of the can so air will circulate from the bottom to the top. Place a heating tab or small ball of C-4 in the middle of the can and light it.

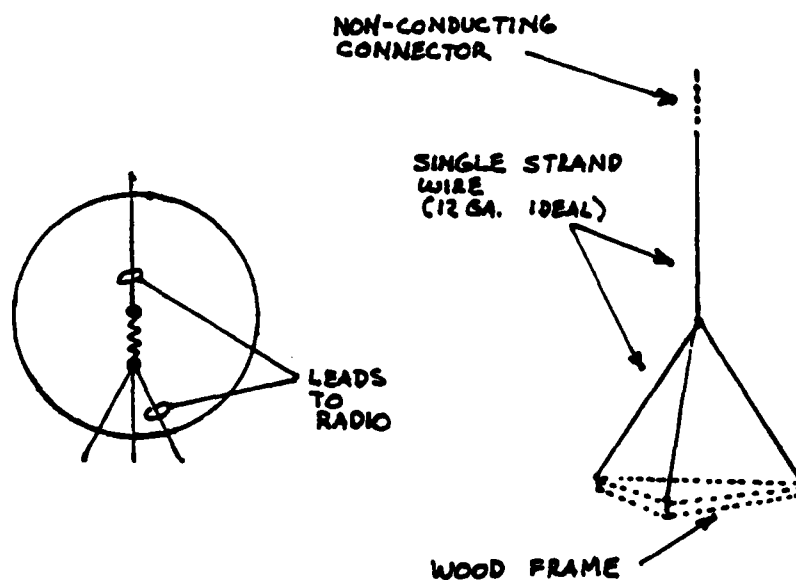
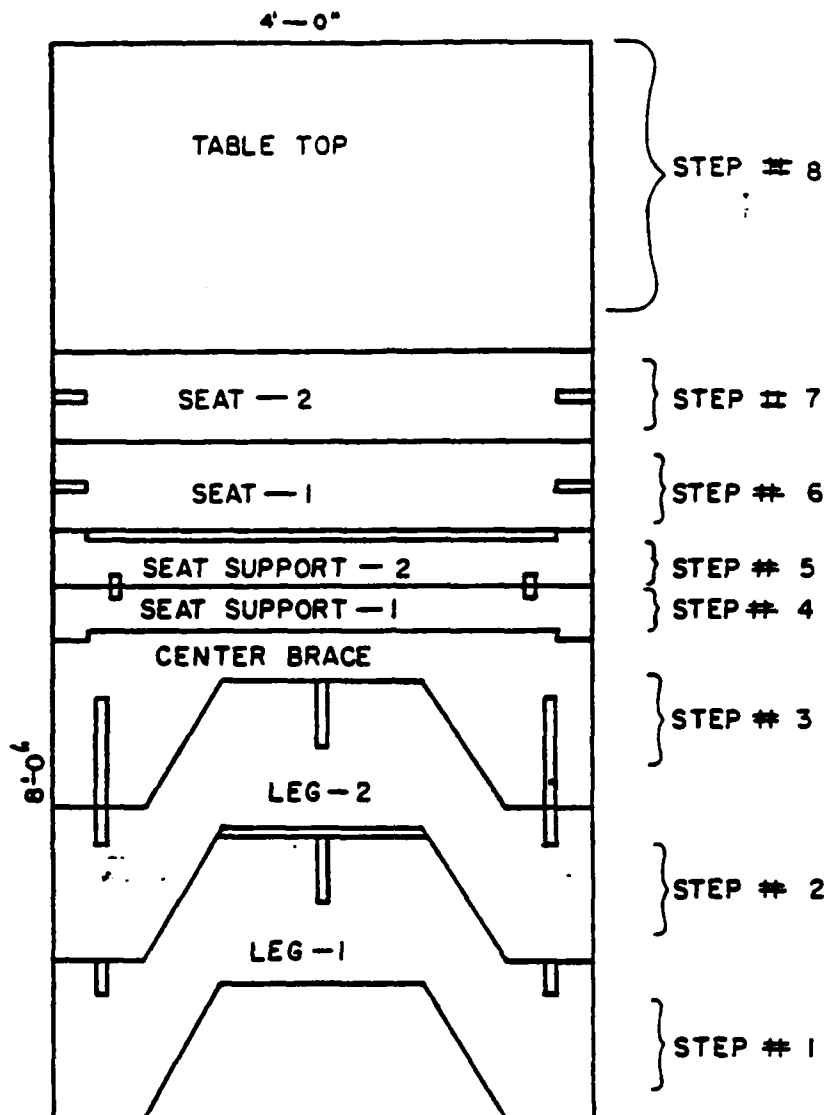


Figure 50. Tools: Long Range Radio/TV Antenna

As Used in Oklahoma

Submitted by 1Lt Jon L. Muller

1. All four wires to be same length (about 3 to 4 feet long).
2. Insulation need not be removed.
3. Can be tied to a tree or any other support.
4. Turn for directional capability.
5. Triples the range of reception.



QUICK PIC. TABLE

1" = 1'-0"

* FOLLOW THE STEPS AS SHOWN OR 1 SHEET OF
4' x 8' x $\frac{1}{4}$ " WILL NOT BE ENOUGH

Figure 51. Furniture: Table and Benches

As Used in Mtn Home AFB ID

Submitted by 2Lt Bruce L. Stealy

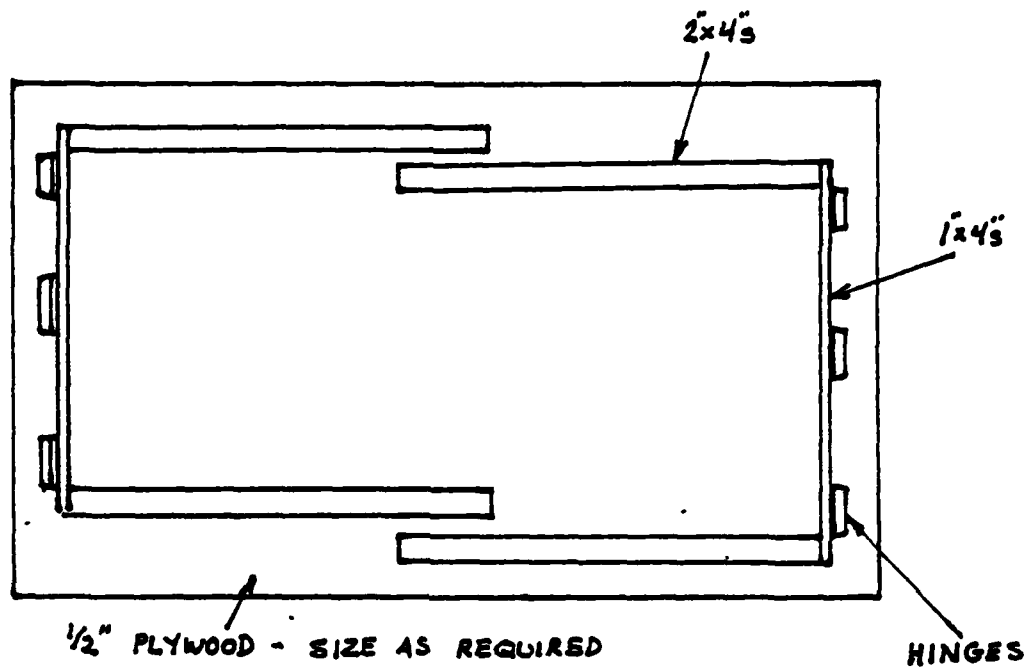


Figure S2. Furniture: Folding Table
As Used During "Team Spirit" in Osan AFB, Korea 1982
Submitted by Capt Mellerski

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