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MILITARY ENVIRONICS--WATER, WASTE WATER, AND SOLID WASTE

James A. Mahoney

TECHNICAL REPORT NO. AFWL-TR-70-97

November 1970

AIR FORCE WEAPONS LABORATORY
Air Force Systems Command
Kirtland Air Force Base
New Mexico

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FOREWORD

This research was performed under Program Element 63723F, Project 683M, Subtask 3.1.000.

Inclusive dates of research were 24 December 1969 through 6 July 1970. The report was submitted 1 September 1970 by the Air Force Weapons Laboratory Project Officer, Mr. James A. Mahoney (DEZ-E).

The author wishes to thank Dr Calvin C. Patterson, Professor of Civil Engineering, Department of Civil Engineering, The University of New Mexico for his guidance, direction, and advice while preparing this paper.

The writer is indebted to the United States Air Force which made the writing of this paper possible and to the individuals who recommended me and endorsed the recommendation for participation in the Air Force Civilian Long-term, Full-time Educational Program. In particular, I would like to thank Col Richard A. House, Col Robert L. Elwell, Col George Darby, Jr., CDR Allen F. Dill, CEC, USNR, LtCol Robert E. Crawford, LtCol John P. Thomas, LtCol Claude J. Stringer, and Maj Donald G. Silva, all of the Air Force Weapons Laboratory, Kirtland Air Force Base, New Mexico.

Information in this report is embargoed under the Department of State ITIARs. This report may be released to foreign governments by departments or agencies of the US Government subject to approval of AFWL (DEZ).

This technical report has been reviewed and is approved.

JAMES A. MAHONEY
Project Officer

CLARENCE E. TESKE
Major, USAF
Chief, Aerospace Facilities Branch

JEAN M. MARCHAND
Lt Colonel, USAF
Acting Chief, Civil Engineering Division

ABSTRACT

(Distribution Limitation Statement No. 2)

The information gained of the United States Armed Forces effort, in the areas of water supply, waste water treatment and solid waste disposal is summarized. The report surveys the state of the art of environmental engineering associated with the military environment. The responsibilities of the military civil engineers and the service laboratories and their locations are discussed. Waste products produced by human activities, namely, sewage, its collection, treatment, and disposal are included. Solid wastes are also discussed.

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SECTION I

INTRODUCTION

1. OBJECTIVE

This report contains state-of-the-art information on the military environmental disciplines of water supply, waste water treatment, and solid waste disposal. It includes the conventional or stateside type (posts, stations, and bases) systems as well as information about combat areas and remote sites. The report is divided into four sections. Section I is a general discussion concerning the installation engineer and military laboratories. The remainder of the report consists of: water supply and treatment, sewage treatment and disposal, and solid waste disposal. Because this study concerns the military, these sections will cover stateside systems and systems in remote and combat areas. In most instances, the bibliography contains documents published by the services describing the research and development accomplished in the sanitary engineering field. This should be of help to the student interested in the military sanitary conditions of field operations, polar regions, and in nations friendly to the United States. The military faces unique problems in trying to bring conveniences to the Arctic and Antarctic, in catching rain from roofs, and in prepared catchments, and water reconnaissance under enemy fire. The documents listed in the bibliography present problems, some solutions, partial remedies, equipment development, experiments, and in general concern unconventional sanitary systems that the military must use.

2. DISCUSSION

The health, well being, and morale of the Armed Forces and their dependents are of great concern to the Department of Defense. The aim of the department is to maintain for the military the high standards of living to which Americans are accustomed, both in the United States and overseas. Attainment of this goal is the duty charged to the Air Force Base Civil Engineer (BCE). (The Navy's counterpart is the Public Works Officer, and the Army's is the Post Engineer. Their duties are identical but peculiar to the individual service.)

A normal military installation functions in a manner similar to that of a municipality. There are differences, however, and the differences are worth noting. The BCE is comparable to a city Public Works Director. A Public Works Director and his department heads are charged with performing services for the resident citizens including provisions for potable water, waste collection and disposal; maintenance of streets and buildings; providing building inspection of the trades during construction of private homes and commercial buildings; and ensuring proper traffic flow by regulating traffic through the use of various electric signals and signs (Ref. 1). The Public Works Director does not have responsibility of repair and maintenance if a citizen's roof leaks, if a tree root has plugged a house sewer service, or if a lawn will not grow, unlike the BCE. An anonymous author once wrote of the requirements of the BCE

> He must be a Civil Engineer, Mechanical Engineer, Electrical Engineer, Architectual and Structural Engineer, Sanitary Engineer, Fire Protection Engineer, Safety Engineer, Management Engineer, Human Engineer, Production Engineer, Agronomist and well versed in Allied Sciences (Ref. 2).

Included in the BCE responsibilities is the repair and maintenance of all the buildings on the installation. He must provide potable water as well as special water treatment for certain base establishments; such as: hospitals, mess halls, laundries, photo laboratories, and other industrial-type organizations. He must provide special treatment, traps, and tanks for certain industrial wastes. He must see that his residents are taken care of and provide all services to support the mission of the base (Ref. 3).

A note should be made concerning financing. Both the BCE and the Director of Public Works submit a planned budget. Both budgets must go through a chain of command before approval is granted and funds are allocated. In the case of the Air Force BCE, his budget must go through his Base Headquarters, then his Command Headquarters to USAF Headquarters where it is finally presented to Congress. The mood and philosophy of the Administration and the Congress may result in drastic changes in the proposed budget. The proposed budget of the Public Works Director, on the other hand, takes a shorter route through the chain of command to the City Commission. The mood and philosophy of the local citizenry determines the extent to which they wish to tax themselves for provision of services.

A comparative description of the Department of Public Works and the Base Civil Engineer would be useful to those readers not familiar with the military organization.

The military Base Civil Engineer Organization Chart, figure 1, is comparable to that of the Public Works Director. His responsibilities are more extensive than his civilian counterpart, for instance, he is the Base Fire Marshall. The BCE also is responsible for the grounds of the base where the municipal counterpart would be the Director of Parks and Recreation (Ref. 3).

Engineering development of water supply and waste water disposal for military establishments follows very closely the criteria and standards which have evolved in the civilian sector of the American society. A military reservation is a community of people gathered together for a specific mission. However, the planning of military sanitary systems has a distinct advantage over their municipal counterparts in that the military system is normally designed on a predetermined population basis and rarely expands beyond these limits. This situation is rarely if ever experienced in the design of public systems. Of course there have been the wartime expansions where many bases experiences population explosion similar to that of most cities today. With the explosion came hurried construction for enlarging these military systems just as many cities are presently being forced to do.

When a military installation is fortunate enough to be located near a city that can furnish approved potable water and can dispose of the wastes through its treatment plants, the federal government will make appropriate arrangements and agreements to utilize the local facilities. In many foreign countries the military has the same decision as in the United States, namely either tie into existing systems or develop their own. In some countries where occupational troops are quartered, expropriated facilities are utilized fully or are revamped to American standards. Some installations depend completely on their own water supplies, treatment plants, and storage facilities and also process their own wastes.

The services world-wide operation, the limited war concept, and the advancement of technical knowledge have created a demand for unique waste disposal and water supply techniques. Since World War II remote areas such as the polar regions have been occupied with small complements to man early warning radar sites. Islands have been occupied for various military reasons. The Air Force alone has personnel deployed in over 65 countries at 4000 major locations (Ref. 4). The United States has been engaged in various limited wars and has acted as advisors

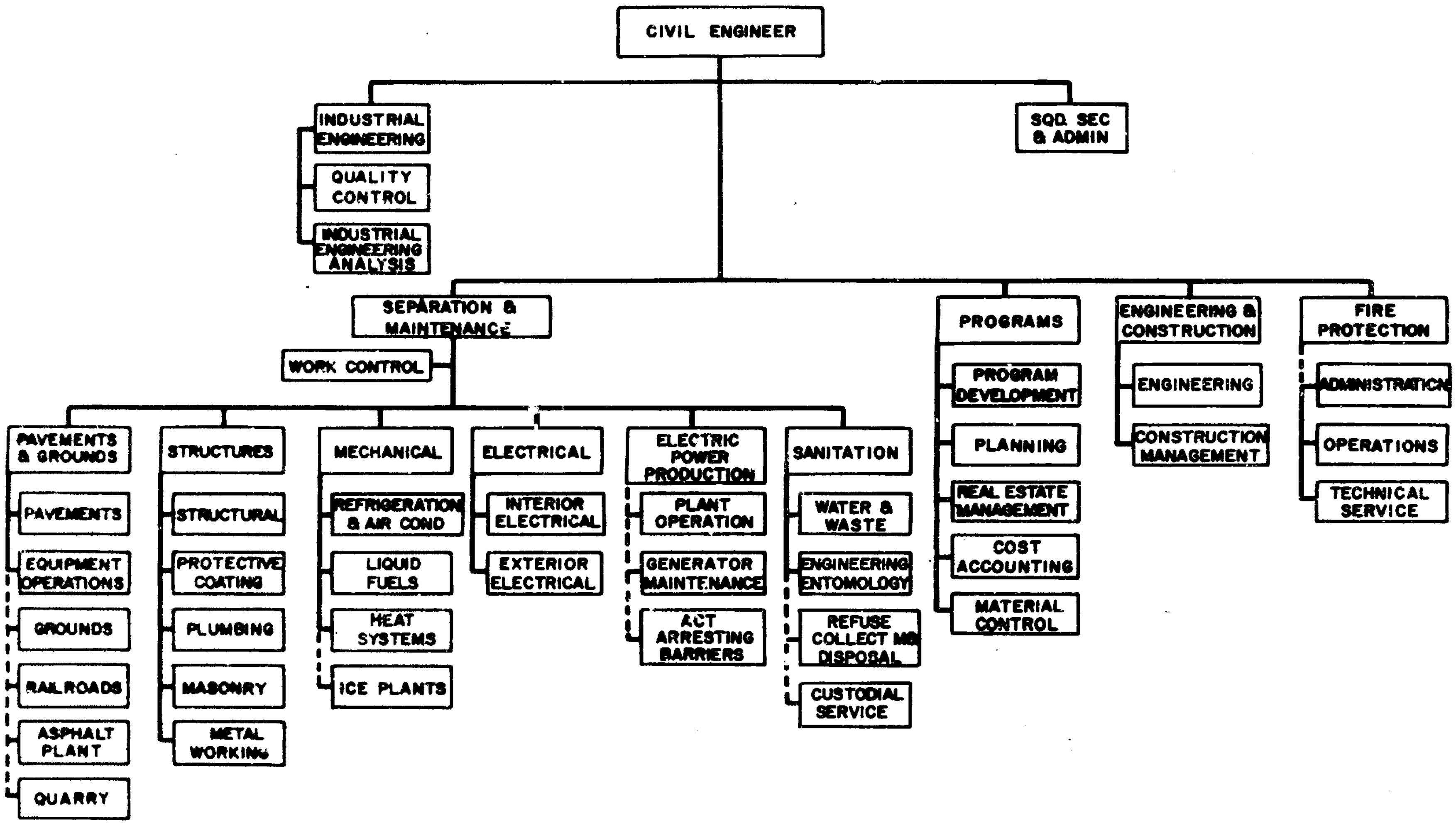

Figure 1. Organizational Chart, Air Force Base Civil Engineering Directorate

or guardians to friendly nations. These all have imposed different problems on engineering staffs, and many research and development hours have been spent to provide "comforts," even if limited, to the military and civilians stationed at these outposts and those participating in the conflicts.

The various services have established laboratories to provide research and development to assist the Post Engineer, the Public Works Officer, and the Base Civil Engineer to perform their tasks on a daily basis and to improve design practices and equipment. The various laboratories by no means devote all their efforts to that end but many man-years are expended in this direction.

A partial list of the laboratories that are engaged in this work would include:

Air Force Weapons Laboratory
Civil Engineering Division
Kirtland Air Force Base
Albuquerque, New Mexico

US Naval Civil Engineering Laboratory
Port Hueneme, California

Air Force Cambridge Research Laboratories
Bedford, Massachusetts

Air Force Flight Dynamics Laboratory
Wright-Patterson Air Force Base, Ohio

US Army Corps of Engineers
Cold Regions Research and Engineering Laboratory
Hanover, New Hampshire

US Army Engineer Research and Development Laboratories
Fort Belvoir, Virginia

US Army Chemical Corps Engineering Command
Army Chemical Center, Maryland

US Army Medical Research Laboratory
Fort Knox, Kentucky

US Army Corps of Engineers
Waterways Experiment Station
Vicksburg, Mississippi

These laboratories undertake a wide spectrum of investigations whose subjects range from snow melting and incinerating toilets to research on a waste system for aerospace stations.

Inputs to this report were obtained from unclassified Army, Air Force, and Navy regulations, technical manuals, design manuals, operational manuals, research reports, command reports, correspondence, service engineering publications, private communications with Military Civil Engineering Officers, equipment manufacturers, and professional journals.

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1. Teevan, J., City of Albuquerque Job Position Description, Director of Public Works, Albuquerque, New Mexico, December 1965.

2. Hq. AMC, AID Orientation Manual, "Job Requirements of a Civil Engineering Officer," Lt Col E. U. Hunsberger, USAF to James A. Mahoney, AFWL, Kirtland AFB, New Mexico

3. Air Force Regulation No. 85-5, Civil Engineering - General, "Operation and Maintenance of Real Property," Department of the Air Force, Washington, DC, 22 June 1967.

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SECTION II

WATER SUPPLY

The conventional and the special installations are discussed in this section. The special installations cover the polar bases, combat areas, friendly nation bases, and island bases.

1. CONVENTIONAL BASE WATER SYSTEMS

The conventional military installation utilizes accepted standards for the design and construction of a water supply system. The supply of raw water is obtained from surface or ground-water, whichever is available and most economical. Treated municipal water supplies are often used when available. Some installations use municipal sources, their own supply system, or a combination of both.

a. Quantity of Required Water

The purpose and function of an installation is known before it is designed. The resident and nonresident populations are governed by the type of organizations and missions the base is to perform. Unit Detail Lists, for a given function, indicate the number of personnel required to fulfill that particular task. The lists are tables setting out the authorized number of men and major equipment for a unit or operation and are sometimes called "Table of Organization" or "Table of Organization and Equipment" (Ref. 5). The per capita water demand is then determined by established allowances. Table 1 (Ref. 6) illustrates the allowances per person in gallons per day (GPD) for the various type installations controlled by the Air Force and the Army. The Navy has similar allowances for its bases and the organizations it services. Shipboard water allowances are also established.

In the process of developing a design population, the effective population must be obtained. The effective population includes all resident, military, and civilian personnel and their dependents plus nonresident personnel. For nonresident personnel a per capita water demand allowance of 50 gallons per day is established at 1/3 of that required for residents. The effective population figure is obtained by adding 1/3 of the nonresident population to the resident figure. The effective population is multiplied by a capacity factor to obtain

Table 1

Per Capita Domestic Water Allowances for Air Force and Army Projects (gallons per day (GPD))

Type of project	Permanent construction (GPD)	Field training camps (GPD)
USAF bases and SAGE support facilities	150*	---
Armored divisions	150	75
Camps and forts	150**	50
Prisoner-of-war and internment camps	---	50**
Hospital units†	150	100
Hotels††	70	---
Depot, industrial, plant, and similar projects	50 gallons per employee per 8-hour shift; 150 gallons for resident personnel	

Note:

1. For Aircraft Control and Warning Stations, National Guard Stations, Guided Missile Stations, and similar projects, special instructions will be issued. (See TM 5-813-7 (EM1110-345-229) or AFM 88-10, Chap. 7.)
2. The Allowances set forth above include water used for laundries to serve the resident personnel, washing vehicles, limited watering of planted and grassed areas, and similar uses. The allowances do not include special industrial or irrigation uses.

*An allowance of 150 gallons will be used for USAF semi-permanent construction.

**For populations under 300, 50 gallons will be used for base camps and 25 gallons will be used for branch camps.

†Includes hotels and similar facilities converted to hospital use.

††Includes similar facilities converted for troop housing.

the design population. The capacity factor varies inversely with the magnitude of the effective population and provides for a reasonable increase in population, variations in water demands, and uncertainties as to actual water supply requirements and for unusual peak demands, the magnitude of which cannot be accurately estimated in advance. Table 2 (Ref. 6) shows the various increments of the capacity factor. See pages 11, 13 through 17 for examples in using the capacity factor.

Table 2

Capacity Factor Increments

Effective population	Capacity factor
5,000 and less	1.50
10,000	1.25
20,000	1.15
30,000	1.10
40,000	1.05
50,000 and over	1.00

Capacity factors for intermediate effective populations are determined by an arithmetical interpolation. The capacity factor is applied to the water supply works, supply lines, treatment works, principal feeder mains, and storage reservoirs. It is also used in planning water supplies for all projects including general hospitals and internment and prisoner-of-war camps. In replacing water mains to fully developed areas, the capacity factor is not used but the new main is the same size as the one being replaced. Capacity factors are not used for design of fire flows, irrigation requirements, or industrial demands.

The required daily demand or the total daily water supply requirements is obtained by multiplying the design population by the per capita domestic water allowances, and adding to this the estimated quantities needed for any special industrial, aircraft wash, irrigation, air conditioning or other demands. Some of these other demands include the amount of water necessary to replenish, in 48 hours, the storage required for fire protection and normal operations. When the supply is from wells, the quantity available in 48 hours of continuous operation of the wells is used in calculating the total supply available for replenishing storage and for maintaining fire and domestic demands and industrial requirements that cannot be curtailed. The peak domestic demand is assumed to be 2.5 times the daily average domestic requirements. As a comparison, a typical civilian practice uses hydrographs of hourly pumpage depicting a typical maximum, minimum, and an average day in Toledo, Ohio. These hydrographs reveal that the peak demand was between 6 and 7 p.m. and was 150 percent or 1.5 times the average daily rate (see figure 2) (Ref. 7). Fair and Geyer indicate that the normal range for peak demand is from 1.2 to 2.0 times the average daily rate or about 1.5 average. The maximum hourly peak demand is 2.5 times the average hourly rate (Ref. 8).

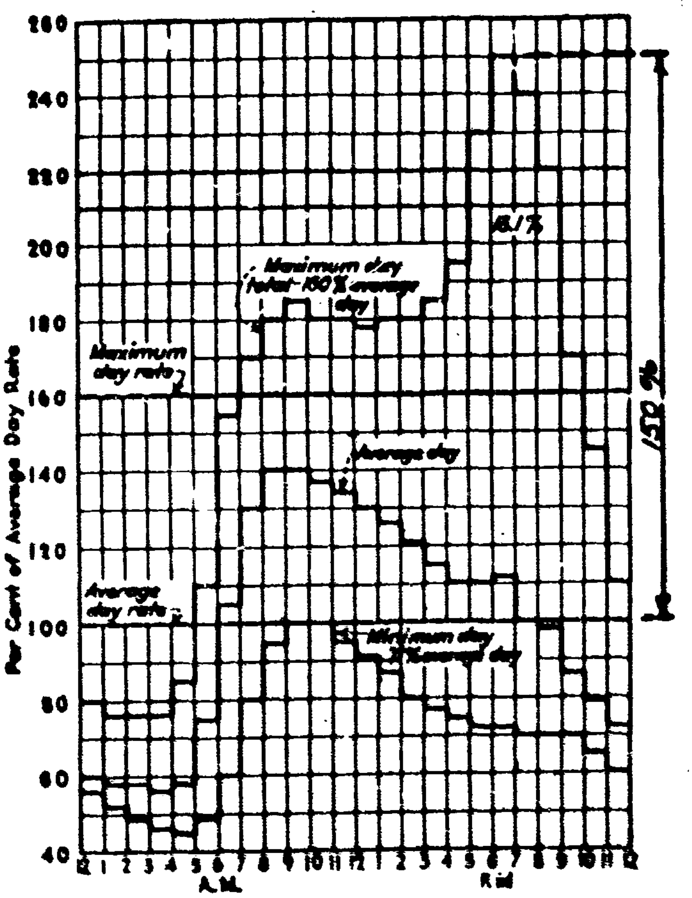


Figure 2. Hydrographs of Hourly Pumpage for Typical Maximum, Minimum, and Average Days, Toledo, Ohio, 1937

The fire flow is the amount of water in gallons per minute (gpm) required at a specific residual pressure at the site of the fire for a specific period of time; it is calculated by the following formula:

fire flow (gals) = rate of flow (gpm) x 60 x number of hours

See table 3 (Ref. 9) for a summary of fire flow requirements.

The fire demand is the amount of water in gallons per minute required during a specified fire period. It is determined by the sum of the fire flow, 50 percent of the average domestic demand rate, and any industrial or other demand that cannot be reduced during a fire period. The residual pressure is specified for either the fire flow or essential industrial demand, whichever is higher. When sprinklers are served directly by the water supply system, the fire demand includes quantities required for automatic sprinkler operation, in addition to direct hydrant fire flow demand as appropriate.

The following examples are furnished as typical design analysis to illustrate the application of capacity factors, per capita allowances, domestic requirements, fire demands, etc., in determining capacity of various components entering into the design of a water supply system (Ref. 10).

Example A

Installation: Permanent camp

Authorized effective population: 20,000

Water source: Surface supply from creek

Required demand and fire flow:

Capacity factor: 1.15

Design population: 20,000 x 1.15 = 23,000

Per capita allowance: 150 gallons per day

Average domestic demands: 23,000 x 150 = 3,450,000 gallons per day = 2,396 gpm

Peak domestic demand: 2,396 x 2.5 = 5,990 gpm

Fire flow:

Quarters: 2 at 1,000 gpm for 4 hours = 2 x 1,000 x 60 x 4 = 480,000 gallons

Warehouse: 1 at 2,000 gpm for 4 hours = 2,000 x 60 x 4 = 480,000 gallons

To meet the domestic demand, a filtration plant with pumping stations and appurtenances having a rated capacity of approximately 3.5 mgd would be provided.

Table 3

Minimum Design Fire Flow Requirements

Type of project	Up to 250 gpm	500 gpm	1,000 gpm	2,000 gpm	3,000 gpm	4,000 gpm
I. USAF bases, Army camps and cantonments						
a. Population 6,000 and greater	---	---	2-4	---	---	---
Warehouse area	---	---	---	1-4S	---	---
b. Population between 1,000 and 6,000	---	---	1-4	---	---	---
Warehouse area	---	---	1-4S	---	---	---
c. Population between 500 and 999	---	1-2	---	---	---	---
d. Population between 300 and 499	1-2	---	---	---	---	---
e. Population less than 300 (see Par. 6c)	---	---	---	---	---	---
II. Hospitals (see Par. 7)	---	---	---	---	---	---
III. Special facilities (see Par. 8)	---	---	---	---	---	---
IV. Storage projects (see Par. 9)	---	---	---	---	1-2S	1-4
V. Aircraft hangars (see Par. 10)	---	---	---	---	---	---
VI. Plants, special weapons, and ordnance processing areas as determined individually	---	---	---	---	---	---
VII. AC&W stations (see EM1110-345-229)	---	---	---	---	---	---
VIII. Surplus-property storage (see Par. 12)	---	---	---	---	---	---
IX. POL storage and handling areas	---	---	1-2	---	---	---
X. Vehicle parking	---	1-2	---	---	---	---
XI. Aircraft fueling, mass parking, and servicing aprons	---	---	1-2	---	---	---
XII. Tent or hutment camps (see Par. 18)	---	---	---	---	---	---

Note:
1. References paragraphs are in Engineer Manual (EM1110-345-228).

2. 1-2 = 1 fire for 2 hours, S = At sprinkler pressure.

Pumping requirements: EM 1110-345-221 specifies that in addition to the motor-driven pumps therein specified, a sufficient number of the pumps should be equiped with electric-motor/gasoline-engine power, or standby gasoline-engine-driven pumps should be installed, capable of supplying 50 percent of the rated capacity of the filtration plant, except where a greater capacity is indicated or required. In this case a 1,225 gpm gasoline-engine-driven pump is included in both the raw-water and filtered-water pumping equipment.

Storage requirements: The following figures are applicable.

Item 1, 50 percent of domestic daily demand $= \frac{3,450,000}{2} = 1,725,000$ gallons

Item 2, fire demand $= \left(2,000 + \frac{2,396}{2}\right) \times 60 \times 4 = 767,520$ gallons

Item 3, 50 percent of domestic daily demand plus fire demand minus amount of water available in 24 hours through the gasoline-engine-driven pumps should electric service be interrupted = 1,725,000 + 767,520 - 1,764,000 = 728,520 gallons.

Item 1 governs, and 1,725,000 gallons storage should be provided. At least 50 percent of storage should be elevated. Two 500,000-gallon elevated tanks or three 300,000-gallon elevated tanks would be satisfactory. The remainder of the required storage could be provided in a ground-storage reservoir.

Filtration plant; The filtration plant would be designed using seven 0.5 mgd filters. Filter areas would be based upon a flow rate of 2 gallons per square foot per minute.

Raw-water pumping station:

Provide two 2,450 gpm electric-motor-driven pumps
one 1,225 gpm electric-motor-driven pump
one 1,225 gpm gasoline-engine-driven pump

High-lift pumping station: Provide pumps having similar capacities and power as for raw-water station.

Water main sizes: The peak domestic rate if 5,990 gpm. The fire demand is 3,198 gpm with a concentrated flow of 2,000 gpm to the warehouse area. It is therefore indicated that both domestic and fire flows must be considered in determining water-main sizes. Peak demands for water will be supplied by a combination of pump output and withdrawal from storage. A post of this size would have a station hospital of approximately 600 beds and would require a fire flow of 1,000 gpm.

Automatic sprinkler supply and pressures for satisfactory operation must be taken into consideration in determining water main sizes to the hospital area. For a discussion on distribution mains see paragraph 2.5 of EM 1110-345-221.

Example B

Installation: Air control and warning station

Authorized population: Military--200 plus dependents. If adequate housing is available in the area, 10 family-housing units will be required. If there is inadequate housing, 50 family units will be required. A total of 3.6 members will be assumed for each family, 1 military and 2.5 dependents.

Total population: Adequate support: 200 + (10 x 2.6) = 226

Inadequate support: 200 + (50 x 2.6) = 330

Water source: Wells on site

Required demand and fire flow:

	Adequate area support	Inadequate area support
Population	226	330
Capacity factor	1.5	1.5
Design population	339	495
Per capita allowance	100 gpd	100 gpd
Average domestic demand	100 x 339 = 33,900 gpd = 24 gpm	100 x 495 = 49,500 gpd = 35 gpm
Peak demand	24 x 2.5 = 60 gpm	35 x 2.5 = 88 gpm
Fire flow	500 gpm for 2 hours = 60,000 gallons	500 gpm for 2 hours = 60,000 gallons

Well requirements:

Based on supplying daily demand in 16 hours operation	24 x 3/2 = 36 gpm one well equipped w/40 gpm dual-drive pump	35 x 3/2 = 53 gpm two wells, equipped w/30 gpm pumps, one of which should be dual-drive type

Storage requirements:

	Well out of service	One well out of service
50 percent of domestic daily demand	$\frac{33,900}{2}$ = 16,950 gal	$\frac{49,500}{2}$ = 24,750 gal

Fire demand	(50C + 24/2) x 60 x 2 = 61,440 gallons 16,950 + 61,440 = 78,390 gallons	(500 + 35/2) x 60 x 2 = 62,160 gallons 24,750 + 62,160 - (30 x 60 x 24) = 43,710 gallons
Required 50 percent of domestic daily demand and fire-flow demand minus production in 24 hours of wells in service. Ground storage preferred for these sites	Combined demand governs. Use 100,000 gal storage tank, equipped with pneumatic tank and one 60 gpm dual-drive pump and one 60 gpm electric-motor-driven pump for peak domestic and one 500 gpm dual-drive pump for fire demand	Fire demand governs. (62,160 - 30 x 60 x 2) = 58,560. Use 60,000 gal storage tank equipped with one 100 gpm dual-drive pump and one 100 gpm electric-motor-driven pump for peak domestic and one 500 gpm dual-drive pump for fire demand

<u>Water main sizes</u>:

Fire demand	500 + 24/2 = 512 gpm	500 + 35/2 = 518 gpm
Peak domestic demand	24 x 2.5 = 60 gpm	35 x 2.5 = 88 gpm

The greater fire demand will govern the determination of pipe sizes.

Example C

<u>Installation</u>: Permanent ordnance depot

<u>Authorized population</u>: 1,500 employees in one 8-hour shift--living off post. 150 military, 100 civilian on post.

<u>Industrial demand</u>: 900 gpm (cannot be reduced during fire)

<u>Water source</u>: Wells on post, 350 gpm yield

<u>Required demand and fire flow</u>:

Capacity factor: 1.5

Effective population:

Resident military	150
Resident civilian	100
Off-post employees, 1500 x 0.33	500
Total effective population	750

Design population: 750 x 1.5 = 1,125

Per capita allowance: 150 gallons per day

Daily domestic demand: 1.125 x 150 = 168,750 gallons

Industrial demand: 900 x 60 x 8 = 432,000 gallons

Total daily demand: 600,750 = 417 gallons per minute

Peak demand: The average domestic demand in this case is based on the assumption that the 1,500 employees living off the post and the 150 military and 100 civilians living on the post will use 50 gallons per capita during an 8-hour period. Applying the capacity factor, the total domestic demand during this 8-hour period will be 131,250 gallons or 273 gallons per minute. The peak demand will be 273 x 2.5 plus 900 industrial demand = 1,583 gpm.

Fire flow: 4,000 gpm for 4 hours

<u>Well requirements</u>:

Total well yield: based on supplying daily demand in 16 hours operation:

$$\frac{600,750}{16 \times 60} = 625 \text{ gpm}$$

Two wells required.

<u>Minimum pump requirements</u>:

One 350 gpm electric-motor-driven

One 350 gpm dual-drive pump

<u>Storage requirements</u>:

Fifty percent of domestic daily demand + 100 percent of unreducible daily industrial demands:

$$\frac{168,750}{2} + 432,000 = 516,375 \text{ gallons}$$

<u>Fire demand</u>:

$$\frac{(4,000 + 273 + 900)}{2} \times 60 \times 4 = 1,208,880 \text{ gallons}$$

Fifty percent of daily domestic demand + 100 percent of daily industrial demand + fire demand - water available in 24 hours through dual-drive pump-equipped well: 516,375 + 1,208,880 - (350 x 60 x 24) = 1,221,255 gallons. Where elevated storage is not objected to by the using service, the tank should have a minimum capacity of 75,000 gallons for initial sprinkler demand. In this example it is assumed the wells discharge directly into the distribution system. The average daily demand during the 8-hour work shift is 1,173 gpm. Since the wells produce only 700 gpm, 473 gpm for 8 hours or a total of 227,040 gallons plus 75,000 gallons for sprinkler demand or 302,040 gallons would be required in elevated storage. A 300,000 gallon elevated tank would be satisfactory. The 4-hour fire demand will be supplied by a 1,000,000-gallon ground-storage reservoir with necessary fire pumps. The capacity of the elevated tank discussed above can be reduced if the size of the ground-storage reservoir is increased accordingly with booster pumps provided to maintain the high water level in the elevated tank under peak domestic and industrial demand.

Water main sizes: The fire flow requirements will govern the size of mains in this case. The industrial demand must be supplied at a residual pressure of at least 30 psi although pressures in other parts of the post may drop to 10 psi during a 4,000 gpm fire demand. At the sprinklered buildings the pressure must be adequate for the highest sprinklers during a 2,000 gpm fire flow.

It should be noted that the calculations in the preceding examples have been set up to illustrate procedures in determining approximate capacities of various components of water-supply systems at Army and Air Force installations. For those not familiar with the US Army Technical Manuals (TM) or the Air Force Manuals (AFM), these manuals are a joint effort published by the Departments of the Army and the Air Force.

b. Sources of Water

When possible, the military utilizes conventional sources of water including existing municipal systems, surface waters, and ground waters. The selection of a water source depends on the quantity of water required, the accessibility of the source, the type of source, and the type of water purification equipment required. If water is readily available and sources are free from unusual impurities, the order of preference in the selection of sources is as follows (Ref. 11):

1. Public water supplies

2. Existing wells or springs

3. Surface water

4. To-be-drilled wells

Some examples of Air Force supplies are

1. Kirtland Air Force Base, New Mexico, has its own deep water wells which supply its needs 95 percent of the time. During the summer months when irrigation, lawn sprinklers, air conditioners, and evaporative coolers are used, Kirtland Air Force Base supplements the base supply with water from the City of Albuquerque.

2. Patrick Air Force Base, Florida, purchases the water for everything but irrigation from Orlando, which is 40 miles away. Water for sprinkling and irrigation is obtained from small shallow wells located on the base.

3. Hill Air Force Base, 30 miles from Salt Lake City, Utah, has a packaged 50,000 gpd vapor compression unit to supplement its water needs (Ref. 12).

When establishing a new base, an economic study is made of the available water supplies. Quality tests are taken from surface waters and municipal systems. For groundwater supplies, existing wells in the area are sampled and local well records are reviewed. Some base locations have all three sources available whereas others are not so fortunate. Where multiple sources are available the most economical is used. If a city is willing to sell water and the quality is approved, that source usually proves to be the most economical.

c. Water Quality

The United States Public Health Service Standards are the most commonly used guide to drinking-water quality and are used throughout the Department of Defense. In April 1968, the Federal Water Pollution Control Administration (FWPCA) published a report titled Water Quality Criteria. A table of surface water criteria for public supplies is included and is much more comprehensive than that of the USPHS table of water impurities. Table 4 (Refs. 13, 14) is a comparison of the two standards.

The Pacific Air Force (PACAF) Regulation No. 161-1, dated 4 March 1968, states that the standards to be used for evaluating the safety and quality of all military operated or purchased base drinking water supplies, regardless of geographic locations, are the "Public Health Service Drinking Water Standards - 1962." In foreign countries the comparable standards applicable to public drinking-water supplies are the "International Standards for Drinking-Water," World Health Organization, Geneva, 1963.

Air Force Manual 160-4 & 4a, "Sanitary Control of Water Supplies for Fixed Installation," places on the Surgeon General the responsibility of exercising sanitary supervision over water supplies from the source to the consumer. The manual briefly describes (1) the various type water sources and the treatment of these waters, (2) the chlorination and disinfection policies, (3) procedures for laboratory examinations of water supplies, and (4) methods of collection of water samples for bacteriological examinations. The following minimum requirements of water samples for bacteriological examinations are specified by this manual:

Table 4

USPHS and FWPCA Limits of Water Impurities

Constituent or characteristic	FWPCA	USPHS
Physical:		
Color (color units)	75	15
Odor	Narrative	--
Temperature	Narrative	--
Turbidity	Narrative	10 ppm (silica scale)
Microbiological:		
Coliform organisms	10,000/100 ml	See Para. 3.2
Fecal coliforms	2,000/100 ml	1962, Drinking Water Standards
Inorganic chemicals:		
Alkalinity	Narrative	--
Ammonia	0.5 (as N)	--
Arsenic	0.05 ppm	0.05 ppm
Barium	1.0 ppm	1.0 ppm
Boron	1.0 ppm	--
Cadmium	0.01 ppm	0.01 ppm
Chloride	250 ppm	250 ppm
Chromium, hexavalent	0.05 ppm	0.05 ppm
Copper	1.0 ppm	1.0 ppm
Dissolved oxygen	4 (monthly mean)	--
Fluoride	Narrative	1.5 ppm
Hardness	Narrative	--
Iron (filterable)	0.3 ppm	0.3 ppm
Lead	0.05 ppm	0.05 ppm
Manganese (filterable)	0.05 ppm	0.05 ppm
Nitrates plus nitrites	10 ppm (as N)	10 ppm (as N)
pH (range)	6.0-8.5	--
Phosphorus	Narrative	--
Selenium	0.01 ppm	0.01 ppm
Silver	0.05 ppm	0.05 ppm
Sulfate	250 ppm	250 ppm
Total dissolved solids	500 ppm	500 ppm
Uranyl ion	5 ppm	--
Zinc	5 ppm	5 ppm
Organic chemicals:		
Carbon chloroform extract	0.15 ppm	0.2 ppm
Cyanide	0.2 ppm	0.01 ppm
Methylene blue active substances	0.5 ppm	--
Oil and grease	Virtually absent	--

Table 4 (cont.)

Constituent or characteristic	FWPCA	USPHS
Pesticides:		
Aldrin	0.017 ppm	--
Chlordane	0.003 ppm	--
DDT	0.042 ppm	--
Dieldrin	0.017 ppm	--
Endrin	0.001 ppm	--
Heptachlor	0.018 ppm	--
Heptachlor epoxide	0.018 ppm	--
Lindane	0.056 ppm	--
Methoxychlor	0.035 ppm	--
Organic phosphates plus carbamates	0.1 ppm	--
Toxaphene	0.005 ppm	--
Herbicides:		
2,4-D plus 2,4,5-T, plus 2,4,5-TP	0.1 ppm	--
Phenols	0.001 ppm	0.001 ppm
Radioactivity:		
Gross beta	1,000 pc/1*	--
Radium - 226	3.0 pc/1	3.0 pc/1
Strontium - 90	10.0 pc/1	10.0 pc/1

*Picocuries/liter.

The minimum number of samples that will be collected at each installation is as follows:

(1) A minimum of eight samples per month regardless of the strength of the installation.

(2) One sample per 1,000 persons per month, on all military installations with strengths in excess of 8,000.

(3) Samples collected will be pro-rated on a weekly basis at the selected sampling points. As an example, at a small installation, eight sampling points will be selected, and two of the samples taken at two of the points per week. Thus, in the course of four weeks the eight sampling points will be progressively covered (Ref. 15).

The usual sampling points are chosen as representative of principal places of water use and include dining halls, hospitals, barracks, and administrative areas.

d. Water Treatment

Water for most installations is held to potable quality found in the 1962 USPHS Standards. Air Force Manual 85-13 presents information on practical methods, procedures, and equipment for providing safe, potable water. Special emphasis is placed on correct operating procedures and a preventive maintenance program designed to prevent failure of service and avoid inefficient, uneconomical operation and maintenance of water supply facilities. The standards of operational maintenance practices and procedures are in accord with nationally accepted codes and standards (Ref. 16).

Air Force Manual 85-31 describes industrial water uses (excepting boiler water) common to Air Force installations, and presents instruction on treatment and testing of industrial water for the prevention and control of scale and corrosion. It discusses chemicals and related specifications, chemical feeders, testing and analytical procedures, and lists testing and analytical equipment. The manual also explains other aspects of the scale and corrosion prevention and control program for Air Force water-using equipment (Ref. 17). Air Force Manual 85-12 treats the subject of boiler water.

There are certain industrial water users on military installations that require a high quality water. Computer centers, laundries, hospitals, power plants, heating plants, dining halls, photographic laboratories, and science laboratories may require various degrees of water treatment above those required for drinking water. Specific examples of industrial water are boiler water (both steam and hot water plants); diesel engine jacket water; cooling water circulated through cooling towers, evaporative condensers, and evaporative coolers; chilled water for air conditioning; chilled brine for dehumidification and freezing; demineralized water for aircraft fuel; and demineralized water for large power amplification tube cooling (Ref. 17).

Whenever special-use buildings are constructed on an installation, special water treatment equipment necessary to remove deleterious material peculiar to the particular installation is included in the mechanical equipment for that building. Occasionally a laboratory will have need of a minimal amount of pure water which can be satisfied by a low-capacity (1 to 5 gph) water still that can be purchased as a laboratory item of equipment.

(1) Softening

Softening of water will depend usually on the type of installation. For permanent posts or bases, softening of the entire supply may be favorably considered if the hardness exceeds 200 ppm as equivalent $CaCO_3$ and the treatment facilities can economically be provided. For Army temporary and wartime construction and for Air Force Bases not in a permanent category, the entire supply is usually not softened unless the total hardness exceeds 300 ppm expressed as equivalent $CaCO_3$. It is not necessary to soften post water supply to a total hardness of less than 100 ppm. However, softening to less that 100 ppm is required for special purposes (Ref. 18). Some of these special purposes are

(a) Laundries. It is recommended that water softeners be installed to reduce hardness to zero. If the total hardness of the water exceeds 43 ppm a softener is installed.

(b) Boiler-Water Treatment. Depending upon local conditions the water may have to be softened by means of a cation exchanger. Satisfactory results have been obtained by utilizing sodium-hydrogen cation exchangers. Feed water may be produced by this means having practically any chemical content desired and could even approach distilled water purity. Using exchangers requires a thorough study of local conditions, water analysis, and economy before deciding what type of exchange material is to be used.

(c) Dining Halls. For protection of equipment and to ensure satisfactory dishwashing in large dining halls, water softeners may be justified to reduce total hardness of water to 43 ppm. Installation of water softeners in small dining halls, latrines, or bathhouses is not recommended.

(d) Hospitals. For hospital use, when the hardness is expressed as $CaCo_3$ exceeds 171 ppm the required proportion of water will be softened to zero hardness and blended with the required quantity of unsoftened water to give a resultant hardness of 51 ppm. When critical equipment requires water with a hardness of less than 51 ppm, softened water might be piped directly before it is blended. Small individual water softeners might be installed with critical equipment if necessary.

(2) Scale Prevention

Many waters when heated cause excessive scale and clogging of hot-water heaters, piping, and storage tanks. This scaling usually occurs in waters with a high calcium and magnesium carbonate content. If permitted to accumulate, the scale reduces efficiency of heating equipment and requires replacement of piping. Scaling is common with waters containing calcium in excess of 50 ppm as $CaCO_3$. Deposit of scale in hot-water heaters and piping can be controlled largely by the addition of nontoxic chemical compounds. In moderate corrosion with scale-forming conditions, experience indicates that a combined treatment with special phosphates and sodium silicate may be effective in protecting water heaters and piping. These chemicals when applied in small amounts may be expected to accomplish satisfactory results even though the water may contain as much as 300 ppm of bicarbonate alkalinity. The chemicals may be applied easily to well or pump-discharge lines by using small electric-motor-driven chemical-feed pumps actuated by the starting equipment controlling the well or booster pumps. Chemical-feeding equipment is not installed indiscriminately and is limited to projects using water that is definitely known to be scale forming (Ref. 18).

(3) Iron Removal

Treatment for iron removal or correction of "red water" difficulties is usually necessary for water supplies obtained from wells or other sources having an iron content in excess of 0.3 to 0.5 ppm. If the iron is present in a soluble or ferrous state, it may become oxidized to the ferric state if the water is exposed to the air or if air is drawn into the water system. A red precipitate will then be formed that will cause deposits in hot-water tanks, staining of plumbing fixtures, and staining of laundry, and may cause objectionable taste and promote the growth of iron bacteria in water mains with resultant clogging and reduction of carrying capacity.

Treatment in some circumstances can be accomplished with sodium hexametaphosphates. Operating experience indicates that for waters containing not more than 3.0 ppm of iron, the iron may be stabilized and kept in solution by feeding sodium hexametaphosphate. For maximum effectiveness, the chemical is introduced before the water has become exposed to the air. In treatment of well waters the hexametaphosphate is usually introduced into the suction side of the well pump. The customary dosage varies with the amount of iron present with minimum treatment usually at the rate of 1.0 ppm of sodium hexametaphosphate for each 1 ppm of iron.

When the iron content exceeds 3.0 ppm, a conventional iron-removal plant with aeration, lime treatment, and sedimentation contact beds or filtration may be necessary. Some well water supplies having a high iron content when the wells are first completed show a reduced iron content under continuous pumping. This emphasizes the need to determine true quality of well supplies before planning treatment works.

(4) Corrosion

Water is a solvent, and since iron is slightly soluble in water it is possible under certain conditions to have serious corrosion not only of the water lines in the water-distribution system but also in house plumbing, hot-water heaters, and storage tanks. Corrosion difficulties are usually associated with waters having a low alkalinity, low pH value, high free CO_2 and free oxygen, with low total mineral content. The action of corrosive water on ferrous materials will cause "red water" difficulties, reduction in carrying capacity of mains, and rapid deterioration of hot-water storage tanks. The lower the pH value of the water, the more rapid will be the rate of corrosion (Ref. 19). Water with a pH value of 9 will dissolve only traces of iron whereas water with a pH value of 6 will dissolve appreciable quantities of iron.

Because the chemical properties of waters vary widely, the methods and types of treatment to prevent corrosion vary. Treatment to control corrosion is installed at bases where a study of the water analysis, or experience, shows conclusively that the water will be definitely corrosive. Certain waters not saturated with calcium carbonate may not be corrosive if dissolved oxygen is absent. Corrosion may be reduced by adjusting the chemical balance of the water to a condition approaching calcium carbonate saturation. It can be said that the chemical balance is the stabilization or an adjustment of the pH and alkalinity of a water to its calcium carbonate saturation-equilibrium value. At this point the water will neither dissolve nor deposit calcium carbonate, and protective coatings of this substance on the interior walls of pipes are stabilized. Since the equilibrium point shifts with temperature it is not possible to attain a perfect balance for both cold-water and hot-water systems at the same time.

W. F. Langelier (Ref. 8) develcped equations in which the pH associated with calcium carbonate equilibrium can be calculated. It can also be determined by laboratory tests. Solution of the Langelier equations with the variables pH, temperature, dissolved solids, and calcium carbonate produces the Langelier Index which sometimes is called the Stability Index or Saturation Index. Figure 3 is included to illustrate the most desirable pH range of industrial waters for different conditions and applications (Ref. 19).

The Air Force Manual AFM 88-10, Chapter 3 (Ref. 19) states that the chemical balance may be secured by adding lime, soda ash, or caustic sode to nonsaturated waters. Lime is most effective when the calcium content of the water is less than 25 ppm. Since hydroxide alkalinity does not contribute to saturation of the water by calcium carbonate, the water must have sufficient CO_2 and bicarbonate alkalinity to convert only added lime to calcium carbonate. Therefore, if hydrated lime, $Ca(OH)_2$, is used, the dosage in ppm of pure chemical should not exceed the sum of 1.68 times the parts per million of CO_2 plus 0.74 times the ppm of bicarbonate alkalinity, expressed as $CaCO_3$. Any lime added in excess of these quantities has the effect of adding lime only. If lime sulphate is present, it may be converted to calcium carbonate by adding soda ash, Na_2CO_3, which will assist in building up the calcium carbonate concentration. Caustic soda is of limited value in correcting corrosion because of the fact that it raises the pH value and alkalinity only and does not add to the concentration of calcium carbonate.

In the treatment of surface waters, if alum is used to coagulate surface water prior to filtration, the filtered water may be corrosive unless it is treated for pH correction. This may be accomplished either by feeding lime

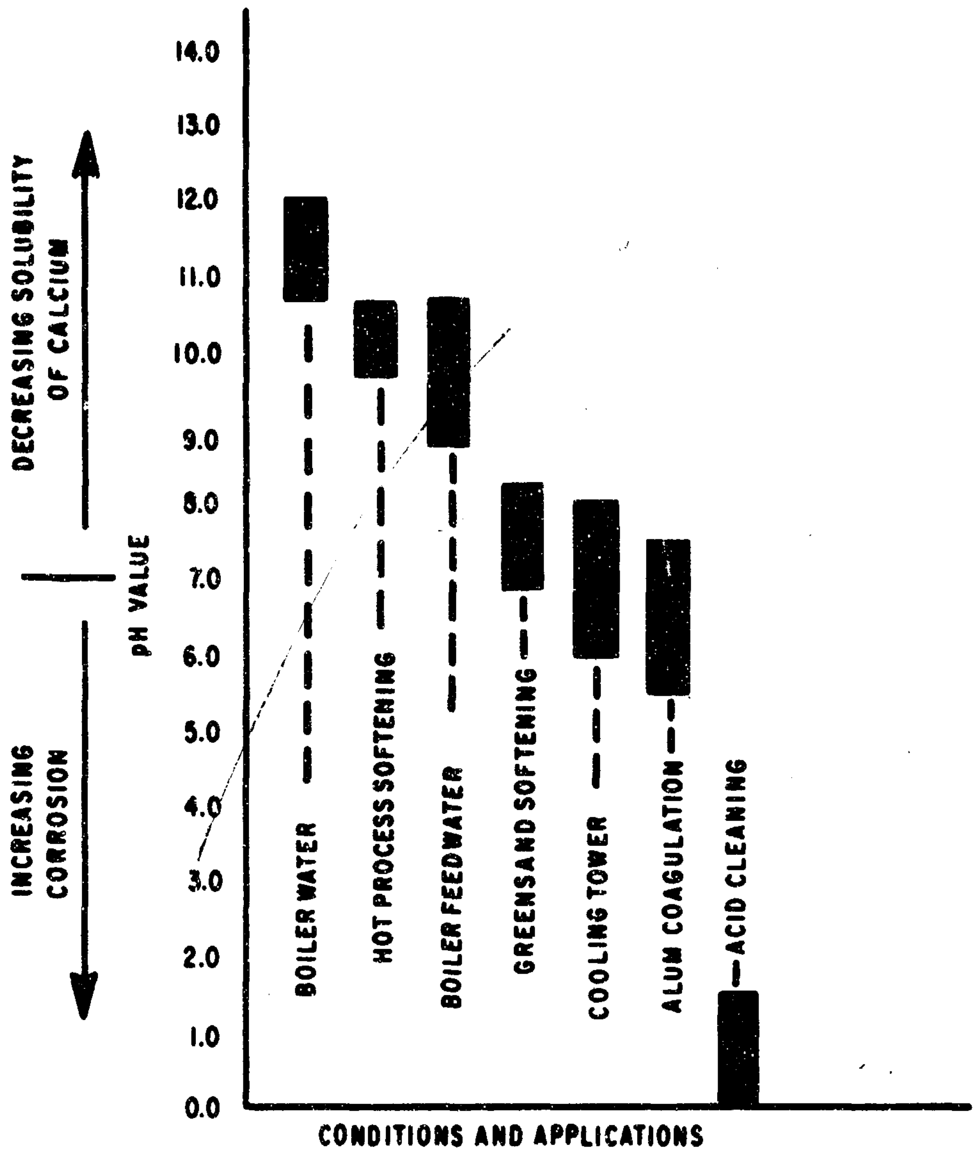


Figure 3. Desirable pH Ranges

with the alum or by applying lime to the filter effluent. Treatment of the filter effluent is necessary when coagulation at low pH is required for color removal. The chemical may be applied to the clear well at a point that will permit thorough mixing before the water is pumped into the distribution system.

Where treatment of well waters is required, the water from all wells may be collected in a central ground reservoir to permit application of the chemical. If the calcium content is low, lime treatment is effective for corrosion control. If the calcium content and pH value will permit, the application of soda ash or sodium silicate is satisfactory for corrosion control.

(5) Chlorination

Adequate and effective chlorination of water supplies is considered necessary to protect the health of personnel by preventing the spread of water-borne diseases. To prevent total absence of chlorination caused by equipment breakdown, duplicate chlorination equipment is generally provided in water supply systems.

Facilities for maintaining a chlorine residual of not less than 0.4 ppm in the active parts of the potable water distribution system is provided at all posts and bases. This requirement applies to both well and surface water supplies. Facilities for chlorination of water obtained from municipal or privately owned sources are provided where the water has not been chlorinated by the municipality or utility company prior to delivery to the post, or where sanitary, physical, or operating defects in the public water-supply system or other special hazards are known to exist, or where water of a uniformly satisfactory quality, as evidenced by the results of bacteriological examinations, cannot be obtained without rechlorination (Ref. 18).

The point of chlorine application should provide not less than a 30-minute contact period except in the case of suitable ground water supplies where additional reservoirs are required. In general, the chlorine dosage will be sufficient to maintain a chlorine residual of not less than 0.4 ppm in the active parts of the distribution systems. This requirement is considered mandatory except under the following two conditions (1) where the presence of iron, manganese, or other chlorine-consuming compounds makes it impractical to maintain a chlorine residual of 0.4 ppm in the active parts of the distribution system, provided these compounds are not of such character or in such an amount as to prevent effective initial chlorination; and (2) where the water is stored in properly protected distribution reservoirs following chlorination. In these cases the chlorine treatment should be sufficient to ensure a potable water supply as evidenced by satisfactory bacteriological samples. In the event the presence of mineral or organic compounds makes it impossible to produce a water of acceptable quality, treatment for the removal of such compounds is required (Ref. 18).

Chlorinating equipment may be either gas type or hypochlorite type. Hypochlorite-feeding equipment is recommended for Air Force and Army installations that use less than 500,000 gallons of water per day.

In new construction there is a danger of contamination resulting from the introduction of harmful bacteria during construction. To ensure a safe supply of water, the water mains, wells, filters, storage tanks, and other units of the water supply system are thoroughly disinfected. The Army Manual EM 1110-345-222, Appendix I furnishes the various types of chlorine compounds that may be used, the dosage calculations, and methods for disinfecting a newly constructed system (Ref. 20).

A great amount of work has been accomplished in the past decade to develop more effective and efficient methods of removing impurities from natural waters. Pressman (Ref. 21) by using a polyelectrolyte coagulant consisting of a poly-quaternary compound together with the Army 3000 gph treatment unit on Potomac River water found that the floc produced was a loose, readily settleable mud. The mud reached a level of only 2 feet, measured during operation, and even after several days of operation with sludge drawoff. This is in comparison with a lighter gelatinous hydroxide floc produced in operation with a metal salt and the same equipment. A floc bed in the same equipment utilizing a metal coagulant is usually built up in the coagulation basin to the drawoff level, 4 feet from the bottom within a few hours. Based upon his studies, Pressman concluded that a cationic polyelectrolyte of the poly-quaternary ammonium type can serve effectively as a prime coagulant, replacing a metal salt, for treatment of natural water in a solids-contact clarifier and pressure-diatomite filter system. He warns that, because of the numerous variations in the character of different natural waters, predictions as to how cationic polyelectrolytes will function in waters of appreciably different character than those studies must be made with reservation.

Experiments and studies have been made utilizing various agents, such as: alum, iron salts to polymers to produce maximum particle removal efficiently in waters of different character makeup. Table 5 is included for information on the various coagulant aids approved by the USPHS (Ref. 22).

Work is continuing on the use of iodine as a disinfectant for water. Chang and Morris at Harvard produced studies that led to the development of Globaline tablets used during World War II for disinfection of small or individual water supplies of the US Army. The University of Florida is continuing studies on the effectiveness of iodine as a disinfectant for swimming pools. In 1963, this program was expanded using two water systems serving three prisons at Lowell, Florida, to determine its effectiveness in disinfection of public water supplies and physoilogical effects on human beings. The experiment has run more than three years, and more than 2,000 samples of untreated and iodinated water have been collected from the water systems at the three institutions. Less than 1 percent of the treated samples examined showed the presence of coliform organisms, although about 95 percent of all samples from one of the wells have contained coliform organisms as well as from two other wells on occasion. There is no evidence in the prison inmates that long-term use of an iodinated water supply has been deleterious to health (Ref. 23).

Laubusch (Ref. 24) in a series of articles discusses hypochlorite-chlorine materials and their use in environmental sanitation control. The subjects he reviews include: the nature, manufacture, storage, and handling of hypochloites; principles fundamental to hypochlorination processes, especially as they relate to municipal water supply, swimming pool and waste treatment practices; and hypochlorite feeding and dosage control equipment that facilitates their safe and effective application.

(6) Fluoridation

Henry and Haskett (Ref. 25) have reviewed the chemical compounds used in the practice of fluoridation; a graphical method that can be applied to determine the quantity and cost of each chemical compound required to impart to the water the concentration of fluoride recommended as being optimum; the mechanics involved in applying the calculated quantity of chemical compound; the type of equipment that is required to provide the mechanics for applying the calculated quantity of chemical compound; and the factors involved in the selection of the particular compound that would present the most economical approach to applied fluoridation for consistency.

Table 5

Coagulant Aids for Potable-Water Treatment

Manufacturer	Product	Maximum concentration recommended by manufacturer (ppm)
Allyn Chemical Company	Claron	1.5
	Claron #207	2
American Cyanamid Co.	Superfloc 16	1
	Magnifloc 990	1
	Superfloc 20	1
	Magnifloc 971-N	1
	Superfloc 84	1
	Magnifloc 985-N	1
Betz Laboratories, Inc.	Poly-Floc 4D	25
The Burtonite Co.	Burtonite #78	5
Calgon Corporation	Coagulant Aids	
	#2	1
	#7	0.75
	#11	4
	#18	15
	#801	6
	#952	3
	#961	5
	Coagulant Aid 233	1
	Coagulant Aid 243	1
	Coagulant Aid 253	1
Commercial Chemical Products, Inc.	Coagulant Aid-Speedifloc #1	10
Dearborn Chemical Co.	Aquafloc 422	1
The Dow Chemical Co.	Separan NP10 Potable Water Grade	1
	Purifloc N17	1
	Separan AP 30	1
	Purifloc A22	1
Drew Chemical Corp.	Drewfloc No. 3 (formerly Alchem Coagu-Aid #261	3
	Drewfloc 21	5
	Alchem Coagu-Aid 252	5
	Alchem Coagu-Aid 265	1
	Drewfloc 265	1:8 alum
	Drewfloc 1	0.5:10 lime*

Table 5 (cont.)

Manufacturer	Product	Maximum concentration recommended by manufacturer (ppm)
Electric Chemical Co.	Ecco Suspension Catalyzer #146	3.5
Garratt-Callhan	Coagulant Aid 70	2
	Coagulant Aid 72	2
General Mills, Inc.	SuperCol Guar Gum	10
Hercules Powder Co.	Carboxmethylcellulose	1
	Reten A-1	1
	Reten A-5	1
Frank Herzl Corp.	Perfectamyl A5114/2	10
Illinois Water Treatment Co.	Illco IFA 313	10
Ionac Chemical Co.	Ionac Wisprofloc 20	5
	Ionac Wisprofloc 75	5
Kelco Company	Kelgin W	2
	Kelcosol	2
Key Chemicals, Inc.	Key-Floc-W	25
Metalene Chemical Co.	Metalene Coagulant P-6	5
Nalco Chemical	Nalcolyte #110	5
	Nalco 671	1
Narvon Mines Ltd.	Sink-Floc Z-3 & AZ-3	10
	Sink-Floc Z-4 & AZ-4	10
National Starch and Chemical Corp.	Floc Aid 1038	5
	Floc Aid 1063	5
North American Mogul Products Co.	Mogul CO-982	1.5
	Mogul CO-980	2
	Mogul CO-983	1
O'Brien Industries Inc.	O'B-Floc	10
Stein, Hall and Co., Inc.	Hallmark 81	1
	MRL-19	1
	MRL-13	1
	MRL-14	1
	MRL-22A	1
	Jaguar	0.5
W. E. Zimmie, Inc.	Zimmite	1

*One part of Drewfloc to 8 parts of alum when used simply as an aid in alum coagulation and 0.5 ppm of Drewfloc to 10 ppm of lime when used in connection with lime softening.

Investigations for military application of the newer developments in water purification should be made and the methods included in the various technical manuals. Because newer treatment techniques are not found in the services technical manuals does not mean that these techniques have not been accepted nor that the service laboratories have not investigated them. Periodically the manuals are updated and eventually completely republished.

e. Water Storage and Distribution

The technical manual AFM 88-10, Chapters 4 and 5 prescribes the procedures to be followed in selecting storage vessels, designing adequate and economical water-distribution systems, and in selecting the type of materials to be used. It determines the maximum and minimum pressures required or permitted in various parts of the system, spacing of fire hydrants and control valves, and cleaning and lining existing water lines (Refs. 26, 27).

In planning the water-distribution system for a military installation the most important consideration is the topography and location of the storage vessels. The type of distribution system used is dependent upon this consideration. Two systems are used in Army and Air Force construction: the direct-pressure system which is considered only where the military use or other special requirements will not permit the utilization of elevated storage tanks, and the balanced-pressure system. The direct-pressure system utilizes booster pumps which maintain a minimum constant pressure, and pressurized tanks. When the direct-pressure system is used EM 1110-345-165 or AFM 88-8 should be consulted for criteria to be followed in determining allowable minimum pressures, size and number of pumps, and size of pneumatic tanks. The balanced-pressure system is a gravity-feed system utilizing high-level storage either in surface reservoirs located on high ground or in elevated tanks.

For water-distribution systems, consideration should also be given to areas of peak domestic demand, fire demand, and special demands for water, together with the source of water. The system will be as simple as possible and at the same time provide adequate service for maximum domestic, industrial, and special requirements and fire protection.

Water main sizes are dependent upon fire demand, special requirements, and the peak domestic demand. In designing a system, special consideration must be given so that pressures in high-ground areas are not drawn down below 10 pounds per square inch during fire demands in lower areas. Fire hydrant runs are 6 inches in diameter, therefore, the minimum main size is 6 inches (Ref. 27).

Normally dual water systems are not permitted, that is, a safe system for domestic use and a contaminated or questionable supply for irrigation, cooling, sanitary or fire protection. Approval for the use of a dual system for the various services must be obtained from the respective Chief of Engineer's Office and the Surgeon General's Office. If approval is granted, there are to be no interconnections between the two systems.

(1) Water Pressure

Water pressures in the distribution system should be in the range of 40 to 75 psi. In low areas where pressures approach 100 psi, pressure reducing valves on feeder mains to those areas are installed to maintain the 40 to 75 psi pressure. Minimum pressures at ground elevation in high areas are 30 psi under peak flow conditions or sufficient to meet fire-flow requirements (Ref. 26).

(2) Storage Vessels

When designing storage vessels, total storage capacity, including elevated and ground storage is provided in an amount not less that the greatest of the following items (Ref. 27):

1. Fifty percent of the total daily domestic consumption plus all industrial requirements.
2. The fire demand. This amount may be reduced by the amount of water available during the period of the fire demand under emergency conditions. Where some water is available under energency conditions, the amounts given in the second and third items must be recalculated before a firm determination can be made as to which of the three items is the greatest.
3. The sum of the first and second items above. This amount may be reduced by the amount of water available in 24 hours under emergency conditions.

In selecting the type of storage vessel to use, some high-level storage should be provided at all projects except where this type of storage is not desirable for military reasons. For projects with a population of 10,000 or less, consideration should be given to providing all high-level storage. For larger installations, at least 50 percent of the total required storage should be high-level storage.

When locating storage vessels, elevated vessels are situated near load centers to equalize pressures in the distribution system as far as practicable. In large areas, such as a division or similar area, the total storage will, if feasible, be provided in at least two vessels located in separate areas. Siting of tanks from the standpoint of hazard to aircraft at Air Force stations is approved by Headquarters, US Air Force, or the Air Force Installations Representative. Glide angles, clearances, etc., must be considered for Army installations also if located near Air Force bases or commercial airports.

Whenever possible standard designs for water storage vessels should be used. Storage vessels are provided with covers to prevent algae growth and possible contamination. Screens are used on all vents and overflows. Manholes are watertight and designed to prevent entrance of rain or surface water. To prevent cross connections, drains are not to be connected to sanitary sewers.

f. Current Specifications

The following specifications are US Army, Corps of Engineers specifications and were extracted from Air Force Regulation 0-4, dated 13 March 1968 (Ref. 28).

CE-500	14 May 1965	Excavation, Trenching & Backfilling for Utilities Systems
	31 May 1965	Change 1
CE-501	15 June 1964	Water Lines; Supply Line & Distribution Systems
	15 October 1964	Change 1
CE-502	29 April 1966	Chlorine-Feeding Machines (Fully Automatic, Semi-automatic, & Non-automatic)
CE-503	30 December 1958	Hypochlorite-Feeding Machines
CE-504.01	15 June 1958	Pumps; Water, Centrifugal, Horizontal
CE-504.02	10 November 1966	Pumps; Water, Vertical Turbine
CE-505	7 January 1955	Elevated Steel Water Tanks
	16 May 1956	Change 1
	31 May 1963	Change 3
CE-506	31 January 1955	Steel Standpipes & Ground Storage Reservoirs w/Changes 1-4
	31 May 1963	Change 5
CE-507	1 June 1958	Cathodic Protection System for Steel Water Tanks
CE-508	15 July 1965	Water Softeners, Cation-Exchange (Sodium Cycle)

CE-E-44-3	30 November 1962	Excavation, Trenching & Backfilling (Utilities System)
CE-E-73-1	14 June 1963	Water Supply Lines & Distribution Systems
BB-C-120		Chlorine, Technical: Liquid
O-C-114		Calcium Hypochlorite, Technical & Chlorinated Lime, Technical
O-S-602		Sodium Hypochlorite Solution

g. Personnel

In the professional ranks, officer category, there is no Sanitary Engineer title. An officer trained in the discipline of sanitary engineering can through experience gained on the job earn the title of either Aerospace Facilities Engineer, AFSC 55XX series or Bio-environmental Engineer, AFSC 91XX series. (AFSC means Air Force Specialty Code.) Civilian Air Force professional employees do not have an AFSC, as such, but may be classified in organizational bookkeeping to simplify job descriptions.

A young officer, just finished school and upon entering duty for the first time, must serve an internship in his particular AFSC. The internship for Bio-environmental Engineers is 18 months, while the Aerospace Facility Engineers must serve 2 years in that capacity to be fully qualified in their AFSC. A civilian counterpart must have had experience to be hired to fill the various General Service (GS) grade level positions.

To enter the category of Aerospace Facilities Engineer an officer must have obtained a bachelor's degree in any one of the engineering disciplines from an approved engineering school. The Bio-environmental Engineer must have a bachelor's degree in civil, chemical, sanitary, electrical, or mechanical engineering and possess a knowledge of biological techniques. Completion of a master's degree program in industrial hygiene, health physics, sanitary engineering, air-hygiene or radiological health engineering, biotechnology or bioengineering at a recognized institute may be substituted for the 18-month experience requirement (Ref. 29).

In the technician level for enlisted men, basic technical courses in preventive medicine and water and waste processing at one of the Air Force technical schools provide the airmen a start in their career field. To qualify for these schools and specialty the Preventive Medicine Specialist must possess high-school level courses in anatomy, physiology, biology, and chemistry (Ref. 30). The Water and Waste Processing Specialist must have completed high school with courses in basic physics, biology, and chemistry; blueprint reading is desirable (Ref. 31). For civilians in the sub-professional level, experience proven by an entry examination is required.

On-the-job-training (OJT) is provided for the enlisted personnel. This consists of prepared study courses and actual work experinece. Service correspondence courses for home study are also available to the airmen. The OJT is provided for the men by their supervisors with assistance of the installation surgeon. Personnel are encouraged to attend conferences and courses provided by state, county, or city health departments and professional association meetings and to visit plants at other installations and municipalities. Advanced service courses are also available to the personnel (Ref. 16). Many civilian employees in this professional level received their initial training while in the service.

Summary descriptions of the duties for both levels are as follows:

1. Aerospace Facilities Engineer. Applies engineering knowledge and techniques in design, construction, maintenance, and operation of base sanitary systems; maintains records and logs; supervises routine sampling and testing.

2. Bio-environmental Engineer. Applies engineering and biological knowledge and techniques for health protection; participates in development of procedures, techniques, and equipment; conducts or supervises engineering services; and participates in medical facility programs.

3. Water and Waste Specialist. Operates, maintains, and repairs water supply, water processing, and waste processing plants and systems.

4. Preventive Medicine Specialist. Performs specialized environmental analyses, makes periodic environmental health survey, develops epidemiological data, and assists in biomedical engineering evaluations.

2. SPECIAL INSTALLATIONS

a. Discussion

Remote, combat, friendly nations, polar regions, and island installations require nonconventional water supplies and systems. Most of these systems deviate from the conventional systems and many require special consideration for standards and regulations.

Limited warfare has the same technological problems as full-scale war. As the technology of arms, aircraft, medical-aid, and armored vehicles has advanced so has the technology of water treatment. The Air Force, Army, and Navy have made considerable strides in providing equipment through their research and development projects to increase the quantity and quality of water in special operations.

b. Quantity of Water

The quantity of water per capita varies upon the area and conditions under which the troops are operating. The supply of water must be sufficient to provide for the maximum amount of work that troops may be doing. Hard-working units, such as engineers, marching men, and labor battalions, may require as much as three gallons of drinking water per man per day, expecially in tropical or desert environments. As a guide for planning purposes only, the Army Field Manual FM 21-10, presents the information in Table 6 for a man's water requirements in quarts per day (Ref. 11).

Table 6

Tropical or Desert Water Requirements

Activity	Duties	Moderate desert or tropical* (quarts)	Severe desert or tropical** (quarts)
Light	Desk work, guard and KP duty	6	10
Moderate	Route march on level, tank operation	7	11
Heavy	Forced marches, stevedoring, entrenching	9	13

*Desert: Air temperature below 105°F Tropical: Air temperature below 85°F
**Desert: Air temperature above 105°F Tropical: Air temperature above 85°F

The Army per capita allowances in gallons per day per man in a theater of operation differ considerably from those in a noncombatant zone. Table 7 (Ref. 32), illustrates combat troop allowances, and is considered the absolute minimum.

Noncombatant area installations in Europe, in areas of Asia and the Middle East, in parts of Africa, and on islands try to maintain mainland allowances of 150 gallons per man per day, plus any industrial usage and fire fighting requirements.

Table 7

Per Capita Water Allowance in a Theater of Operation

Description	Allowances (gal/man/day)	Remarks
Combat	1/2	Absolute minimum, drinking only, not over three-day supply
	1	A small additional allowance for cooking
March or bivouac	2	Minimum for drinking, cooking, washing mess utensiles, hands, and laundry
	5	Allows in addition some bathing and laundry
Temporary camp	5	Minimum; see preceding
	15	Includes bathing and water-borne sewage on an economy basis
Semi-permanent camp	30-60	
Cantonment (theater)	60-100	
Hospital	10	Per bed minimum
	50	Per bed; allows for water-borne sewage
Potable Water for Army in the Field		
Personal use	5	Includes: drinking, cooking, personal hygiene; may be reduced in emergencies for not more than 3 days
Hospital use		Same as for post above
Nonpotable Water for Army in the Field		
Laundry	18	
Showers	10	
Vehicles (radiators)	1 gal/vehicle/day	
		Additional required for decontamination of vehicles and equipment during chemical-biological-radiological warfare

In the polar regions harvesting of usable water is a difficult problem. The quantities of water required depend on the degree of development of the station. Where flush toilets and normal bathing and laundry facilities are provided, the domestic consumption is in the range of 30 to 50 gallons per man per day. Efforts are made to reduce the water demand by installing self-closing faucets and water closets having a minimum demand of 1 to 3 gallons per flush. When flush toilets are not provided, 10 to 20 gpd is sufficient (Ref. 33).

c. Sources of Water

Selection of a water source depends on the quantity of water required, the accessibility of the source, the type of the source, and the type of water purification on hand. If water is readily available and the sources are free from unusual impurities, the order of preference in the selection of sources is as follows:

1. Public water supplies
2. Existing wells or springs
3. Surface water supplies
4. Wells drilled
5. Distilled sea water
6. Ice or snow
7. Rain
8. Muskeg areas (Ref. 34).

The selection of a water source is normally preceded by a ground reconnaissance. If time permits a photographic air reconnaissance is made which will disclose changes in terrain not usually shown on regular or military maps. If a helicopter is used, the air and ground reconnaissance can be conducted simultaneously. Under combat conditions reconnoitering in enemy-held territory can be extremely hazardous. The ground reconnaissance team, in any case, must estimate the quantity of the water supply, test for the quality of the supply, and locate routes of communication because a satisfactory water point must be accessible to vehicles and personnel. Figure 4 defines a typical water point. The team should also note in their report whether the water point can be used as naturally found or whether it must be developed and by what method, such as an impounding dam, baffle dam to protect the inlet strainer, or a float-surface intake.

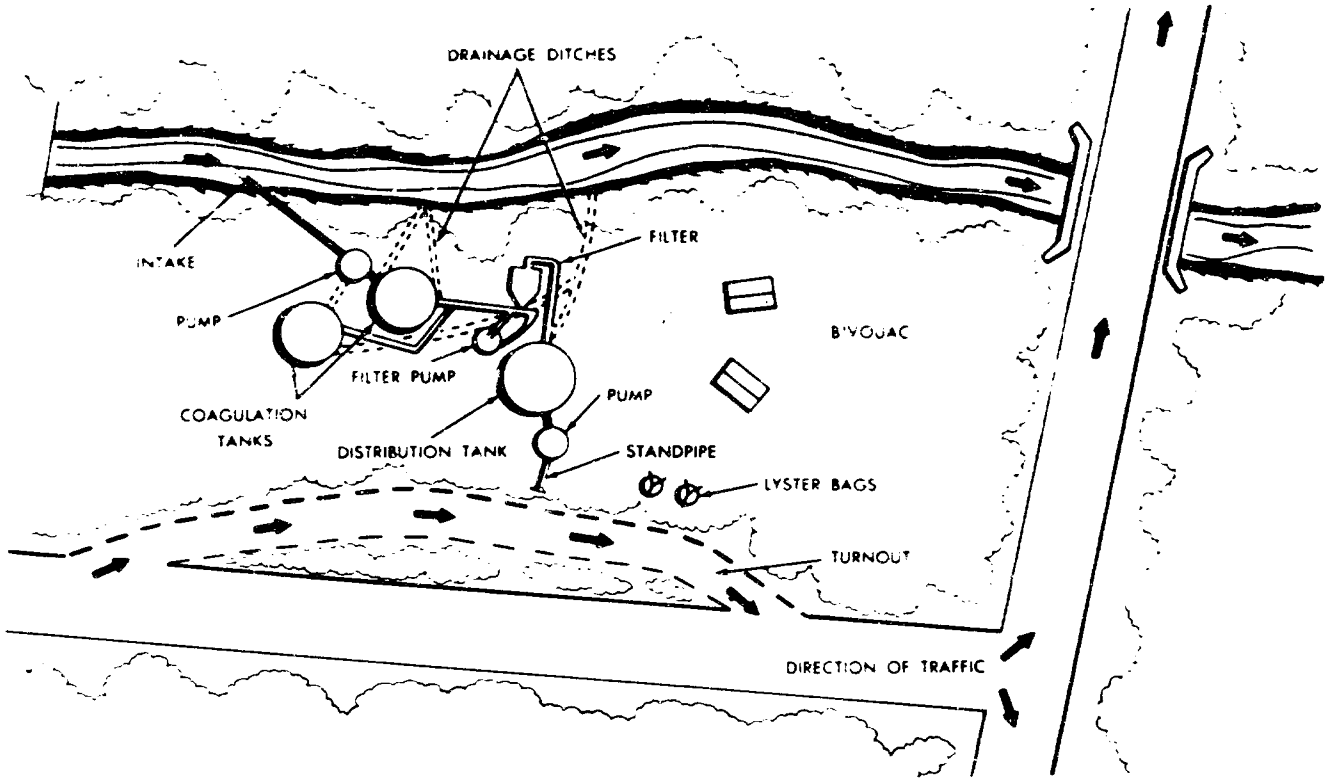


Figure 4. Typical Field Water Point

Water is obtained from snow and ice by a number of methods. One method uses the Rodriguez system of reclaiming heat from a diesel generator engine exhaust gas and coolant. By a heat exchange system, a large reservoir is formed by melting the ice or snow (see figure 5). The water is retained within the reservoir and then pumped out with the help of a submersible pump (Ref. 35). Another method is a hot-water melter which can produce water at a rate of 100 gallons per hour (Ref. 35). At Point Barrow, Alaska, the Navy used an Aeroil "Flash-Guard Heet-Master," 55-gallon asphalt kettle which was converted into a snow melter and sled mounted for portability. The average production rate for 24 hours operation provided water for 60 men based on 30 gallons per man per day (Ref. 37). In some Antarctic camps, a snow melter is operated by gun-type oil burners, with the exhaust discharging through a coiled pipe. Thermal energy transfer from the pipe to the snow is relied upon to produce water. One of these units has an average output of 1,660 gallons per day (Ref. 38).

During the summer season the Arctic has natural streams as a result of the melting ice and snows. In some areas, during this season, wells are sunk and operated in the vicinity of the stream. This method, rather than taking the water from the stream directly, produces a better quality water, as the streams usually contain a high quantity of organic material and are quite high in turbidity (Ref. 39).

Because snow more often contains dirt, soot, and animal and human contaminants, glacial ice if available should be considered a source of water. Glacial ice is normally pure and gives roughly twice the water per fuel unit in half the time as does snow when melted (Ref. 40). However, this depends on location. Some glaciers can be highly contaminated by wind-borne debris especially near Arctic base camps, airfields, depots, etc.

d. Water Quality

Standardization of Operations and Logistics (SOLOG) Agreement 125 between the United States, United Kingdom, Canada, and Australia concerns the concentration of chemical substances present in water for military field water supply. These standards are presented in table 8. They represent the minimum potability standard for a safe emergency water supply intended for human consumption under field conditions. For other than field conditions (rear areas, fixed installations, etc.) military water supplies should not contain impurities in concentrations exceeding the values of the USPHS Standards of 1962 (Ref. 34).

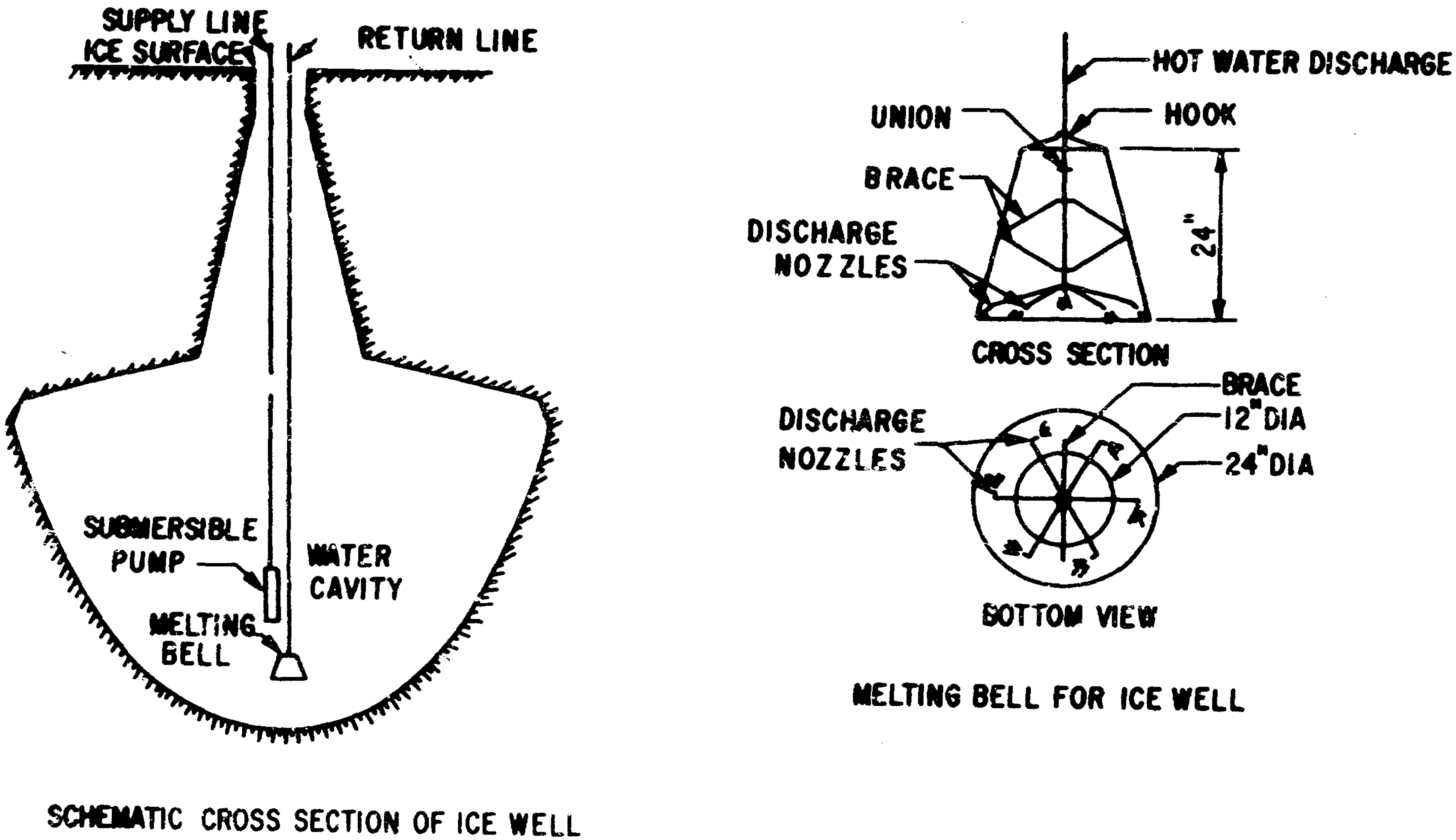


Figure 5. Rodriguez Well

Table 8

Permissible Concentrations of Impurities - SOLOG Agreement

Military Field Water Supply

(1) Short term standards. The maximum limits listed below are mandatory for emergency water supply for a period not exceeding seven days. (Asterisked standards are interim pending completion of more exacting studies.)

Arsenic (As)	2.0 mg/1
Cyanides (incl cyanogen chloride)	20.0 mg/1
Mustard (sulphur and nitrogen)	2.0 mg/1*
Nerve gas (A)	0.1 mg/1*
(B)	0.05 mg/1*
(Vx)	0.005 mg/1*

(2) Long term standards. The limits listed below are preferable in water to be used continuously in excess of seven days. (Asterisked standards are interim pending completion of more exacting studies.)

Arsenic	0.2 mg/1
Cyanides (incl cyanogen chloride)	2.0 mg/1
Mustard (sulphur and nitrogen)	2.0 mg/1*
Nerve gas G (A)	0.1 mg/1*
G (B)	0.05 mg/1*
(Vx)	0.005 mg/1*
Chloride (Cl)	600.0 mg/1
Magnesium (Mg)	150.0 mg/1
Sulphates (SO_4)	400.0 mg/1
Color	50 units
Total solids	1500.0 mg/1

(3) Radiological standards (gross fission products).

(a) For short term consumption, no absolute numerical standard is recommended or considered necessary. This is based on the conclusion that, if the external radiation hazard permits occupancy of the water point, the water is suitable for consumption during occupancy not exceeding the one-week period.

(b) For long term consumption, available information does not permit the establishment of a practical standard.

AFM 160-4 "Sanitary Control of Water Supplies for Fixed Installations" states that the physical and chemical standards for water contained in US Public Health Service Drinking Water Standards provide a measuring stick for determining the quality of water as drawn and the effectiveness of different treatment units. They also serve as a guide for adjusting water treatment processes (Ref. 15).

The health of personnel must not be endangered by contamination of any kind. Standards for the quality of water supplied to polar stations are the same as for any other station. Because of the difficult conditions encountered in construction and operation of water supply systems in polar stations, the danger of accidental contamination is somewhat greater than for other locations (Ref. 33).

Investigations have been conducted by the United States Air Force Arctic Aeromedical Laboratory at Fort Wainwright, Alaska, in color removal from surface waters and determining pollution of surface waters. Studies utilizing the presence of echenococcosis and coliform organisms as pollutant indicators have been conducted (Refs. 41 and 42).

The Office of Civil Defense, Department of Defense, has done studies in the areas of fallout contamination from surface water runoff, contamination of open reservoirs, ground water movement, internal consumption of fallout contaminated water, utilization of waste water in protective shelters, and contamination of ground water from underground nuclear detonations. Various sized municipal systems have been studied for problems arising if they have been destroyed or partially knocked out by a nuclear detonation. The Atomic Energy Commission and the Office of Civil Defense have also performed joint studies concerning contamination of water by radioactive material (Refs. 43 and 44).

e. Water Treatment

In a theater of operation a water point consists of a water source, a portable water treatment plant, bivouac area for attendants, and an access road. Potable water is the product and the product is transported by vehicles to the consumers. The water point equipment is mobile because as the troops move so does the water point.

Field troops are issued water disinfectant kits for their personal use, as at times it is impossible to them to return to their main bivouac area. The water may be disinfected in individual canteens or in the lyster bag. Instructions are included in the kits on how to use the chemicals, and are also printed in the Army Engineer Field Data Manual from which the following instructions were extracted (Ref. 32).

Water Disinfection

Calcium Hypochlorite. Add calcium hypochlorite to produce residual chlorine of 1 part per million (ppm) after 10-minute contact time, and wait additional 20 minutes before drinking. For 36-gallon lyster bag, 1 calcium hypochlorite capsule is usually enough. For individual use, prepare a disinfecting solution by placing 1 calcium hypochlorite capsule in a canteen of water. Add 1 canteen-capfull of disinfecting solution to each canteen of water, shake, and allow to set for 30 minutes before using.

Iodine Tablets. Use 1 tablet per canteen of water for clear water and 2 tablets per canteen of water for cloudy water. Allow the water to stand for 5 minutes, shake vigourously, and allow to stand another 10 minutes before drinking. Allow cold water to stand 20 minutes before drinking.

Boiling. Bring the water to a rolling boil for 1 minute.

Destruction of Amoebic Dysentery Cysts. When cysts are suspected pretreat all water by coagulation and sedimentation followed by sand filtration at reduced rates or by diatomite filtration. Water treated in this way is safe to drink if it has a residual chlorine content of 1 ppm after a 10 minute contact time. In emergencies, disinfect water in individual canteens by following the directions on the bottle of individual water purification tablets, unless an increase is directed by the medical officer. Small units may boil their own drinking water; this is a sure method. If the lyster bag is used, the following steps must be taken:
(1) Break 1 ampule and pour into filled bag; stir with clean paddle.
(2) Disinfect faucets by flushing 1/2 cup of water through each faucet.
(3) After 10 minutes, residual should exceed 1 ppm. Then add another ampule. Keep bag covered.
(4) Water is potable 30 minutes after adding last ampule.

A US Army Engineer Research and Development Laboratories document (Ref. 45), published in December 1966, covers the Army's inventory of water purifying apparatus for combat operations. Table 9 is a general summary of the Army's inventory.

In 1961, the available equipment for purifying water for Army combat troops was of two types: (1) batch and (2) continuous-flow. Batch-type equipment was issued in three sets with capacities of 15, 35, and 50 gpm. The equipment was completely portable and the entire unit and its auxiliary equipment

Table 9

U.S. Army Water Purification Unit, Inventory

Type	Capacity (GPH)	Mounted	Power	Weight (lbs)	Dimensions
Water Purification Equipment					
Filter unit, water purification	15	Knapsack	Hand	7	1/2 cu. ft.
Water purification equipment set	600	Trailer	Elect.	5,820	85 x 96 x 160 in.
Water purification equipment set	1,500	Truck	Elect.	20,585	96 x 128 x 280 in.
Water purification equipment set	3,000	Truck	Elect.	23,275	96 x 128 x 340 in. 8 x 7 x 10 ft.
Water purification equipment set	3,000	Base	Elect.	22,000	Crates 4 x 7 x 8 ft. 4 x 7 x 10 ft.
Water purification plant	10,000	Base	Elect.	32,000	---
Hypochlorination unit	6,000	Frame	Water	312	15.4 cu. ft.
Distillation set, thermocompression	150	Trailer or skid	---	5,535	96 x 94-1/2 x 171 in. 52 x 68 x 106 in.
Items Under Development					
Water purification equipment set	420	Various vehicles	Elect.	1,700	112 cu. ft.
CW-BW H_2O pretreatment decontamination set	600 1,500 3,000	Trailer	3 gas	2,850	147 x 74 x 83 in.
Ion exchange unit	600 3,000	Mtr. van	Elect.	21,640	281 x 99 x 124 in.
Seawater distillation unit	3,000	Mtr. van	250-hp mtr.	60,000	40 x 96 x 109 in.
Reverse osmosis unit					
Coagulation with cationic molyelectrolyte					

Note: U.S. Army Inventory, December 1966.

could be carried in nine man-sized packs. The unit was designed primarily for use by isolated troops in the field who could not be supplied with water by larger units. The batch-type system was not suitable for use in subfreezing temperatures without special techniques of heating and insulation.

By 1966, the batch-type equipment was phased out to be replaced by the continuous flow water purification equipment. This equipment was developed as a result of a need for a combat type mobile water purification unit which incorporates necessary facilities and techniques for the treatment and purification of surface waters under all climatic conditions (Ref. 46).

The following discussion describes an interim purification unit not included in table 9. It is the newest addition to the long line of purification units in the Army Engineers' inventory. This unit has a capacity rating of 600 gph and is base mounted. The set consists primarily of a diatomite pressure filter, three 500-gallon collapsible fabric water storage tanks, three gasoline-engine driven pumps, suction and discharge hoses, and a supply of water-treating chemicals. The set also contains a chlorine comparator for measuring total chlorine residuals of the processed water. The equipment shown in figure 6 provides for the chlorination, coagulation, and sedimentation of raw water in two of the fabric storage tanks, filtration of the settled water through a diatomite filter and collection of filtered potable water in the third storage tank for distribution. Figure 7 shows the construction of the diatomite filter (Ref. 47).

A second 600-gph water purification set, called an erdalator (figures 8 and 9) is furnished in a special-purpose cargo body mounted on a 2-1/2-ton, two-wheel trailer. The erdalator assembly, diatomite filter, filter pump, chemical feed equipment with the necessary piping and valves, and the electrical controls are mounted on the cargo body. They are designed to be operated without removing them from the trailer. Supporting equipment furnished with the water purification set but not mounted includes a 3-kilowatt engine generator set, a gasoline engine driven pump, a portable electric driven pump, two 500-gallon collapsible water storage tanks, necessary hoses and fittings, water testing equipment, and a supply of chemicals. The erdalator assembly (figure 10) reduces the content of the organic and suspended matter of the water and produces an effluent suitable for application to the diatomite filter. The erdalator tank serves as a separator which hydraulically separates the slurry blanket from the clear water in the upper section of the tank in what is termed the separation zone. Figure 11 shows a typical installation of this type of equipment (Ref. 48).

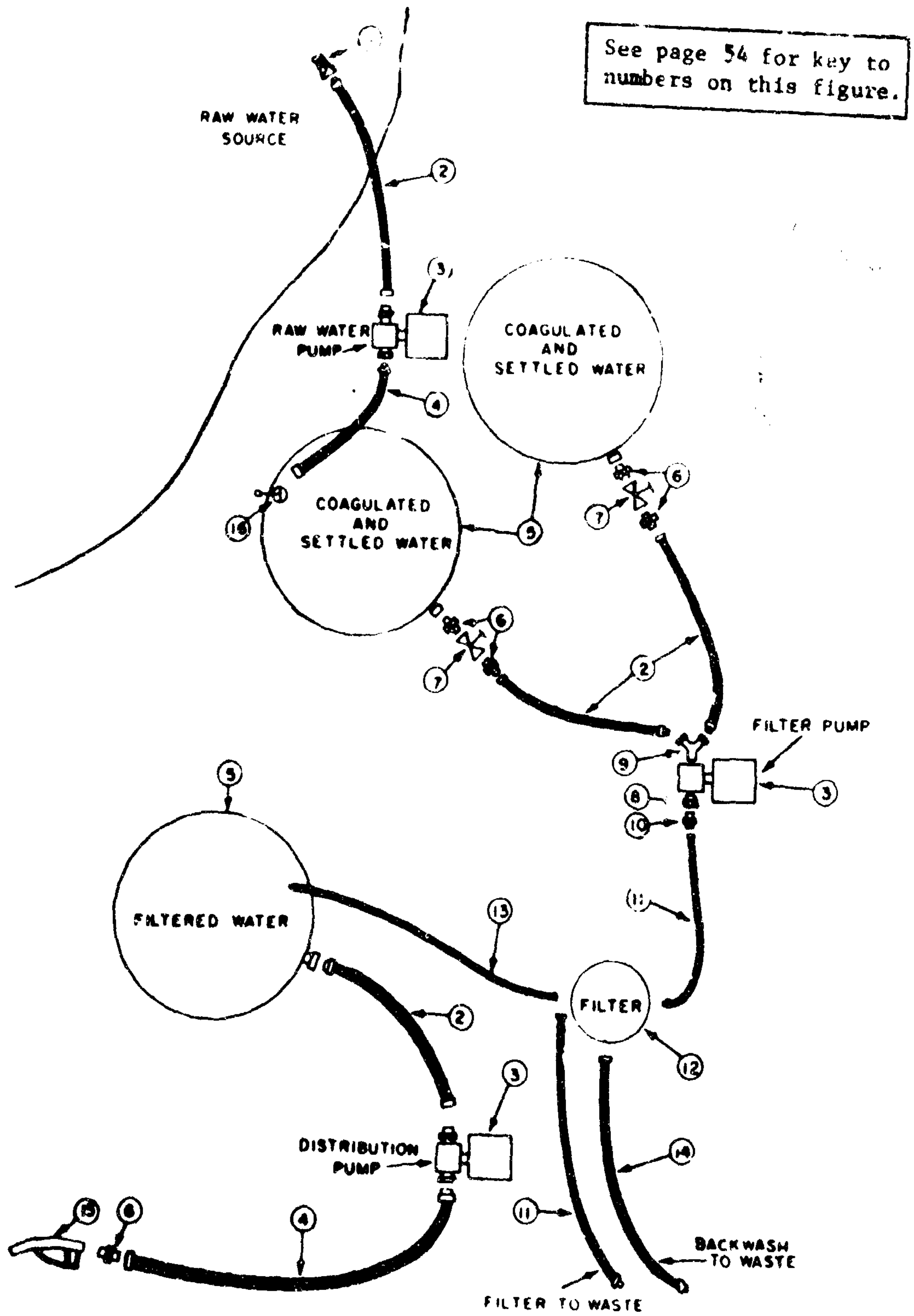


Figure 6. 600 GPH Interim Water Purification Unit Layout

Key:

1. Filter element (four required)
2. Filter housing cover
3. Filter window
4. Wash ring
5. Influent section
6. Effluent section
7. Plastic cups (32 required)

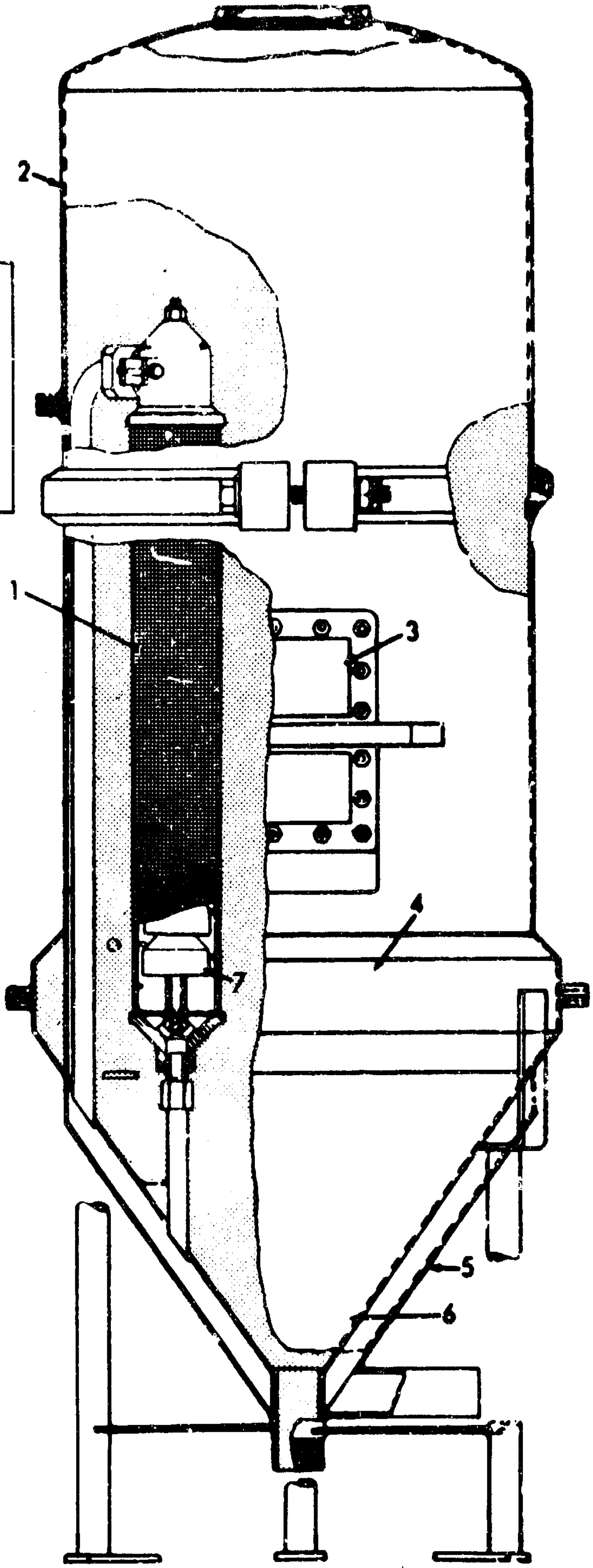


Figure 7. Diatomite Pressure Filter

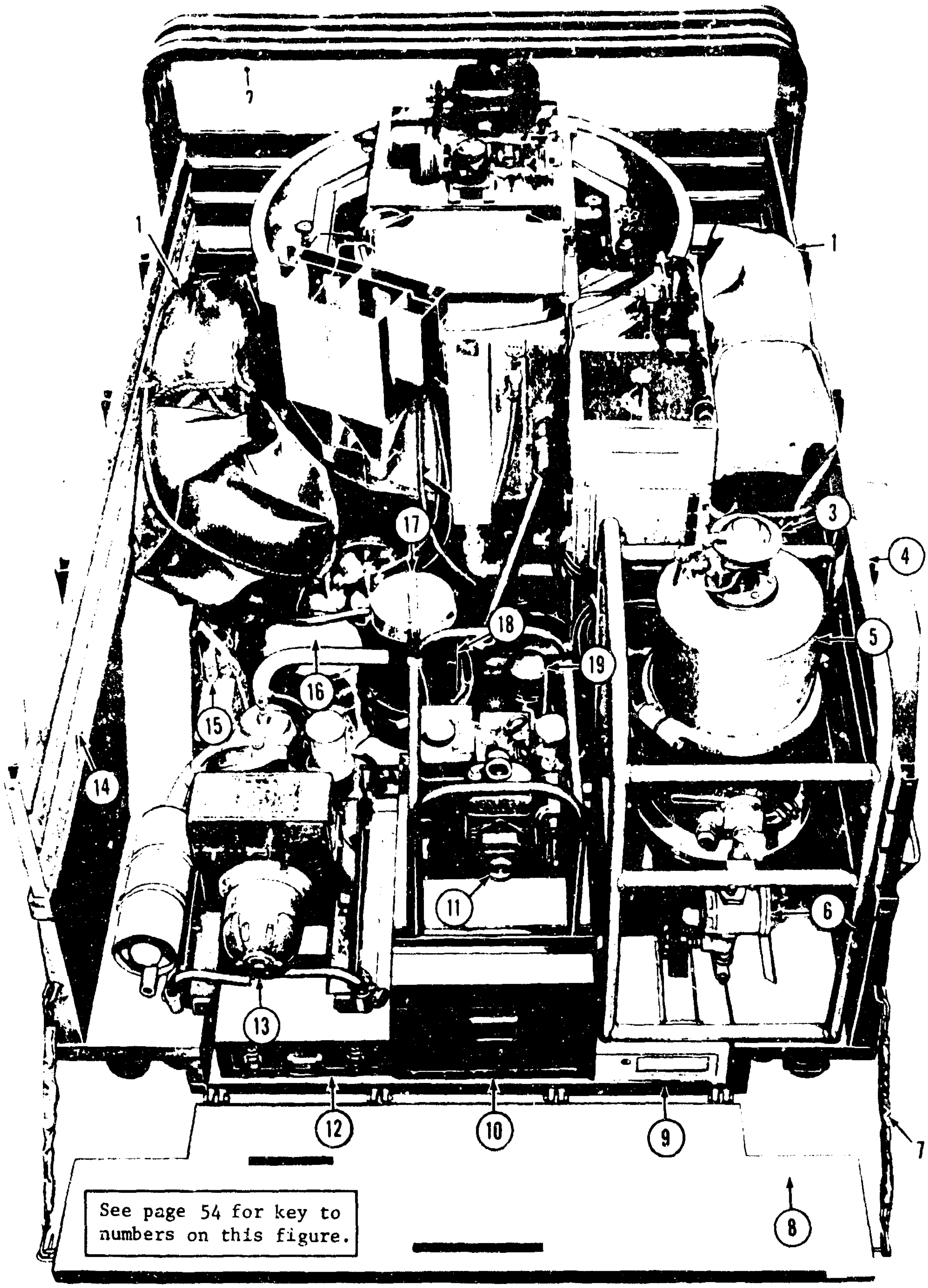


Figure 8. Water Purification Set, Trailer Mounted, 600 GPH

See page 54 for key to numbers on this figure.

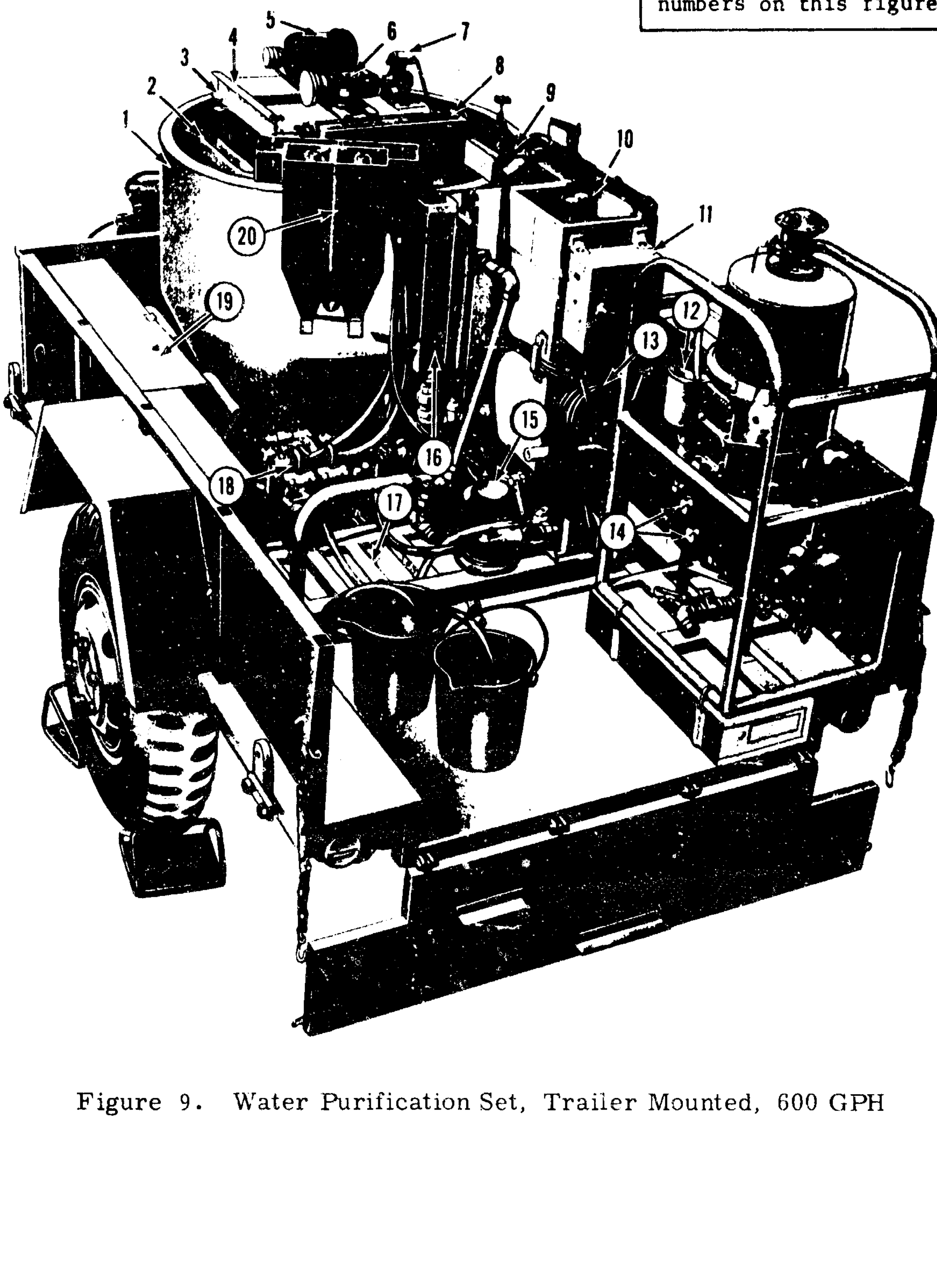


Figure 9. Water Purification Set, Trailer Mounted, 600 GPH

See page 55 for key to numbers on this figure.

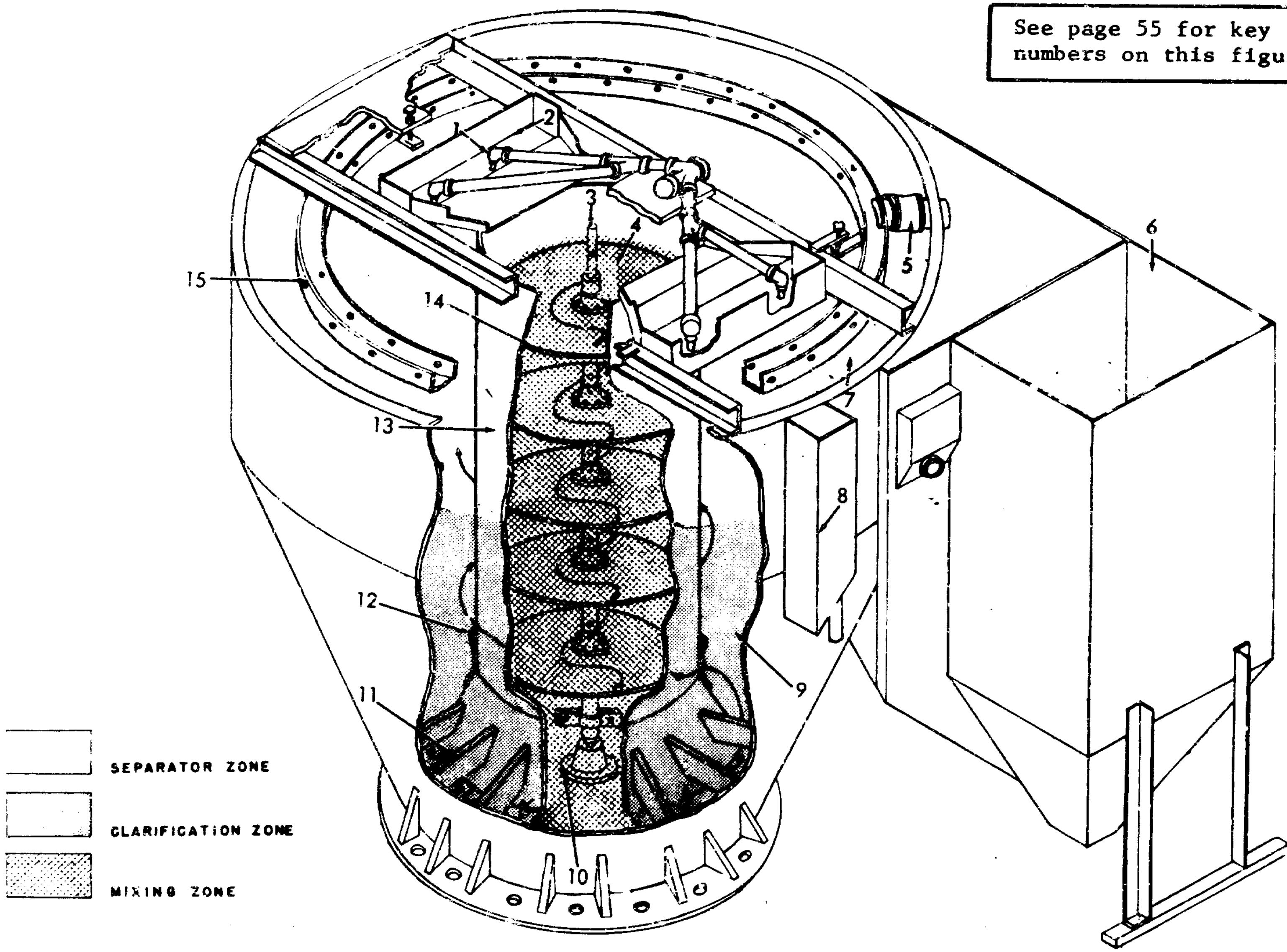


Figure 10. Schematic of an Erdalator

See page 55 for key to numbers on this figure.

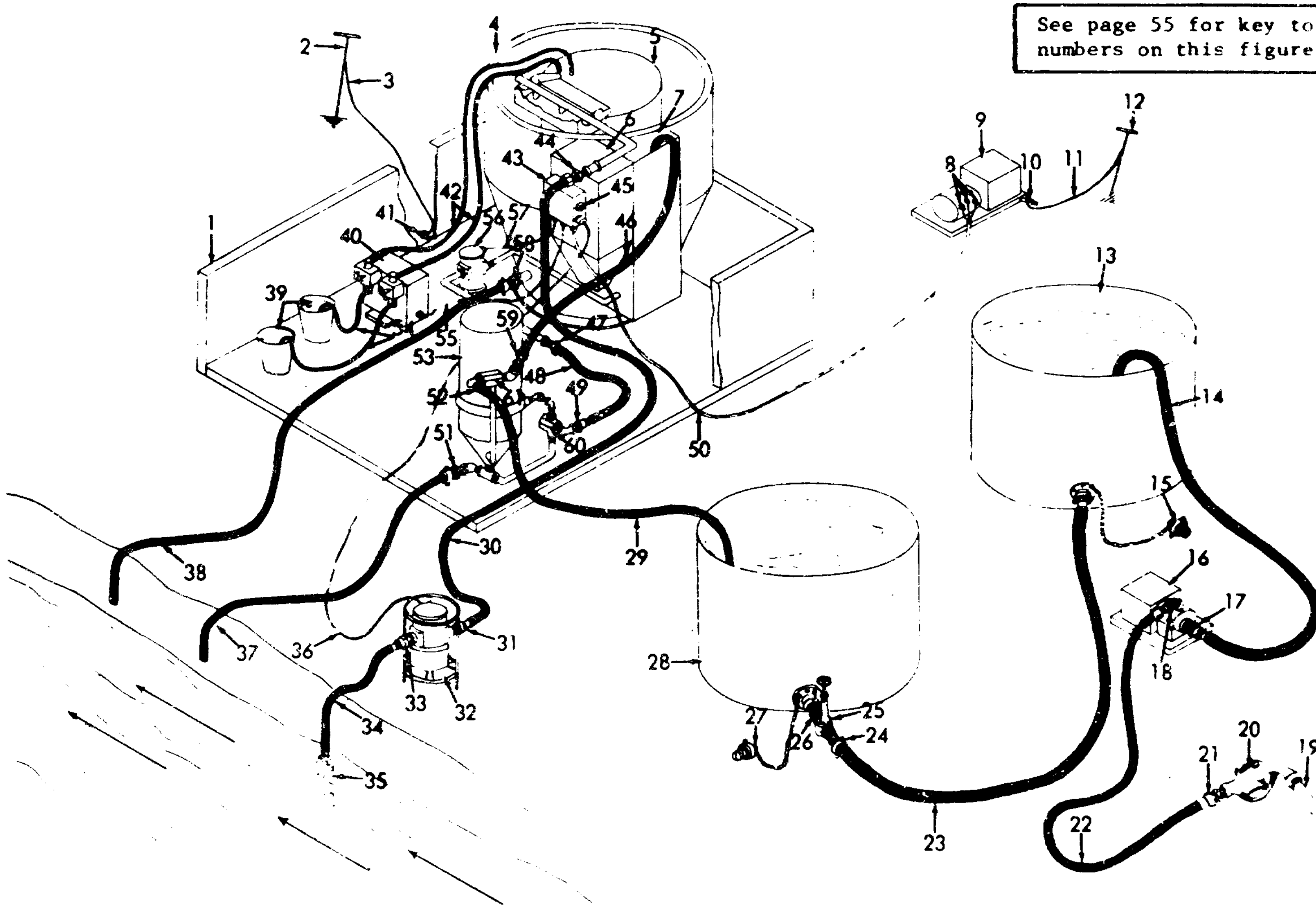


Figure 11. Typical Installation of Water Purification Set, Trailer Mounted

Key to Figure 6

1. Strainer, 1-1/2 inch
2. Hose, rubber, suction, 1-1/2 inch, 10 feet
3. Pump, GED
4. Hose, cotton, discharge, 1-1/2 inch, 25 feet
5. Tank, rubber, collapsible, 500 gallon
6. Adapter, 1-1/2 inch, male NPT to 1-1/2 inch, male NPSH
7. Valve, gate, 1-1/2 inch
8. Bushing, pipe, 1-1/2 inch, ext. thd., 1 inch int. thd.
9. Siamese connection, 1-1/2 inch, pipe to hose
10. Adapter, 1 inch, male NPT to 1 inch, male NPSH
11. Hose, rubber, suction, 1 inch, 10 feet
12. Filter, diatomite, 4 sq. ft.
13. Hose, dacron, discharge, 1 inch, 25 feet
14. Hose, rubber, suction, 1-1/4 inch, 10 feet
15. Nozzle, dispensing, 1-1/2 inch
16. Bottle, dropper, ferric chloride

Key to Figure 8

1. Collapsible fabric tank, 500 gallons (two required)
2. Roof bows
3. Air release valve
4. Filter tubular frame
5. Filter
6. Flow controller valve
7. Trailer tailgate chain
8. Trailer tailgate
9. Tool box
10. Chemical box
11. Distribution pump
12. Accessory box
13. Generator
14. Trailer body rack
15. Tank staves
16. Raw water pump with canvas cover
17. Pail tiedown strap and metal cover
18. Rubber pails
19. Filter pump

Key to Figure 9

1. Erdalator tank
2. Effluent launder
3. Effluent launder leveling rods (three required)
4. Bridge rail
5. Agitator drive motor
6. Speed reducer
7. Air pump
8. Influent launder
9. Wet well tank
10. Sludge concentrator tank
11. Electric control box
12. Precoat funnel

Key to Figure 9 (cont'd)

13. Power cable
14. Pressure gages
15. Filter pump
16. Weir box
17. Erdalator mounting base
18. Chemical solution feeder
19. Storage box
20. Chemical slurry feeder

Key to Figure 10

1. Aspirator (four required)
2. Influend launder (two required)
3. Agitator shaft
4. Mixing zone
5. Effluent launder discharge tube
6. Sludge concentrator tank
7. Separator zone
8. Slurry weir box
9. Clarification zone
10. Bearing support
11. Baffle
12. Baffle ring
13. Downcomer tube
14. Circular disk (five required)
15. Effluent launder

Key to Figure 11

1. Cargo body
2. Cargo body ground rod
3. Ground cable
4. Erdalator tank
5. Downcomer
6. Sludge concentrator tank
7. Wet well
8. Generator terminal lugs
9. Generator set
10. Generator ground lug
11. Generator ground cable
12. Generator ground rod
13. Second filtered water storage tank
14. Distribution pump suction hose, tubber, 1-1/2 inch x 10 feet
15. Filtered water tank chain and cap, 1-1/2 inch, male hose
16. Distribution pump (gasoline driven)
17. Adapter, male pipe to female hose, 1-1/2 inch
18. Adapter, male pipe, 1-1/2 inch
19. Distribution nozzle extension pipe
20. Distribution nozzle, 1-1/2 inch, pipe thds.
21 Adapter, male, pipe to female hose, 1-1/2 inch
22. Distribution hose, fabric, 1-1/2 inch x 25 feet
23. Hose, rubber, 1-1/2 inch x 10 feet
24. Adapter, male pipe to hose, 1-1/2 inch

Key to Figure 11 (cont'd)

25. Valve, gate, 1-1/2 inch, female pipe
26. Adapter, male, pipe to hose, 1-1/2 inch
27. Cap and chain male pipe, 1-1/2 inch
28. First filtered water storage tank
29. Filtered water hose, 1 inch x 25 feet
30. Raw water pump discharge hose, fabric, 1 inch x 25 feet
31. Adapter, male pipe to female hose, 1 inch
32. Raw water pump
33. Adapter, male pipe to female hose, 1 inch
34. Raw water pump suction hose, rubber, 1 inch x 10 feet
35. Strainer, raw water pump suction, 1 inch, female
36. Raw water pump electric cable
37. Filter, waste water hose, rubber, 1-1/4 inch x 10 feet
38. Erdalator tank waste water hose, rubber, 1-1/4 inch x 10 feet
39. Rubber pails
40. Chemical solution feeder
41. Cargo body ground lug
42. Chemical solution feeder discharge, plastic tubing, 3/4 inch OD x 68 inches (two each)
43. Electrical control box
44. Adapter, male, pipe to male hose, 1 inch
45. 120-volt outlet receptacle
46. Recirculating hose, rubber, 1 inch x 10 feet
47. Adapter, male pipe to hose, 1 inch
48. Hose, rubber, 1 inch x 10 feet
49. Adapter, male pipe to female hose, 1 inch
50. Main power cable
51. Adapter, male pipe to hose, 1 inch
52. Adapter, male pipe to male hose, 1 inch
53. Diatomite filter
54. Chemical solution feeder suction tubing, 3/4 inch OD x 48 inches
55. Chemical solution feeder power cable
56. Filter pump
57. Filter pump power cable
58. Adapter, male pipe to male hose, 1-1/4 inch
59. Adapter, male pipe to male hose
60. Influent plug valve, 1 inch
61. Effluent plug valve, 1 inch

A 1500-gph van type, electrically driven model is available but is so similar to the 3000-gph model, except in capacity output and arctic conditioning, that it will not be described.

The 3000-gph water purification unit is installed in a van-type body, mounted on a 2-1/2-ton truck. Supporting equipment furnished with the unit includes a 10-kw engine-driven generator set, mounted on a standard 1-1/2-ton cargo trailer. It also includes two 3000-gallon collapsible fabric water storage tanks; three portable centrifugal pumps, two electric driven and one gasoline driven; a 30-day supply of chemicals; and the necessary hose assemblies. Figure 12 shows a view of the van assembly and figure 13 is an illustration of a typical field layout for this piece of equipment (Ref. 49).

Another type of treatment plant in use by the Services is the Infilco Accelator. This type of equipment is normally used at a fixed installation such as an air base or a headquarters organization. At Osan Air Base, South Korea, an Accelator water-treatment plant which has a design output of 0.75 mpd is used. In conjunction with the Accelator a rapid sand filter is provided. Using several Accelators and sand filters Osan has a total quantity of 2.25 mgd of treated water (Ref. 50). Figures 14 and 15 illustrate a typical Infilco Accelator cross section and installation (Ref. 51).

At Don Muang RTAFB, Thailand, wells are used as a source of water treated by filtering with diatomaceous earth filters and chlorinated. The U-Tapao RTAFB, Thailand, obtains their water from the Klong Bang Phai and TRN Reservoir. They use two parallel accelator-type upward flow coagulation and sedimentation units and two parallel automatic, valveless, sand filtration units. Each of the parallel units has a rated capacity of 1 mgd, for a total plant capacity of 2 mgd. The Korat RTAFB, Thailand, installation uses eight 160-foot deep wells with only chlorination. At the Nakhon Phanom RTAFB, Thailand, the base water supply is currently derived from two sources. Water is obtained from wells which are located on base and from the Huey Somhong Reservoir which is an irrigation reservoir, 8 km away. The wells receive chlorination as the only treatment. A portion of the surface water receives full treatment using two 3000-gph erdalators. The remaining surface water receives diatomaceous earth filtration and chlorination only. They have a total treated water storage of 51,000 gallons.

The Taipei Air Station, Taiwan, water supply is furnished by the Taipei municipal water distribution system. The station has the capability to filter (pressure sand filters) and rechlorinate the city water. However, the city water as delivered has a residual averaging 2.0 ppm, therefore no rechlorination is necessary and only the filters are used (Ref. 52).

Clark Air Force Base in the Philippines has a water intake structure on the Bamban River. Two and one quarter mgd of water is transported from the river to the base by means of a twin pipeline system consisting of 3 miles of 10-inch pipe and 3 miles of 14-inch pipe. Clark also has two deep wells with pumping

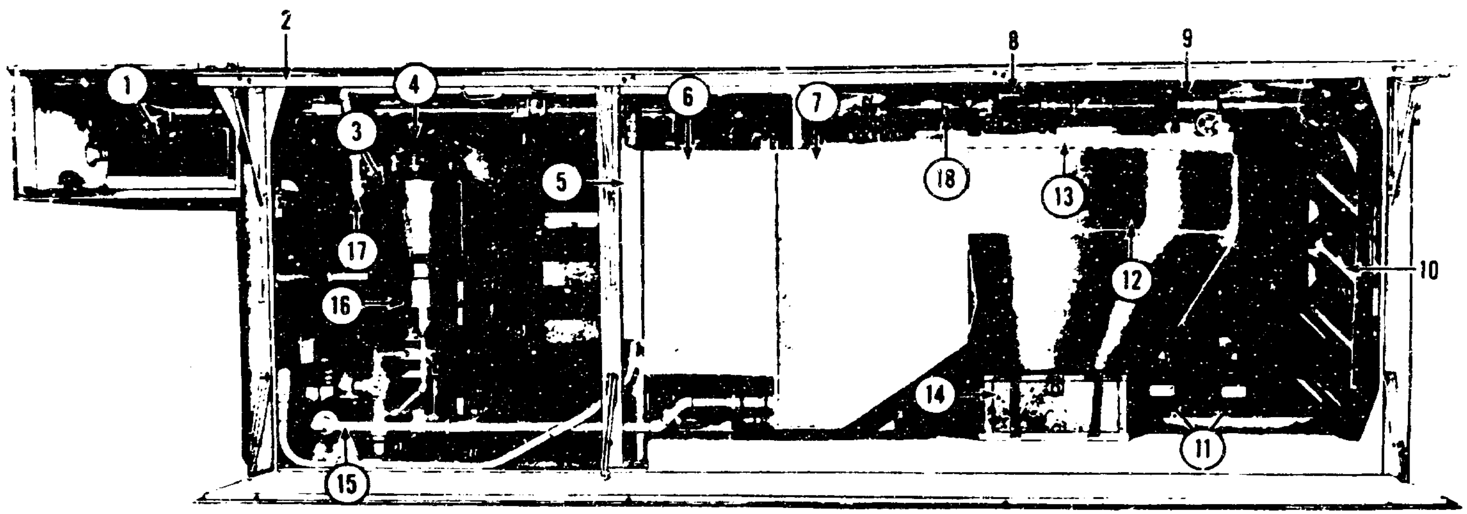


Figure 12. View of Van Mounted 3000 GPH Purification Unit

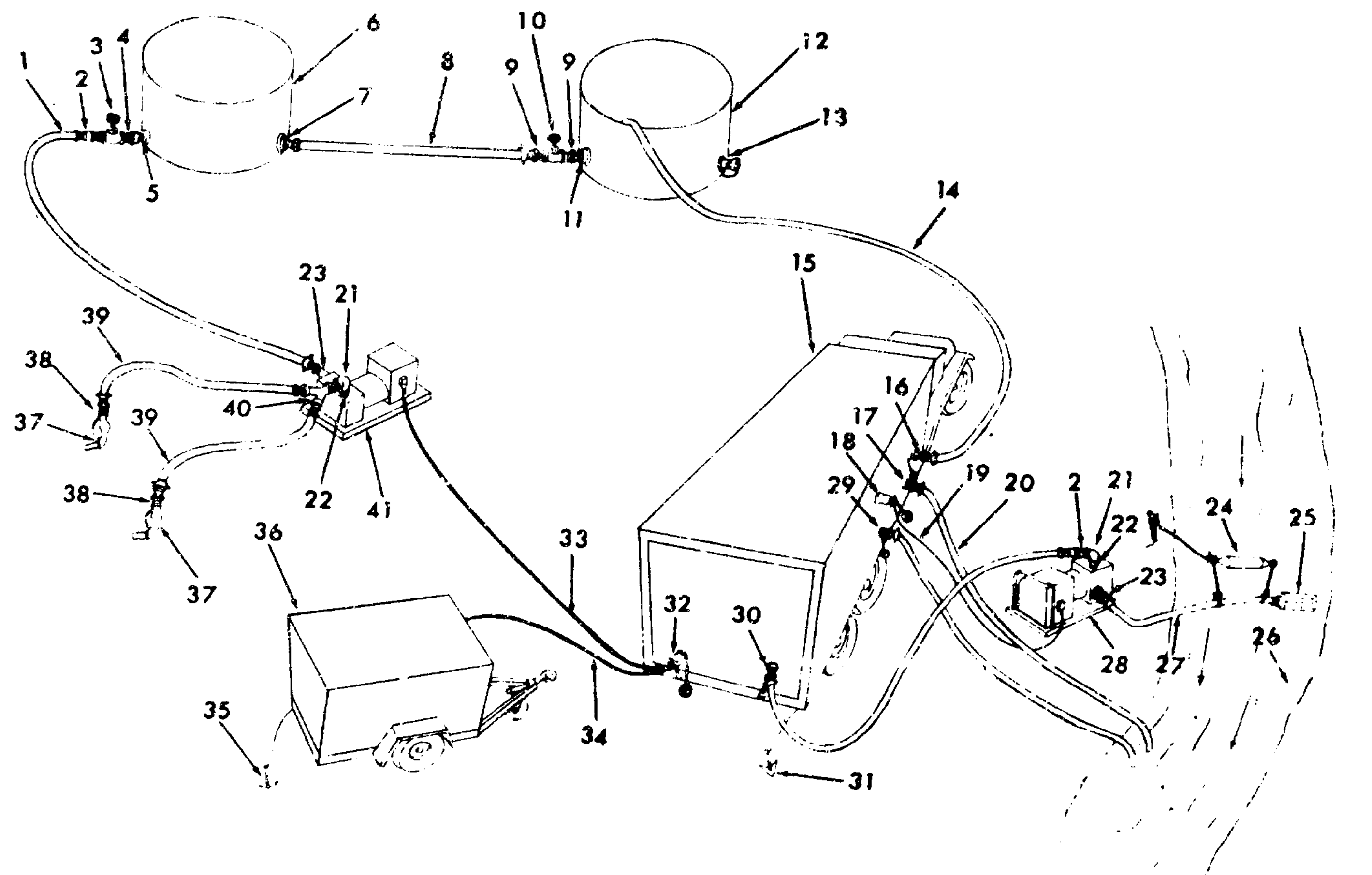


Figure 13. Typical Layout for Van Installed Purification System and Generator Trailer

Key to Figure 12

1. Personnel heater
2. Side panels, opened
3. Diatomite filters
4. Air release valve (two required)
5. Electric control cabinet
6. Sludge concentrator tank
7. Wet well tank
8. Erdalator agitator speed reduced
9. Erdalator agitator drive motor
10. Entrance ladders (two required)
11. Raw water pumps (two required)
12. Erdalator tank
13. Erdalator bridge rails
14. Accessory stowage box
15. Filter pumps (two required)
16. Precoat funnel (two required)
17. Draincock DC-52, 1/8 inch
18. Effluent launderer leveling rod (three required)

Key to Figure 13

1. Storage tank to distribution pump hose, 1-1/2 inch
2. Adapter, 1-1/2 inch, male NPT to 1-1/2 inch, female NPSH (two required)
3. Gate valve, 1-1/2 inch
4. Adapter, 1-1/2 inch, male NPT to 2 inch, female NPSH
5. Male outlet second storage tank, 2 inch, NPSH
6. Second storage tank
7. Second storage tank female inlet, 2 inch, NPSH
8. First storage tank to second storage tank hose, 2 inch
9. Adapter, 2 inch, male NPT to 2 inch, male NPSH (two required)
10. Gate valve, 2 inch
11. First storage tank female outlet, 2 inch, NPSH
12. First storage tank
13. First storage tank male outlet, 2 inch, NPSH
14. Filter hose, 1-1/2 inch, to first storage tank
15. Truck-mounted water purification unit
16. Van body filtered water outlet hose adapter
17. Van body filter waste water outlet hose adapter
18. Cable outlet
19. Raw water pump cable
20. Raw water pump discharge hose, 1-1/2 inch
21. Pipe elbow, 1-1/2 inch, 90° (two required)
22. Pipe nipple, 1-1/2 inch by 1-3/4 inch (two required)
23. Adapter, 1-1/2 inch, male NPT to 1-1/2 inch, male NPSH (two required)
24. Float
25. Strainer, 1-1/2 inch, female NSPH
26. Water supply source

Key to Figure 13 (cont'd)

27. Raw water pump section hose, 1-1/2 inch
28. Raw water pump
29. Van body erdalator waste water outlet hose adapter
30. Van body raw water inlet hose adapter
31. Truck chassis ground rod and cable
32. Generator and raw water pump cable inlet
33. Distribution pump electric cable
34. Generator cable
35. Trailer ground rod and cable
36. Trailer mounted generator set
37. Nozzle, 1-1/2 inch, female NPT (two required)
38. Adapter, 1-1/2 inch, male NPT to 1-1/2 inch, male NPT (two required)
39. Distribution pump discharge hose, 1-1/2 inch (two required)
40. Siamese connection, single end, 1-1/2 inch, male, Siamese end, 1-1/2 inch, female NPSH
41. Distribution pump

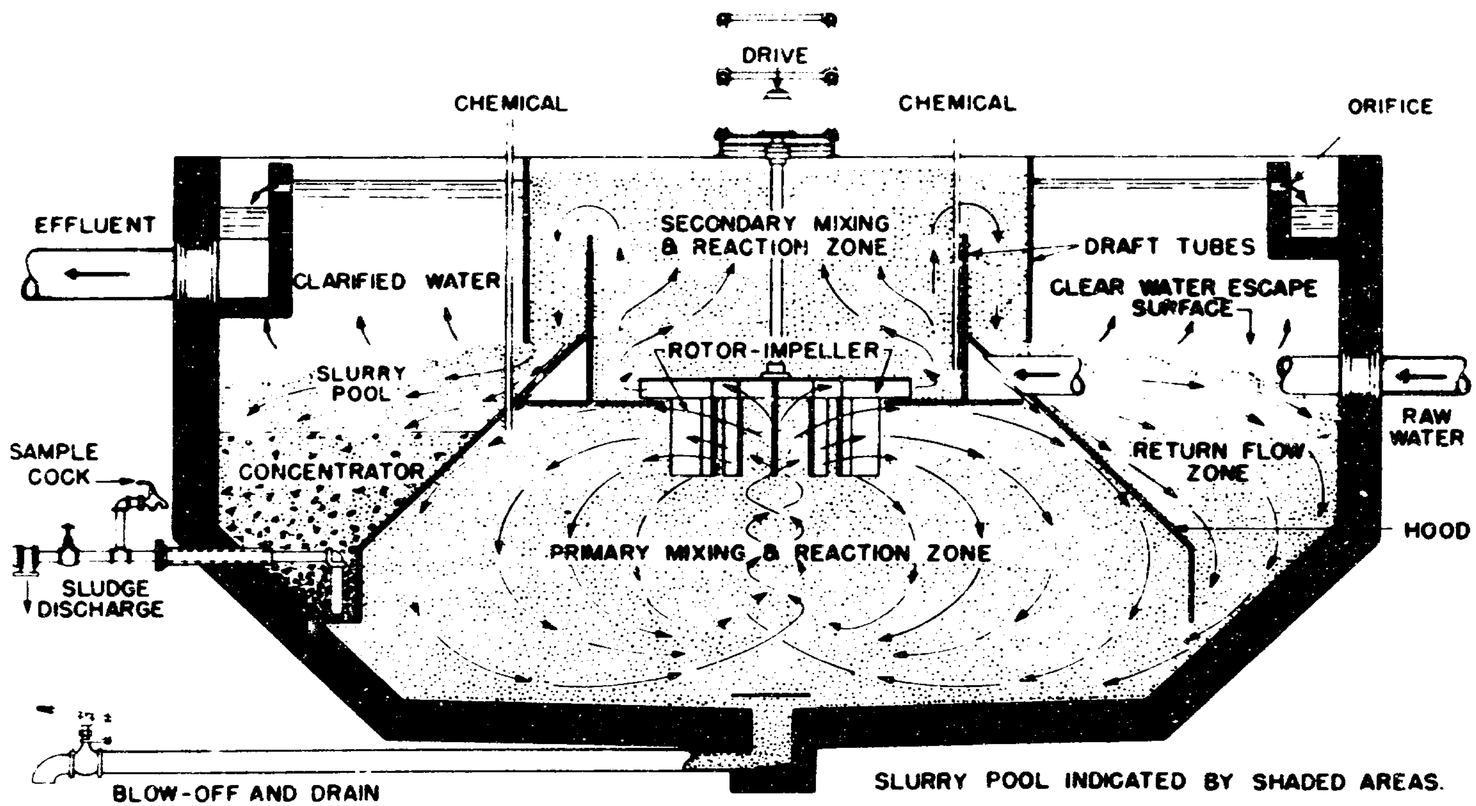


Figure 14. Cross Section of Typical Infilco Accelator Purification Unit

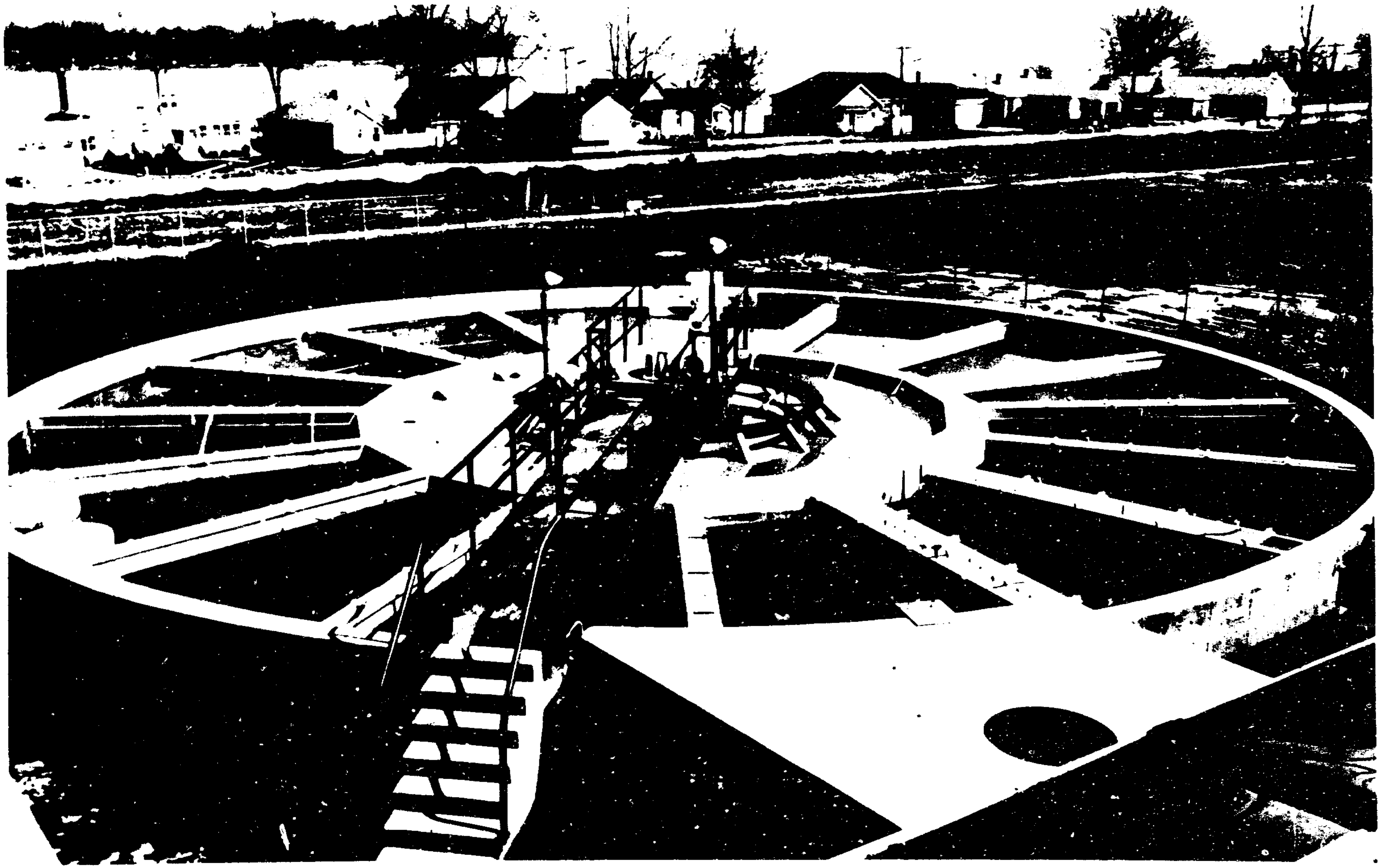


Figure 15. Typical Infilco Accelator Installation

capacity of 2 million gallons per day. These wells are only used to supplement the river water and complete the daily requirements of 3 mgd. The base is equipped with a permanent water treatment plant consisting of chemical mixer, flocculator, sedimentation basin, and chlorinator (Ref. 53).

The 7th Air Force base at Pleiku, South Vietnam, obtains water from nearby Lake Bien Ho. They treat their water with an erdalator system (Ref. 54). Also in South Vietnam, Da Nang Air Base obtains water from several wells which vary from 40 to 50 feet in depth. An erdalator water treatment system is installed at Da Nang because of the shallow wells and possible contamination may result because of native practice in disposal of sewage (Ref. 55).

Located on the Island of Bermuda is Kindley Air Force Base. Kindley is a relatively small base with some 400 buildings on it. The Bermuda Isles have no fresh-water streams, lakes, or wells which provide significant amounts of potable water. The average rainfall of 50 inches provides enough fresh water for prudent users; however, a 30-day drought can cause many households to either run short or completely out of water.

Kindley obtains 40 percent of its potable water from roof and specially prepared catchments. Runoff from 500,000 square feet of roof area is diverted into 14 reservoirs, while runoff from 600,000 square feet of prepared catchment areas drains into three large reservoirs with a combined capacity of over eight million gallons.

To maintain a balanced system, and to keep all reservoirs ready to receive water when it rains, water is constantly transferred between reservoirs; this, in turn, requires chlorination at 11 points to ensure purification. Because the catchments are subject to seeding with algae, bacteria, fungi, and microorganisms, chemicals must be used to keep the water potable. The rainwater is processed through coagulators, clarifiers, and chlorinators before use.

The most interesting and complex portion of the Kindley Air Force Base water system is the salt water conversion plant. Originally built in 1954, the 200,000-gpd plant at the time of its completion was the world's largest thermocompression sea water conversion facility (Ref. 56). A new 100,000-gallon per day flash evaporator supplements the supply from the original conversion unit (Ref. 12)

The original four-unit thermocompression system produced 2000 gph. Each unit was driven by a 260-hp diesel engine. All heat used in the conversion process is generated by the engine and through thermocompression. Heat is extracted from the coolant, lubricating oil, and exhaust, plus the blowdown and distillate. Roughly 1/2 gallon of fresh water is obtained from each gallon of sea water, and approximately 200 gallons of fresh water are produced for each gallon of fuel consumed. The flash evaporator-type distillation unit uses approximately 5 gallons of sea water for every 1/2 gallon of fresh water obtained and approximately 36 gallons of fresh water are produced for each gallon of fuel consumed.

The product of almost pure, ranging from 5 to 50 ppm in impurities. Soda ash and lime are added to give it flavor and to raise the pH content before it enters the base distribution system (Ref. 56).

Although the above statistics would lead one to believe that the first system did not function properly, when two of the older units were supplemented by the flash evaporator type, the following should be noted. Salt water and high compression are not a desirable combination. Temperatures above 160°F cause scaling, which impedes liquid flow and heat transfer and requires that a unit be taken out of service for descaling after 15 days of operation (Ref. 56). The flash evaporator literally flashes water into steam without heat transfer through surfaces; this system greatly reduces scaling (Ref. 57). The new distillation unit still requires the use of hydrochloric acid, as do the older vapor compression units, to clean and descale all the equipment that comes in contact with salt water; however, only 100 pounds of acid in comparison to between 3000 and 4000 pounds of acid used on the older units. One hour downtime for cleaning is all that the flash evaporator requires with a great deal less frequency (Ref. 58).

The following further illustrates the difference between a flash evaporator and thermocompression still (Ref. 59).

> In the flash evaporator type unit, a relatively large flow of feed water is heated in stages by condensation of the distillate vapor. As the feed water proceeds from stage to stage, it is heated by condensation of distillate vapors at successively higher pressures and the feed water leaving the warmest stage is still further heated by steam from an independent source. This hot feed water is then throttled back through the successive stages with a drop in pressure as it goes from one stage to the next so that

vapor is formed by flash from the feed water as it passes through each stage. This vapor is then condensed in each stage to provide for heating of the feed as noted above. Figure 16 gives the flow diagram for a three-stage, low-pressure flash-type distilling unit.

In a sense, the vapor-compression type of distilling unit carries the principle of using heat of condensation to a high state of perfection. As illustrated by the flow diagram in figure 17, the compression type of unit is so arranged that vapor leaving the evaporator is compressed to sufficient pressure to permit its use as a heating medium in the steam chest. Thus, the heat of condensation is continuously recirculated and the vapor compressor may be regarded as a form of heat pump.

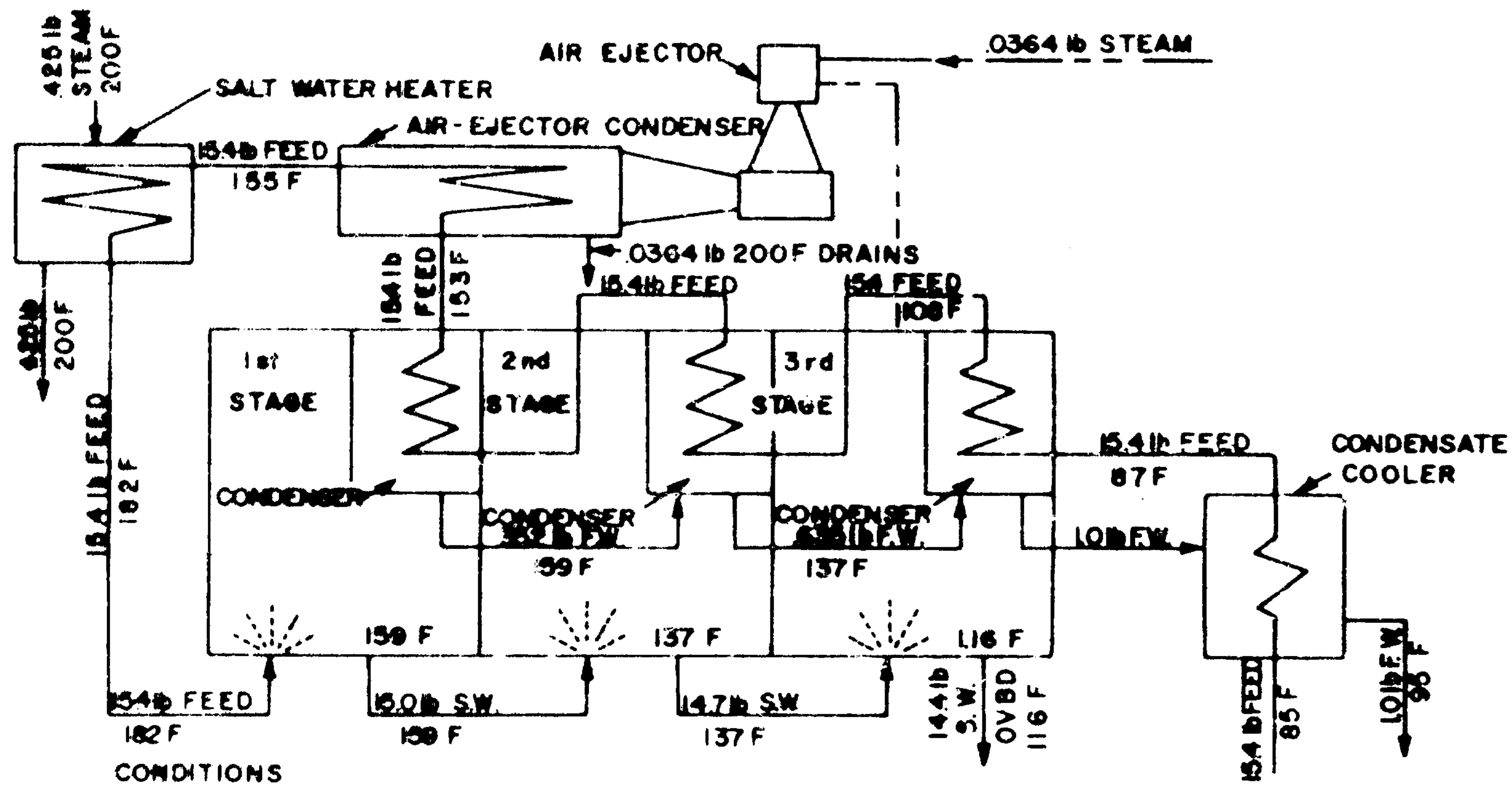
Note the high operating temperatures of the compression distillation unit (figure 17) as compared to the much lower temperatures of the flash evaporator type (figure 16).

In opening a session on distillation, the chairman had this to say (Ref. 60):

"I would like to read a brief excerpt from a magazine of 1885. This was at the time when the British troops were very busy in Egypt and here is the quote: 'The distilled water produced for Egypt is made in special apparatus. Various forms of condensers are employed made under various patents. The principle involved in all cases, however, is the same. Steam is generated in one of the ship's boilers, condensed, filtered, and aerated in a special device.' That, I think, is one of the first instances of distilled water being used for advanced field operations of a military force. Up to that time soldiers had to get along the best they could with water picked up from the surface or in other ways."

Today, one assumes that all ocean-going vessels utilize desalinization equipment. The more modern vessels are using the flash evaporator type units. The nuclear-powered carrier USS Enterprise has four "Aqua-Chem" 70,000-gpd flash evaporator seawater conversion units which supply 280,000 gallons of fresh water per day. This is equivalent to approximately the daily needs of 1400 homes. Other United States vessels using this type of system are the nuclear-powered ship NS John F. Kennedy, NS Savannah, the USS Constellation, Independence, Kitty Hawk, and Tullibee (Ref. 12).

In a coastal Antarctic camp a 16-stage flash evaporator desalinization unit is used. The 14,400-gallon a day facility during the summer months will yield 15 gallons of potable water per man per day (Ref. 38). Figure 18 is an



CONDITIONS

SEA-WATER TEMPERATURE	85 F
STEAM PRESSURE	11.5 PSIA
STEAM TEMPERATURE	200 F
DENSITY OF SEA WATER OVERBOARD	1.07/32

Figure 16. Flow Diagram Three-Stage Low-Pressure Flash Type Distillation Unit

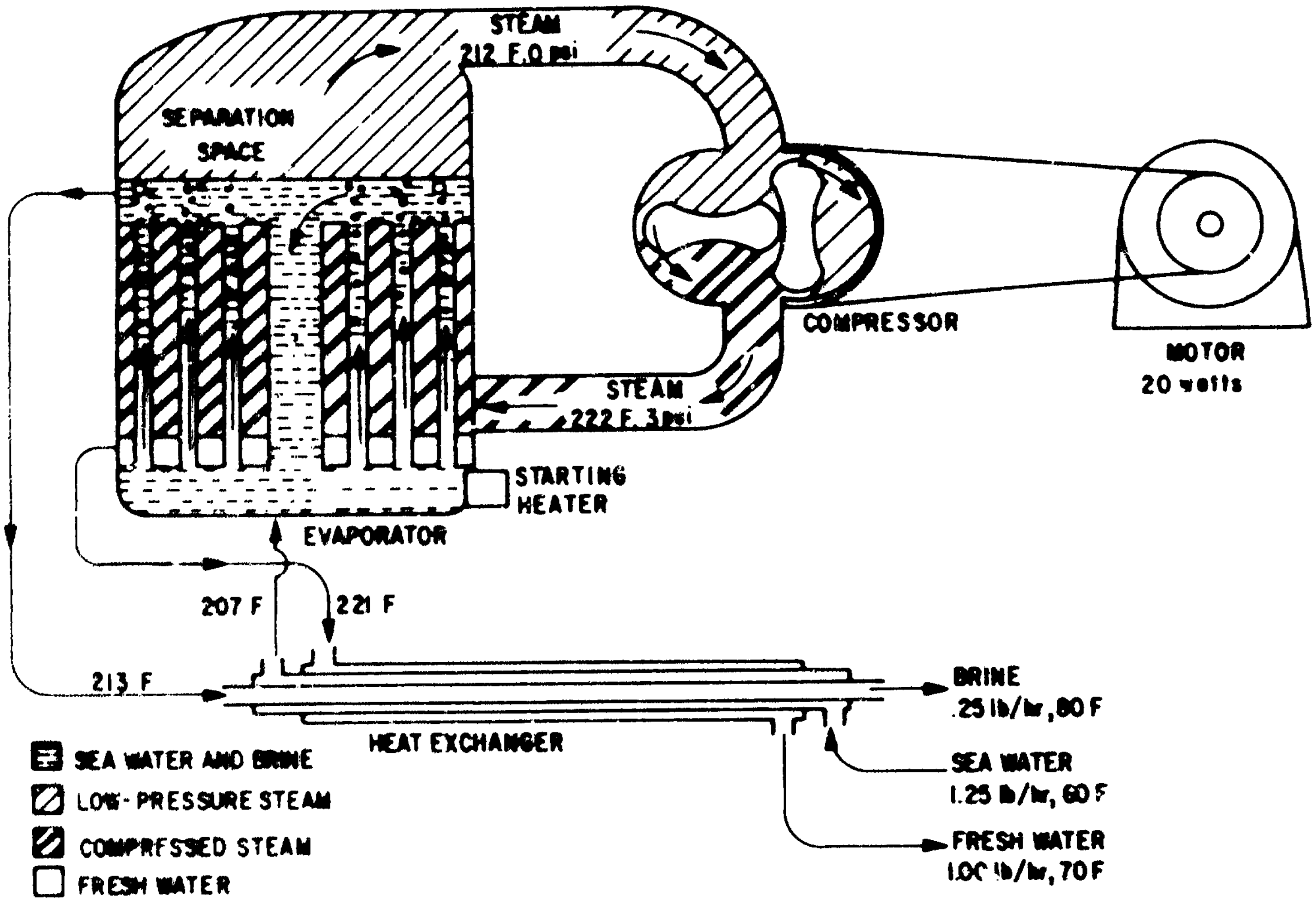


Figure 17. Flow Diagram, Compression Distillation Unit

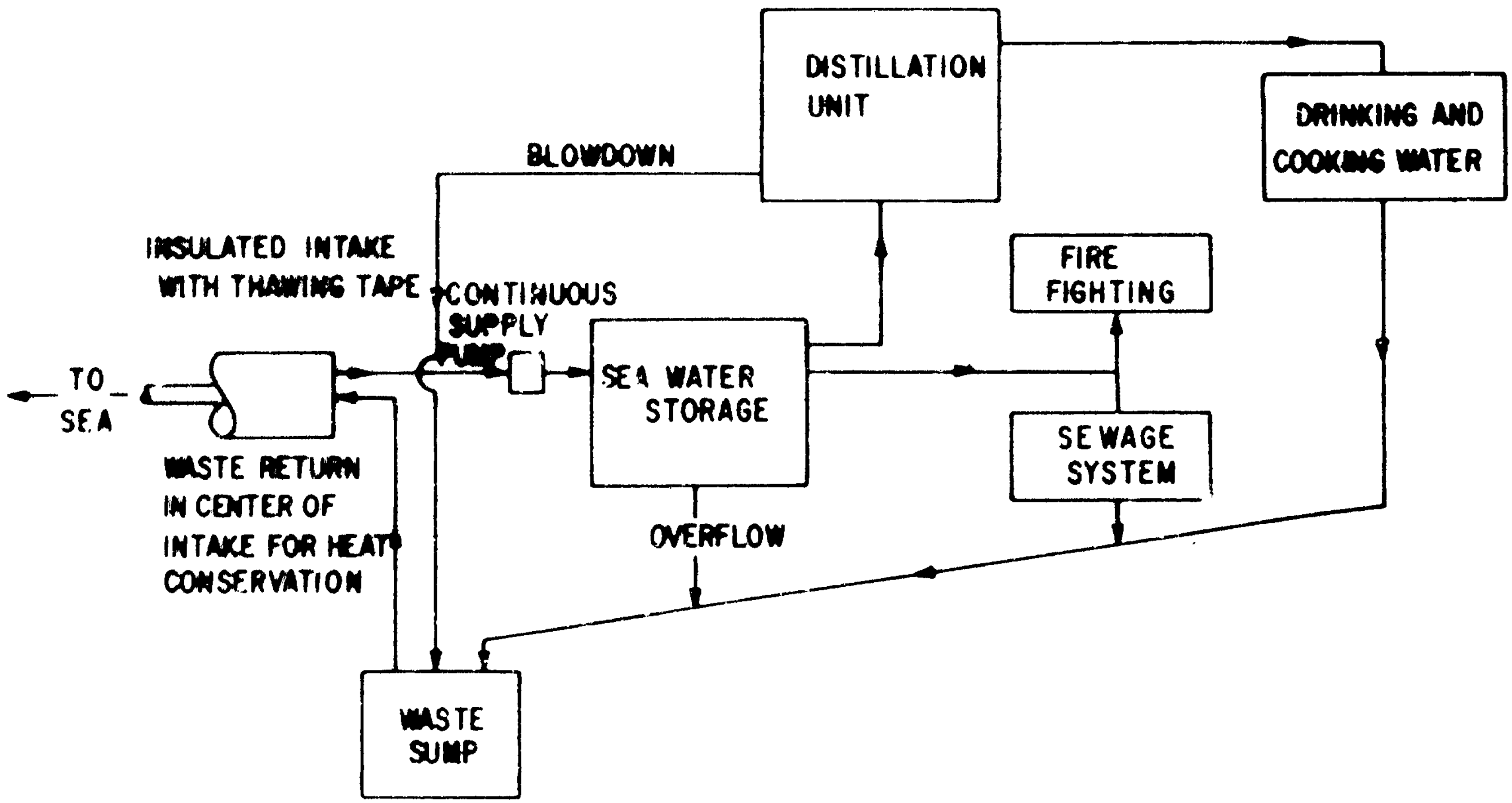


Figure 18. Polar Camp Type, Distillation System

example of a distillation system which could be applied to a polar camp. Figure 19 is a schematic drawing of an Aqua-Chem Vapor Compression Distiller used by the Navy at remote camps. The Navy has run extensive evaluation tests at their Civil Engineering Laboratory on a 200-gph Aqua-Chem distillation unit (Ref. 61). The distillation units are used for both salt water and fresh water. When used to remove certain impurities from fresh water, one receives a 91-percent return in product in comparison to a 50-percent return on sea water usage (see table 10).

Providing access to sea water is usually a difficult construction problem depending on local climate and soil conditions. If permanent, fast ice occurs over reasonable depths of water near the station, an intake pipe can easily be provided. If annual shifting ice formation occurs in shallow rocky areas, construction of a permanent intake can be almost impossible, and it can be necessary to combine storage facilities with a replacable temporary intake. Where soil conditions permit, a permanent underground line extending to an intake crib may be used (Ref. 33).

In the polar regions, where ice and snow are used, chlorination of the end product is normally the only treatment applied. Glacial ice is normally pure and does not require treatment. Few sources of fresh water will be found in the Antarctic. As Captain Hedblom, USN, states it (Ref. 40), "The few summer lakes or ponds which are found away from inhabited areas are believed to be safe for drinking though esthetically they may not be too palatable because Skua gulls have dirty habits." Most surface supplies and some ground waters will require clarification in addition to routine disinfection. General principles of treatment are similar to temperate climate practice in northern midwest cities in the United States. Increased viscosity and lowered chemical reaction rates are the principal physical changes with near-freezing water. Treatment processes generally are slowed by low-temperature water, although filtration may be more effective because of the increased viscosity. Because of the need to operate in heated enclosures, a process should be selected to give the desired treatment efficiencies in the shortest time and in the least space. Often, pretreatment of water (together with the relatively large units needed) may be eliminated by the use of diatomaceous earth filters. Filters made of plastic should not be used where the raw water is from snow melters, because the heated water will warp the filter elements (Ref. 33).

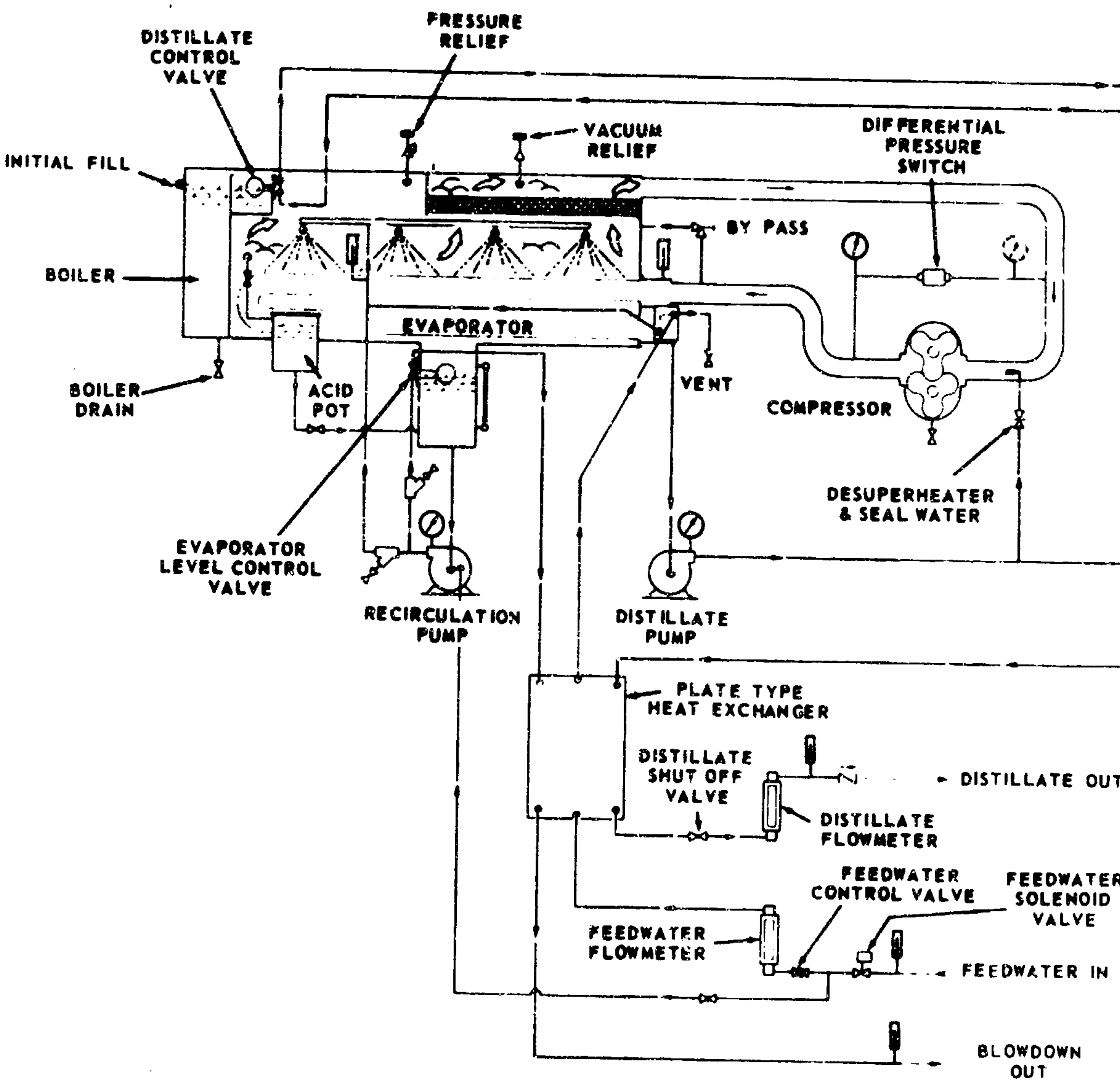


Figure 19. Schematic of Aqua-Chem Vapor Compression Distiller

Table 10

Flow Ratio Table for Aqua-Chem Vapor Compression Distiller

Flow	Type	Freshwater units				Saltwater units			
Size	GPH	200	300	400	600	200	300	400	600
	GPD	4,800	7,200	9,600	14,400	4,800	7,200	9,600	14,400
Feedwater	lb/hr	1,834	2,750	3,666	5,500	3,333	5,000	6,666	10,000
In	GPM	3.66	5.50	7.32	11.0	6.66	10.0	13.33	20.0
Blowdown	lb/hr	167	250	333	500	1,666	2,500	3,333	5,000
Out	GPM	.33	.50	.66	1.0	3.33	5.0	6.66	10.0
Distillate	lb/hr	1,666	2,500	3,333	5,000	1,666	2,500	3,333	5,000
Out	GPM	3.33	5.00	6.66	10.00	3.33	5.00	6.66	10.00

Ratios:

Freshwater units: 11 parts feedwater, 10 parts distillate, 1 part blowdown

Saltwater units: 2 parts feedwater, 1 part distillate, 1 part blowdown

f. Storage and Water Distribution

Combat troops require a different approach to water service, as their units vary in size, location, and remoteness. Water is stored in various containers. The canteen, which is a personal issue item, is carried by the individual. Some small units still use the eight-faucet, 36-gallon, lyster bag supported by a tripod arrangement or hung from a tree. Most company-size units in the field are authorized a 1-1/2-ton, two-wheel, 400-gallon water-tank trailer which is pulled to the bivouac area by a 2-1/2-ton truck (Ref. 46).

In the field, motor vehicles replace the normal water distribution system of fixed installations. Water tank trailers or a truckload of 5-gallon water containers (figure 20) are filled at the water point and delivered to the bivouac area. As noted before, certain size groups utilize tank trailers for storage and dispensing of water. The lyster bag, when used, might be filled from the tank trailer or easy-to-handle 5-gallon cans.

Collapsible pillow tanks have been used for the transportation of potable water in air transports, to various points in South Vietnam. These tanks hold 3000 gallons of water apiece. One pillow tank weight 190 pounds empty and when full of water is 12 feet 4 inches long, 12 feet 4 inches wide, and 3 feet 8 inches high.

Fixed installations have normal water distribution systems but, because of the conditions under which most installations were built, the water delivery system might be makeshift. Scarcity of construction materials causes a "use what you can acquire" condition, so pipe sizes, type of pipe material and fittings, etc., produce a working system, but not necessarily constructed as a stateside system would be built.

Water storage may be in the collapsible type tanks (figure 21) or metal tanks. The tanks may be elevated on a wooden platform to provide a gravity feed system or pumps may be employed.

In Bermuda, Kindley Air Force Base has a dual water system and uses some 25 miles of water mains. For all sanitation and fire protection requirements, sea water is used. This of course necessitates dual mains, dual pumps, and dual internal plumbing (Ref. 56).

Water distribution is a critical problem in polar station design because of the expense of installation and the danger of freezing lines. Three types of distribution systems are possible, depending on terrain and climate. If the

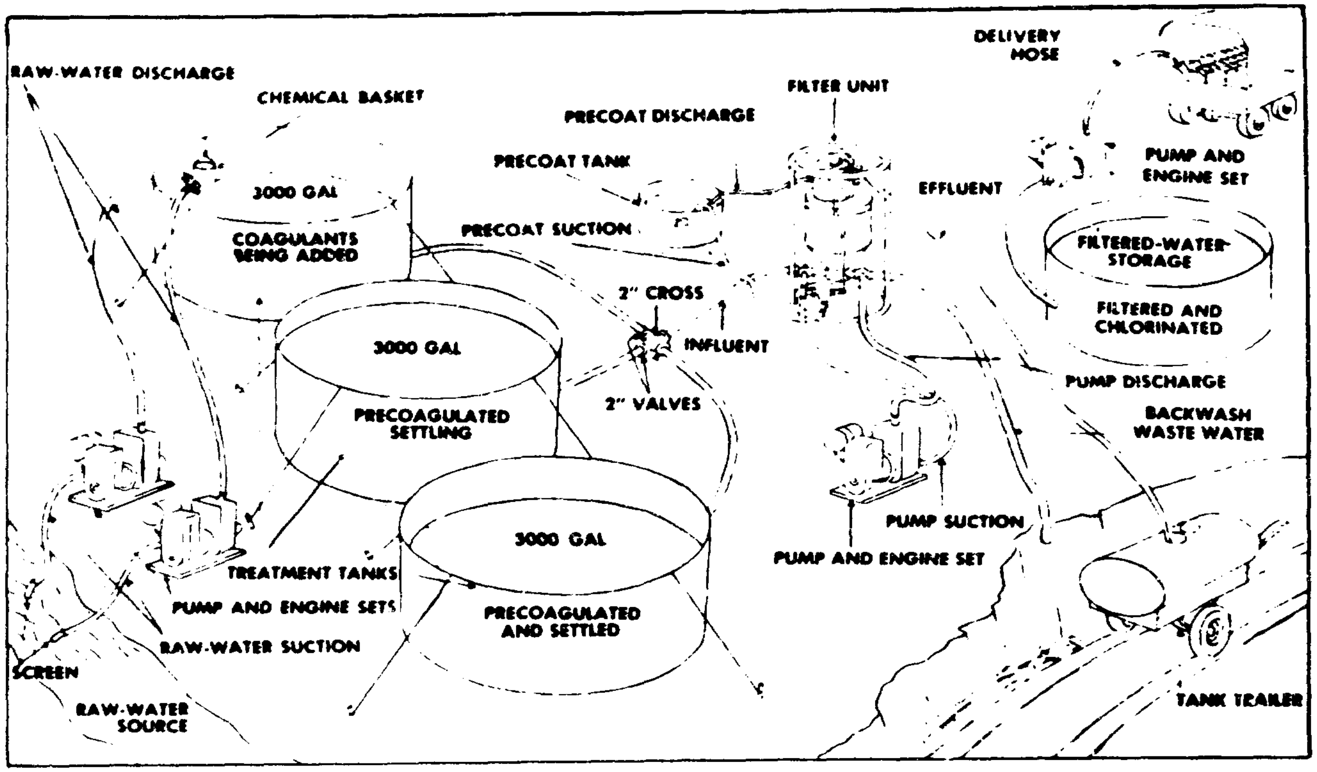


Figure 20. Water Point, 3000 GPH, Base Mounted Water Purification System Layout

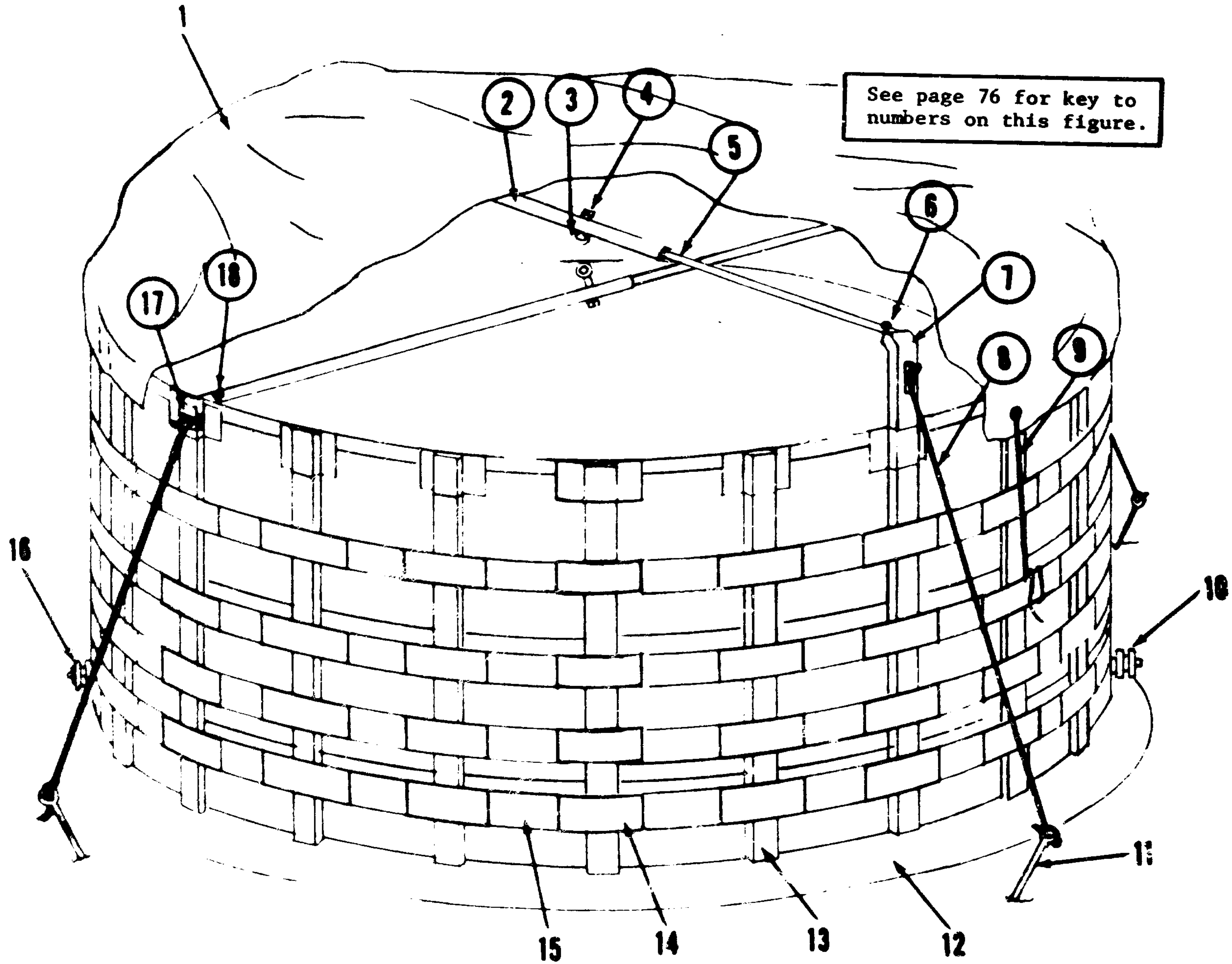


Figure 21. 3000-Gallon-Capacity Fabric Tank

Key to Figure 21

1. Top cover
2. Outer support tubes (two required)
3. Eyebolts, 3/8-20 x 1-1/2 inch (two required)
4. Nuts, square head, 3/8-20 (welded to outer support tube, two required)
5. Inner support tubes (two required)
6. Rivet pins, 1/4 x 11/16 inch (four required)
7. Long stave caps (two required)
8. Guy ropes, 1/2 inch x 10 feet (four required)
9. Top cover ropes, 1/2 inch x 6 feet (six required)
10. Female hose outlet
11. Wood test pins (four required)
12. Ground cloth
13. Wood staves (twenty required)
14. Stave pockets (twenty required)
15. Fabric, tank, 3000 gallon
16. Male hose outlet
17. Short stave caps (two required)
18. Cotter pins, 1/16 x 1/2 inch (four required)

terrain allows excavation, and a nonfreezing layer exists between permafrost and winter-freezing ground, a distribution system of plain pipes can be laid with relative ease. If excavation is possible, but hard freezing occurs where the pipes must be laid, a distribution system based on heat conservation with insulation, controlled circulation, and preheating is necessary. Absolute assurance must be provided that no surface or subsurface melt water will enter the trench. If excavation for lines is impractical at the station site, above-ground insulated lines may be necessary (Ref. 33). Water pipes wrapped with heat tapes are used at smaller installations such as the remote US Air Force sites. Fairbanks and Unalakleet use circulating water systems which continuously pump and reheat the water in the system to prevent freezing. Utilidors, heated enclosures containing the water system and other utilities, either underground or supported above the ground, have been used successfully at Inuvik, Northwest Territories, and the larger military installations in Alaska (Ref. 62).

At Thule Air Force Base, Greenland, where the winds reach 100 miles per hour and the temperatures fall to minus 50°F all utility piping is above ground. Pipes are not buried because permafrost begins about a foot below the ground surface. Wherever possible, electric, steam, condensate, water, and sewage lines are run parallel to each other. These lines rest on sleepers laid on the ground. All piping is insulated with a 3-inch-thick rigid foam glass insulation and then a 16-gage sheet metal jacket is banded over the insulation to protect it from the elements and to hold it in place.

Electric heating is used to keep the pipes from freezing. Their entire length is heated by MI (mineral insulated) cable. Two separate No. 12 cables are taped to the outside of the metal pipe and emit 9 watts (30 BTU per hour) per foot of cable with 480 volts applied. One cable is used for emergency use and the second one for normal use. Power stations housing a 50-kva single-phase transformer are set about a mile apart. Water is obtained from a lake 5 miles from the site and an emergency generator is installed in the pump house which can be started in the event base power fails. Heat to all water lines is automatically turned on or off by a thermostat but manual operation can be used. A warning system is also incorporated. Average power consumption during the winter for heating 3000 feet of 8-inch water main is 24 kwh; 12 kwh per hour are required for 3000 feet of 4-inch pipe (Ref. 63).

Other methods of distribution are used which could be described as primitive. One method used is by tractor pulling a snow melter and reservoir on a sled to dispense water into containers at each building. Another method used in some camps is to locate the snow melting apparatus within the various buildings; the snow is delivered in trucks and placed in hoppers of the snow melter. In those camps that use sea water, dual systems are used; one system for treated water and the other system for fire protection and sanitary use.

The quantity of water to be stored depends upon the type of source and whether or not any reliance for fire protection is to be placed on the water system. In addition, a reserve must be established, and the type of supply will be a major influence in establishing this reserve. The minimum storage, in addition to that for firefighting, should be a 2-day supply. If water intake or pumping facilities are subject to prolonged interruptions by ice movement, storms, or other difficult conditions, additional storage capacity may be necessary. Small storage tanks can be insulated and a small heated enclosure used to protect components. Particular attention must be paid to design of foundations to ensure structural stability and to prevent heat flow to the permafrost (Ref. 33).

Some study has been made on large storage tanks for use under arctic conditions. At the request of Headquarters, US Alaskan Air Command, the Environmental Engineering Section of the Arctic Health Research Laboratory, USPHS, conducted a study of the heat balance of the 2-million-gallon water storage tank at Kotzebue US Air Force Station. The objective of the study was to develop design and operating criteria for water tanks in the arctic (Ref. 62)

g. Specifications

Listed below are the Military Specifications which partially cover field-type purification systems and accessories.

MIL-D-5850D	31 July 1964	Distillation kits, sea water, solar
MIL-M-52016A	13 May 1965	Melter, Ice and Snow, direct fired, wick-type, base-mounted, 25 GPH
MIL-P-3641A	8 April 1965	Pumping and hypochlorination unit, frame-mounted, gasoline engine-driven, 50 GPM
MIL-W-52116	22 April 1966	Water purification unit, cargo-body-mounted, electric-motor-drive erdalator-type clarifier, diatomite-type filter, 600 GPH
MIL-W-52187A	28 September 1964	Water purification plant, semi-permanent, electric motor-driven, erdalator-type clarifier, sand filters, 10,000 GPH
MIL-B-273B	17 August 1965	Bag, water sterilizing: cloth, cotton duck, porous
MIL-F-1128B	13 December 1965	Filter unit, water purification, frame-mounted, diatomite, 15 GPH
MIL-F-4556	13 December 1965	Filter, water, portable, diatomite, 50 GPH
MIL-D-38362 (USAF)	9 February 1965	Demineralizer, water A/E32U-5, portable, 300 GPH capacity
MIL-W-5248A	17 May 1967	Water purification unit, electric-motor-driven, erdalator-type clarifier, diatomite-type filter, van-body-mounted, 1,500 GPH
MIL-W-52492A	11 October 1967	Water purification unit, electric-motor-driven, erdalator-type filter, base-mounted, 3000 GPH
MIL-D-15691	10 July 1964	Distillation units, water, thermo-compression, diesel or gasoline engine driven, skid or trailer mounted, 60 to 1,000 GPH

h. Personnel

See Section II.1.g.

i. Water costs

The worldwide dispersal of service bases, posts, stations, and camps costs money over and above the normal costs to house troops in a conventional manner. A few examples are presented here to show how much water does cost and to illustrate that water is not cheap, because in some places it is not plentiful.

In remote areas, water costs are high in comparison to what residents must pay in a United States city. The City of Albuquerque, New Mexico, is a typical Southwestern city which changed its water rates effective 1 November 1968. Being in the arid Southwest, the city has a two-rate system to encourage beautification of the residential areas. The summer rates are reduced from the winter rates during the planting and growing season of 1 May to 30 September. Table 11 was published by the city to educate the residents of Albuquerque to the new rates and to compare them to the old rates. During the summer months the residents will pay approximately 0.0005 cent a gallon for water and about 0.0007 cent a gallon during the winter. This, of course, will vary according to the size water service and meter one has.

In a paper presented by Stanley L. Cohen, CPA, he stated that the average price for minicipal water (which represents 80 percent of all water utilities) is about 30 cents per 1000 gallons at the tap or 0.0003 cent per gallon (Ref. 64).

The Navy estimates that in using distilled water for a 25-man polar camp the cost for a gallon of water is 15.8 cents. For a 100-man camp the cost is reduced to 5 cents a gallon. The cost of using snow melt water for a 25-man camp is 7.8 cents per gallon, while for a 100-man camp, it is 6.2 cents a gallon. See table 12 for the breakdown of these estimated costs (Ref. 65).

At Kindley Air Force Base, Bermuda, the estimated cost of catchment rainwater and processing it for human consumption is $6.00/1000 gallons or 0.006 cent per gallon. The original desalting equipment at Kindley produced fresh water for approximately 0.0074 cent a gallon. This was reduced to 0.0055 cent a gallon when a vapor-compression unit was added. With the addition of the flash evaporator the average cost per gallon was reduced to 0.003 cent per gallon (Ref. 58). This remains a factor of 10 above the average cost of a gallon of water in the United States.

3. CONCLUSION

The desirability of potable water for the troops was known even to the Roman Armies. Zinsser (Ref. 66) writes,

> "An indication of the frequent occurrence of camp disease in the Roman armies is found in Vegetius's De Re Militeri dedicated to Valentinian about 375 A.D. "An Army must not use bad or marshy water, for the drinking of bad water is like poison and causes plagues among those who drink it. If a large group stays too long during the summer or autumn

Table 11

City of Albuquerque, Water and Sewer Rates

CITY OF ALBUQUERQUE
WATER AND SEWER RATES

EFFECTIVE: NOVEMBER 1, 1968

WATER

OLD RATES (Per Month)

Basic Rate

1st 5,000 gal. for $1.50
5,000 - 18,000 gal. @25¢/1,000
18,000 - 90,000 gal. @22½¢/1,000
all over 90,000 gal. @17½¢/1,000

Industrial @17¢/1,000 gal.

Outside City Limits

1st 6,665 gal. for $3.00
6,666 - 18,000 gal. @60¢/1,000
18,001 - 90,000 gal. @50¢/1,000
all over 90,000 gal. @40¢/1,000

Residential summer garden rates

(May 1 - September 30)

1st 5,000 gal. for $1.50
all over 5,000 gal. @19¢/1,000

NEW RATES (Per Month)

(Effective with November, 1968 billing)

Basic Rate

Meter Size	Monthly Minimum Use: Gal.	Cu. Ft.	Amount
5/8" X 3/4"	3,000	400	$ 1.50
1" & 1" X 1¼"	4,000	535	3.00
1½"	7,500	1,000	6.50
2"	22,500	3,000	15.00
3"	36,000	4,800	25.00
4"	54,000	7,200	45.00
6"	69,000	9,200	75.00
8" & over	75,000	10,000	115.00

Rate for all use over minimum

24¢/1,000 gal. (133 cu. ft.) up to 30,000 gal. (4,000 cu. ft.)

22¢/1,000 gal. (133 cu. ft.) from 30,000 gal. to 90,000 gal. (4,000 cu. ft. to 12,000 cu. ft.)

20¢/1,000 gal. (133 cu. ft.) from 90,000 gal. to 1,000,000 gal. (12,000 cu. ft. to 133,600 cu. ft.)

18¢/1,000 gal. (133 cu. ft.) over 1,000,000 gal. (133,600 cu. ft.)

Additional residential meter - one minimum charge on largest meter only, rate computed on combined volume - sewer charge computed on household meter only.

Summer Garden Rates (April 1 - October 31)

25% off the regular rate for all water used over the median amount of the 5 months from November to March, up to 1,000,000 gal. per month.

SEWER

Old rates

Basic Rate

For 1st 4 outlets $1.05
Next 21 outlets @20¢/outlet
Thereafter @5¢/outlet

New rates

Basic Rate

50% of the water bill, with a $1.25 minimum monthly bill on all accounts

Maximum rate (April 1 - October 31)

Monthly bill no higher than the median sewer bill of the 5 months from November to March

OUTSIDE CITY LIMITS

Twice the basic rate for both water and sewer

Table 12

Estimated Water Costs at a Polar Camp

Distilled water	25-man camp	100-man camp
Water distilled (gal/year) (25 gal/person/day)	230,000 $	900,000 $
Distillation unit (cost/year)	10,000 (85 gph)	15,000 (200 gph)
Labor (1-1/2 man-years/year)	18,000	18,000
Repair parts	2,000	2,000
Fuel ($1 per gal) (economy 200:1)	1,300	5,500
Shelter expense	5,000	5,000
Total	36,300	45,500
Cost per gallon	15.8	5

Snow melt water		
Water used (gal/year)	230,000	900,000
Equipment cost	5,000	15,000
Labor ($12,000 per man-year)	6,000	18,000
Repair parts	1,000	2,000
Fuel (direct melting - $1.00/gal)	2,800	11,200
Shelter expense	3,000	10,000
Total	17,800	56,200
Cost per gallon	7.8	6.2

in one place, the water becomes corrupt, and because of the corruption, drinking is unhealtny, the air corrupt and so malignant disease arises which cannot be checked except by frequent change of camp.'"

These people realized something was wrong with the water and they knew of the pollution caused by the troops but their only solution to the problem was to move. The Chinese and Egyptians knew thousands of years ago that to put alum in tubs of water would clarify it. They also knew to keep water in vessels, expose it to the sunlight, and filter it through charcoal. It was not until the 19th century that James Simpson, an Englishman, constructed the first modern filter. Mid-nineteenth century saw the treatment of water to remove pathogenic organisms (Ref. 7).

Water treatment has rapidly developed since the 19th century but there is much to do yet in reducing treatment costs and to develop inexpensive methods of removing various mineral contents that cause expensive repairs and extensive maintenance to distribution mains, boilers, house systems, steam lines, and water heaters.

Corrosion causes the replacement of 3 million home hot water heaters a year in the United States. Approximately 8 billion dollars a year is spent in the United States on corrosion-caused repairs, replacements, and protection against corrosion damage (Ref. 67). The Air Force estimates that maintenance and repair costs 25 million dollars a year because of corrosion.

In the field, obtaining supplies to maintain a base is a logistic problem. But a preplanned distribution system comprised of modular packages of quick-connect and disconnect pipe and fittings designed on a capacity or population basis would be of great help to the installation engineer overseas. Easy to erect and maintain elevated water storage vessels, mobile packaged lift stations, and self-contained pumps would be an aid to the engineer. As it is, the present water storage facilities and distribution systems, in many instances, depend greatly upon the ingenuity of the installation engineer and his ability to cumshaw materials.

Rapid troop buildup in the Southeast Asia theater is a prime example of the taxing and complex problems that the installation engineer has to cope with. The base at Da Nang is an example of rapid growth. The Air Force maintained a small advisory group there until 1964 when the base population grew rapidly from less than 500 to a small community of 25,000 in 1966. Construction was slowed down by utilizing standard materials, when available, coupled with native labor that lacked training (Ref. 55).

There is much needed work to be done to improve the distribution systems and storage of water in the Arctic regions. Comfort stations could be greatly improved.

All in all, the field of water supply has advanced greatly since the days of the Roman Army and the 19th century but almost every facet of military water supply and treatment can be improved upon.

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SECTION III

SEWAGE DISPOSAL AND TREATMENT

1. INTRODUCTION

As in Section II, this section summarizes the state of the art in conventional sewage disposal and treatment systems and systems used at special installations.

Some installations are equipped to process sewage through primary and secondary treatment as well as chlorination of the effluent. Other installations only process the sewage in the primary phase before it is disposed of, while some reservations have no treatment at all and dump raw sewage directly into a carriage medium. Others are connected directly to a municipal system.

2. CONVENTIONAL BASE SEWAGE SYSTEMS

a. Sewage Flow Determination for Collection Systems

The average quantities of sewage per capita for different types of posts and classes of installations are given in table 13. The ratios of the extreme rates of flow, which occur occasionally, to the average rates of flow are indicated in figure 22.

Additional capacity to provide for population increases is not considered for lateral and branch sewers where the areas served are fully developed. In the design of long outfall sewers and main sewers serving areas that are likely to continue to develop, provision of approximately 25 percent additional capacity over the computed initial requirements is allowed.

There are exceptions to the general rule that sewers are designed entirely on a population bases. Among these exceptions are industrial-waste sewers, laundry sewers, and house connections.

Included in the industrial-waste category would be: ordnance plants, experimental laboratories, airplane washracks, plating shops, and such industries which cannot be designed on a population bases. The flows from such plants depend upon the type and extent of the activities. Cooling water and similar unpolluted waste waters are not generally discharged into industrial-waste sewers leading to treatment works. Sewers serving one or more aircraft washracks are designed for a

Table 13

Table of Per Capita Sewage Quantities

Type of post	Permanent posts	Theater of operation camps	Field training camps
Hospitals (including station hospitals)	100	85	70
All other types of posts - air fields, forts, camps, depots, plants, etc.	100	50	35
All types	30 gallons per 8-hour shift per non-resident or worker in an industrial area (90-gallon per day rate)		

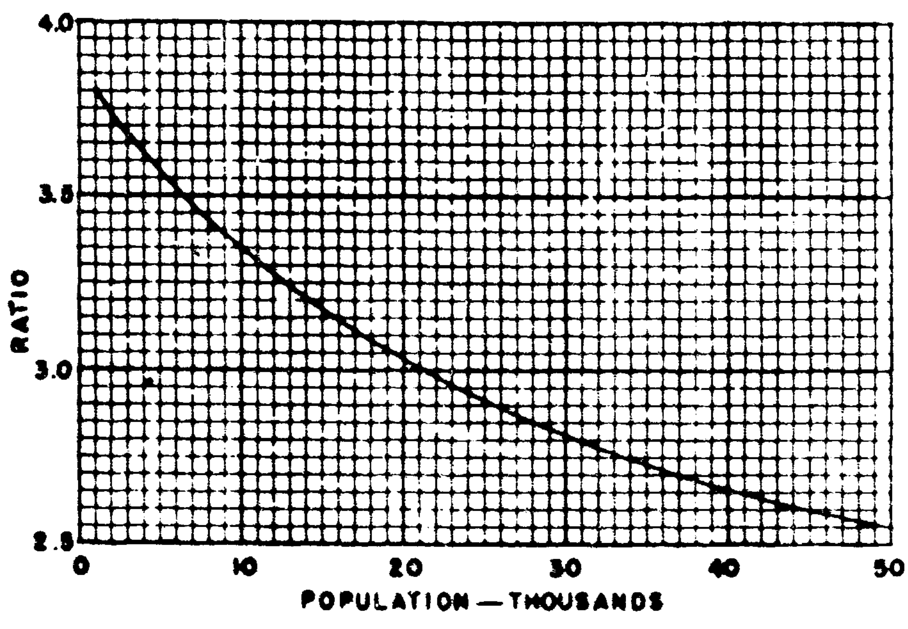

Figure 22. Curve Showing Ratio of Peak Flow to Average Flow

peak rate of flow of 75 gpm for each washrack served. Other industrial-waste sewers will be designed for the peak flow as determined for the particular activity. Sewers serving aircraft washracks and other industrial uses will be designed for the combined peak flows. Outlet sewers from treatment works will be designed for the peak rate of treatment contemplated in the design of the treatment plant. The pipe size should not be less than 6 inches diameter for any industrial-waste sewer.

For sewers serving laundries, capacity to discharge the waste from one-third the number of washers when completely emptied in 2 minutes plus the back-wash from one of the water softeners is required. When the laundry sewer connects to a relatively small main, branch, or lateral, the influence upon the peak flows in such sewers might require consideration. This might apply to trunk and outfall sewers if the laundry serves more than one post and is considerably larger than would be required if it served only the one post. These cases are to be considered individually.

The size of house connections, including those from mess halls, theaters, clubs, and other such buildings is in all cases large enough to discharge the flow computed on a fixture-units basis as set forth in the manual on plumbing (Ref. 68).

AFM 85-20, "Installation-General-Plumbing" presents the following information on fixture-unit calculations (Ref. 69).

> To select the proper-size sewer service connection and building drain, the maximum discharge of the complete plumbing installation of the building must first be calculated. The maximum discharge is equal to the sum of the fixture units discharging into the drainage system. One fixture unit corresponds to the 7-1/2 gallons or 1 cubic foot of water which an ordinary lavatory would discharge into the drainage system in an interval of 1 minute. All other fixtures commonly used in plumbing installations have been tested, and the unit value of these fixtures has been established as multiples of the fixture unit. Table 14 shows the fixture unit values of various plumbing fixtures.
>
> After the fixture units of a plumbing system have been totaled to obtain the maximum discharge, the total fixture unit value must be translated into building pipe size. This may be accomplished by using table 15, which prescribes sanitary capacities in terms of fixture units. For example, if a plumbing installation has a total fixture unit value of

Table 14

Fixture Unit Values

Fixture	Private	Public
Water closet, flush tank	6	10
Water closet, flushometer	6	10
Urinal	-	5
Lavatory	1	2
Kitchen sink	2	4
Slop sink	-	3
Laundry tub	2	4
Floor drain	1	2
Shower	2	4
Bathtub	2	4
Garbage grinder	1	1

Table 15

Sanitary Sewer Capacities in Fixture Units

Diameter of pipe (inches)	Fall of pipe per foot (inches)			
	1/16	1/8	1/4	1/2
2	--	--	21	26
2-1/2	--	--	24	31
3	--	--	27	36
4	--	180	216	250
5	--	390	480	575
6	--	700	840	1,000
8	1,400	1,600	1,920	2,300
10	2,500	2,900	3,500	4,200
12	3,900	4,600	5,600	6,700
15	7,000	8,300	10,000	12,000

> 303 units, and assuming a 1/4-inch fall per foot on the sanitary sewer, the correct sewer service connection and building drain size will be a 5-inch diameter case iron soil pipe.

This requirement applies to house sewers only and not to the lateral or other sewers to which they connect.

W. A. Hardenbergh states in his chapter on "Design of Sanitary Sewers" that the more important factors which must be considered in estimating the required capacities of the sewers are the probable increase both in the population and occupied area of the community; the estimated quantity of water used for domestic and industrial purposes, whether from public or private sources; the water pressure maintained in each sewage district; the probable amount of ground-water infiltration into the sewers; and the number of years for which the system is expected to serve.

Generally, the daily domestic consumption will average around 100 gallons per person, but may be more or less. Although conditions vary greatly, it is not unusual to find that about 60 to 70 percent of the public water supply reappears as domestic sewage. The remainder is used in industrial processes and for such purposes as sprinkling lawns, washing streets, and putting out fires, or is lost through leakage (Ref. 70).

Fair and Geyer note the requisite capacity of sanitary sewers is determined by the tributary domestic and institutional population, commercial water use, industrial activity, height of ground water table, and enforcement of rain-water separation. It is generally found convenient to arrive at unit values of domestic sewage on the basis of the population density and area served but it would also be possible to develop figures for the number of people per front foot in districts of varying occupancy and make sewer length rather than area served the criterion of capacity design. Length (sometimes coupled with diameter) of sewer offers the more rational basis for the estimation of ground-water infiltration. Unit values for flow from commercial districts are generally expressed in terms of the area served.

In determining the required capacity of collection for basis of water consumption: an average day 95 gpcd; maximum day 175 percent of average; maximum hour 140 percent of maximum day is used. To calculate domestic sewage use 70 percent of water consumption with a maximum 285 gpcd for 5 acres decreasing to 245 gpcd for 100 acres or more (Ref. 71).

b. Sources of Waste

"Waste" is defined in many ways. It can be defined as excreted from the body as useless or superfluous material; left over, refuse, or no longer of use (Ref. 72); or in terms of pollution of water or water quality (Ref. 73). However, for this paper, the term "waste" will be used as covering all types of refuse resulting from the living activities of humans (Ref. 74).

Waste resulting from the living activities of humans may take many forms directly or indirectly depending upon the waste product. Sewage is one of the waste products and is defined as the liquid waste of a community (Ref. 70). It consists of wastes from toilets, baths, sinks, lavatories, and other plumbing fixtures in residences, institutions, and business buildings; certain wastes from various types of manufacturing or industrial plants; and in many communities, the runoff from the streets and other surfaces that results from storms or street-flushing operations.

Sewage, then, may be classified according to its source, as follows: That from residences, institutions, and business buildings is domestic sewage; that resulting from manufacturing or industrial processes is known as industrial waste or trade waste; and that from runoff during and immediately following storms is called storm water or storm sewage.

Domestic sewage ordinarily consists of the water that has been used for bathing, washing dishes or clothing, flushing toilets, and garbage disposal units and other household purposes. It normally contains 1 to 2 parts per thousand of such solid materials as excrement, soap, grease, small particles of garbage, and rags. About half of this solid material is in solution and half is in suspension or floating (Ref. 70).

Industrial wastes are liquid wastes derived from industrial activities as distinct from domestic or sanitary sewage. These wastes vary widely in strength, character, and composition, so much so that they may interfere with biological treatment processes of the sewage. Some of the most prevalent sources of industrial waste on a military reservation are: ordnance plants; all phases of aircraft and motor vehicle cleaning, repairing, remodeling, and repainting during which cyanide, cadmium, and other toxic materials are produced; washracks, oil, grease, gasoline, and other obnoxious cleaning fluids that are associated with aircraft and vehicle maintenance; photographic processing which may contain many different chemicals--acids, alkalies, cyanides, salts, chromates, heavy metals, bromides, and organic compounds; wastes produced from electroplating processes; radioactive wastes; pharmaceutical wastes; printing and wastes from reproduction processes; metal plating wastes; laboratory slaughterhouse-type waste; and detergent wastes. Almost any industrial waste found in commercial industry can be found to some extent on various military establishments; and the mission of that establishment governs the amount of such waste.

c. Treatment Requirements

Sewage treatment and disposal is the concern of Military Civil Engineering programming, construction, operation, and maintenance personnel.

Sewage disposal is one of the Air Force activities which is very much a concern to the local civilian authorities. It is a neighborhood problem, and the Air Force must maintain its standing as a neighbor. Thus, the Air Force cooperates with state and local authorities responsible for public health and water pollution control in determining the type of sewage treatment facilities and the method and degree of treatment, and in operation of plants, to achieve the desired results. The key word here is "cooperates." The Air Force is not in a subordinate position. There are good reasons for this. If it is agreed that any state may direct the Air Force to take specific action in one activity, it follows that it could do likewise in other areas or activities, which possibly could interfere with national defense (Ref. 75).

The Navy in their way of cooperation with the state or local governments state the following in the manual NAVDOCKS MO-212:

> Personnel in charge of maintenance and operation at Naval sewerage works are thoroughly familiar with Federal, State and other regulations to control stream pollution. In most instances, Navy treatment plants have been designed to meet the minimum requirements of the State Board of Health with respect to the allowable quality of effluent to be discharged into inland or tidal waters. Liaison is maintained with the Bureau of Medicine and Surgery, the United States Public Health Service, and state and municipal authorities in all matters pertaining to pollution prevention for water supplies, shellfish-harvesting areas, and recreational waters, including the related odor and fly nuisances (Ref. 76).

The Army and Air Force manuals are in most instances joint-use documents and reflect the position of cooperation by stating that installations may submit plans and specifications of the proposed facilities to state or local authorities for information or comment, but not for approval.

The Federal Water Pollution Control Act, as amended by the Water Quality Act of 1965, authorizes the states and the Federal Government to establish water quality standards for interstate (including coastal) waters by 30 June 1967. This placed a state in a peculiar position, as in establishing standards it had no way of directing a military establishment to update its disposal system.

On 22 October 1968, a memorandum of agreement between the Department of Defense and the Federal Water Pollution Control Administration of the Department of the Interior was put in effect. It is designed to meet the requirements of Section 2(b) of Executive Order 11288(31 F. R. 9261, 7 July 1966) and of Section 807 of the Military Construction Authorization Act of 1969 (P. L. 90-408). Edward J. Sheridan, Deputy Assistant Secretary of Defense for properties and installations signed for the DOD, while Joe G. Moore, Jr., Commissioner, signed for the FWPCA.

The agreement circumvents a sticky situation between the military establishment and the state. It honors the position of the military by placing the FWPCA as the go-between and as consultant to the military. Among the other provisions in the agreement, the following appears to substantiate best the above stand.

> "It is the responsibility of FWPCA to evaluate pollution abatement programs in areas around DOD installations and to advise DOD (a) whether the degree and type of waste disposal and treatment required in such areas are consistent with applicable Federal or State water quality standards or other requirements and (b) whether the water pollution control measures proposed for each military installation will be coordinated with a state, county, or municipal program."

The pertinent provisions of Executive Order 11288 and P. L. 90-408 are as follows:

> Executive Order 11288
>
> Sec. 2. Procedures for new Federal facilities and buildings. (b) Prior to any solicitation of bids for reconstruction of any such new facility or building a description of the essential features of the water pollution control and treatment measures proposed for the project shall be submitted to the Secretary of the Interior for prompt review and advice as to the adequacy and effectiveness of the measures proposed and for advice as to any related operating procedures and continuing laboratory examinations deemed necessary to ensure effective plant operation.

P. L. 90-408

> Sec. 807. None of the funds authorized by this Act or by any military construction authorization Act hereafter enacted shall be expended for the construction of any waste treatment or waste disposal system at or in connection with any military installation until after the Secretary of Defense or his designee has consulted with the Federal Water Pollution Control Administration of the Department of the Interior and determined that the degree and type of waste disposal and treatment required in the area in which such military installation is located are consistent with applicable Federal or State water quality standards or other requirements and that the planned system will be coordinated in timing with a state, county or municipal program which requires communities to take such related abatement measures as are necessary to achieve area-wide water pollution cleanup.

The agreement also covers procedures for FWPCA visits to existing facilities, on which improvements to prevent or abate water pollution are provided for in Section 3 of Executive Order 11288.

The preceding discussion of the agreement between the DOD and the FWPCA has not affected the various manuals and regulations of the services as yet. Letters of direction have come from higher headquarters concerning the agreement which affects the Military Construction Program, but as far as documentation of printed manuals and regulations is concerned, they are still in effect, with the letters as guidance. So for any future Military Construction Programming of any installation the Department's manuals and regulations must correlate the documents with the letters of direction. Again, it takes time to bring the published manuals and regulations up to date.

Major commands maintain surveillance of sewage treatment plant operations. Plant operations are recorded daily for proof of proper operation. Records are required to be kept for the life of the plant according to the Records Management Manual, AFM 181-4. State agencies may be given one-time reports, but routine or continuous submission of reports is not authorized. This is, again, to prevent the Air Force from coming under surveillance by a state agency. Representatives of local authorities may visit AF sewage treatment plants, accompanied by a representative of the Base Civil Engineer. Recommendations of state agency representatives may be accepted, but not as directives. In this connection, a problem has occasionally arisen in that base personnel have accepted such recommendations as being mandatory. Base personnel are advised to consult higher authority for validation of requirements before complying with recommendations from any local agency (Ref. 75).

Determination of the degree of treatment to be used in the design of sewage-treatment works requires two main considerations. The first is the protection of the health of the command and of the community and the prevention of damage to the property of riparian owners. The degree of treatment required to accomplish this will depend upon the amount of diluting water in the stream during periods of minimum flow, the condition of the stream as regards pollution, and the use of the stream below the point of sewage discharge. The second main consideration is the requirements of local authorities relative to stream-pollution abatement. Policy, as established by Executive Order No. 10014 and implemented by C2AR 415-105, AFR 88-10A, requires cooperation with state authorities having statutory authority in stream-pollution control. Accordingly, when an Army or Air Force installation is discharging or proposes to discharge liquid wastes into state-controlled waters and the state authorities have established standards of purity that might be necessary to conserve the water of such stream for public water supply, propagation of fish and aquatic life, recreational purposes, or agricultural industrial, and other legitimate uses, the Department of the Army or the Department of the Air Force, as appropriate, will, so far as practicable, take action parallel to that required of the local communities and industries. When new facilities for the treatment of sewage or other liquid waste are proposed, the state authorities will be consulted relative to locally established standards. When requested by state authorities, plans for proposed facilities may be furnished for information (except when such action would violate security regulations), but are not subject to review and approval by state agencies. Where state authorities require local communities to recharge sewage-treatment-plant effluent into ground-water tables as a water-supply conservation measure and request the Department of the Army or the Department of the Air Force to do likewise, the state authorities will be consulted as to recharge methods, and the practicability of complying with the request bill be determined.

Where the effluent from a sewage-treatment plant is to be discharged into a stream where dry-weather flow is equivalent to at least 4 cubic feet per second per 1,000 persons served by the plant, or is sufficient to provide a dilution ratio of 25 to 1, primary settling, chlorination of the effluent, and sludge digestion and disposal will usually be adequate treatment for the prevention of a nuisance. Primary treatment may also be sufficient where the effluent is to be discharged into tidal waters or disposed of by irrigation. Primary treatment will usually remove from 30 to 40 percent of the biochemical oxygen demand and from 50 to 60 percent of the suspended solids. The percentage of removal can be considerably increased by the use of coagulants, that is, by chemical precipitation. This would be particularly applicable to the treatment of industrial wastes, but is not recommended for general use at Army camps in view of occasional difficulties in obtaining the necessary chemicals and in view of the special training required in their use.

Secondary treatment will be provided only to the extent necessary for the prevention of stream pollution or of a nuisance. The degree of treatment produced by a given type of plant or process will vary according to the applied loading of organic matter and to its condition. The term "complete treatment" is often incorrectly and indiscriminately used in reference to any form of secondary treatment regardless of the type and of the loading. Treatment is considered to be complete only if it removes at least 85 percent of the 5-day biochemical oxygen demand and produces an effluent in which nitrification has become well established. The activated sludge process, standard or low-rate trickling filters, sand filters, or oxidation ponds will provide complete treatment if properly designed and loaded. Where more than primary but less than complete treatment is required, high-rate trickling filters can be used to advantage (Ref. 77).

d. Treatment Methods

Selection of a sewage treatment plant or a method of disposing of waste products depends upon the degree of treatment required (noted above), the geographical location, proximity of the post to a community or effluent carriage medium, mission, and population of the station. Table 16 was obtained by a random selection of Air Force bases and stations to illustrate the various methods utilized to treat and dispose the installations wastes as reported in the Water Pollution Control Report Requirements by Installation FY 1968-1972 (Ref. 78).

Table 16

Random Picked A. F. Base Annual Waste History

Base name and location	Effluent discharge location	Type waste	Discharge amount (MGD)	Type treatment
Calumet AFS (ADC) Calumet, Mich.	Eagle River	Domestic	0.032	Wet burning sewage treatment plant
Barksdale AFB (SAC) Bossier City, La.	Red River and Mack's Bayou	Domestic	1.0	None
		Washrack	0.002	
Keesler AFB (ATC) Biloxi, Miss.	Back Bay	Domestic		Secondary treatment and chlorination
		Washrack	0.003	
Little Rock AFB (SAC) Jacksonville, Ark.	City treatment	Domestic	0.97	---
		Washrack	0.003	Storm sewers
Patrick AFB (AFSC) Cocoa Beach, Fla.	Banana River	Domestic	1.80	Two activated sludge plants
		Plating waste	0.10	Plant under construction
		Washrack	0.009	Oxidation ditch
Elmendorf AFB (AAC) Anchorage, Alaska	Cook Inlet	Domestic	2.00	No treatment
Cannon AFB (TAC) Clovis, New Mexico	On-base oxidation lagoons	Domestic	0.40	Oxidation/evaporation ponds
McChord AFB (ADC) Tacoma, Wash.	Fort Lewis	Domestic	0.844	Fort Lewis treatment plant
	Clover Creek	Storm collection	---	Direct to creek

Table 16 (cont.)

Base name and location	Effluent discharge location	Type waste	Discharge amount (MGD)	Type treatment
Chanute AFB (ATC) Rantoul, Ill.	Village of Rantoul Salt Fork Creek	Domestic	0.75 1.75	Rantoul village system Secondary treatment Imhoff-trickling filter plant
Wake Island AFS (MAC) Wake Island Pac. Ocean	Pacific Ocean	Domestic	0.10	Comminutor, primary settling tank trickling filter, sludge digester
Andersen AFB (SAC) Guam, M. I.	Pacific Ocean	Domestic	1.6	None
Howard AFB (SOU) Balboa, PCZ	Bay of Panama via Rio Venado	Domestic	1.0	Two Dortmund cones w/ separate sludge digestion
Ramey AFB (SAC) Puerto Rico	Atlantic Ocean	Domestic Washrack	1.25 0.06	None None
England AFB (TAC) Alexandra, La.	Red River Rapides Bayou to Red River	Domestic Washrack	0.382 0.071	None Holding tank and oil skimmer
Driftwood Bay DEW Sta. Dutch Harbor, Alaska	Bering Sea via seasonal stream	Domestic Industrial	0.0045 0.0005	Septic tank ---
Hickam AFB (PAF) Honolulu, Hawaii	Mamala Bay, Pacific Ocean	Domestic Industrial	1.50 0.70	None None
Williams AFB (ATC) Chandler, Ariz.	Roosevelt water con. dist. pipeline by individual to irrigate private property	Domestic	0.435	Comminutor, biofilters, clarifiers, chlorinator, digester, and sludge beds

In an engineering development study of sanitary facilities in arid regions, which was prepared by Hostrup, Lyons and Associates (Ref. 79) for the Navy, certain recommendations are made for treatment methods dependent upon population, temporary establishments, mobilization establishments, permanent stations in a small group class, and temporary large or permanent large installations. Their first finding states the average volume of sewage presently required by engineering manuals is believed to be inadequate for arid regions and suggested a value of 175 gallons per capita be used. This figure is based on peak flow calculations obtained from reports submitted by a number of stations located in Arizona, New Mexico, and California. Recommendations for a particular type sewage treatment based on a per capita value of 175 gallons are as follows:

A. Stations exceeding 7500 men--Two-stage digestion.

B. Complements exceeding 5000 men--Package unit treatment plants with special reference to hospitals and wherever a high degree of treatment is necessary.

(A and B recommended for both permanent and temporary stations.)

C. Permanent installations for small groups such as weather stations--Septic tank and subsurface irrigation or subsurface filters.

D. Small mobilization camps, use-life of 2 years or longer--175-gpcd design value and for use-life of less than 2 years 100 gpcd. If station complement exceeds 200 Imhoff tanks are recommended. For smaller complements septic tanks should be used.

E. Temporary stations for very small personnel groups for short durations--Use of deep pit latrines and urine soakage pits are recommended.

The initial construction of sewage-treatment plants for Army and Air Force will be based on the authorized military and civilian tributary population, increased by the capacity factors indicated in table 17.

Table 17

Sewage Treatment Plant Design Capacity Factors

Authorized project population	Capacity factor	Authorized project population	Capacity factor
5,000	1.50	30,000	1.10
10,000	1.25	40,000	1.05
20,000	1.15	50,000	1.00

The capacity factor for populations between those indicates may be determined by straight-line interpolation. The design population is obtained by multiplying the authorized military and civilian tributary population by the proper capacity factor. The capacity factor provides for reasonable increases in population, uncertainties as to actual quantities and characteristics of the sewage, and unusual peak flows, the magnitude of which cannot be accurately determined in advance. Where additions to existing facilities are proposed, adequacy of each element of the plant for the newly authorized population will be checked without applying the capacity factor. The elements that are thus definitely determined to be deficient will be enlarged to provide total capacity for the new population and sized for proper integration into the enlarged plant. The capacity factor will not be applied in design of sewage treatment facilities for AC&W sites and similar size Air Force stations (Ref. 77).

Data on sewage characteristics at Army projects indicate larger amounts of gases and slightly larger quantities of biochemical oxygen demand than are normal for domestic sewage. The sewage reaching the treatment plant usually will be relatively fresh and have good settling qualities, and the settled sewage will be readily treatable by biological processes. Table 18 indicates the sewage characteristics to be used in plant design. ASCE Manual No. 36, Sewage Treatment Plant Design, recommends using values of 0.17 to 0.25 pound BOD_5/day as compared with the BOD as shown in table 18.

Table 18

Sewage Characteristics

Item	Resident personnel pounds per capita for 24 hours	Nonresident personnel pounds per capita for 8-hour shift
Suspended solids	0.20	0.10
Biochemical oxygen demand	0.10	0.10
Ether-soluble matter	0.09	0.05

The Air Force and Army consider a primary treatment plant to consist of the following elements:

1. screens
2. comminutors
3. grit chambers
4. measuring devices
5. primary settling tanks
6. sludge digesters
7. drying beds
8. chlorination facilities
9. plant sewers and flumes
10. laboratory and control buildings

A secondary plant consists of the primary elements plus the use of trickling filters, the activated-sludge process, intermittent sand filters, oxidation ponds, or combinations of such facilities (Ref. 77).

In small plants for populations of about 3,000 or less, an Imhoff tank is recommended for treatment. In general, septic tanks may be used to serve small or scattered installations if the effluent can be disposed of by means of subsurface irrigation without endangering a water supply, or into a convenient water course without creating objectionable conditions. This method of treatment is limited to installations where the contribution population does not exceed 500.

Sewage ponds are considered to be of two types: oxidation ponds and raw sewage lagoons. Oxidation ponds are for secondary treatment of sewage prior to discharge into a water course and in some cases are for additional treatment following other forms of secondary treatment. Raw sewage lagoons are used for the treatment of raw sewage to the full extent required; thus, in effect, combining primary treatment and secondary treatment. Their use is expecially suitable in areas where the net evaporation is high and disposal can be accomplished through evaporation and percolation without overflow to a carriage medium (Ref. 77). An excellent example of using a limited sewage disposal-facility and oxidation-pond combination for a better quality effluent, for conservation of water and beautification of a local eyesore, has been accomplished by the Santee County Water District in California (Ref. 80).

Reference 77 is now 11 years old and a number of lagoons and ponds have been built by the Federal Government in various geographical areas. State and municipal authorities have investigated this method of utilizing waste waters for the benefit of the people. The Federal Government is usually slow in adopting new methods (in all fields) because it wants to be sure it is advising the citizens the right way to go. When completed studies are furnished for evaluation, the government will make them public.

In treatment plants serving populations greater than 5,000, such elements as primary settling tanks, filters, final settling tanks, and digesters will be provided in at least two units each and with piping arranged so that any individual unit can be taken out of service. The arrangement of plant units will be such as to permit future enlargement of the plant at minimum cost and minimum interference with plant operation. Provision will be made in Army installations for the occasional dewatering of tanks to facilitate maintenance and repairs. Piping for this purpose will be as simple and economical as feasible, and equipment provided for normal operation will be utilized to the maximum practical extent. Where gravity drains are installed, adequate provision is made for ready inspection to detect improper and unauthorized bypassing of plant units. Gravity drains or other fixed facilities for dewatering of tanks are not provided in Air Force installations except when specifically authorized.

e. Design Requirements

(1) Screens

Of the two types of screens frequently used--basket and bar screens--the bar screen is recommended for use in Army and Air Force construction. Usually the manually cleaned bar screens are recommended except in special cases where their installation might not be practicable. The portion of the screen rack that would be submerged at times of maximum flow will have an area equal to at least twice the cross-sectional area of the inlet sewer. The recommended clear space between bars is 1 to 1-1/2 inches for manually cleaned screens and 5/8 to 1 inch for mechanically cleaned screens.

(2) Measuring Devices

Equipment for indicating, recording, and totalizing sewage flow will be provided for all secondary-treatment plants serving populations greater than 2,000 and for all primary-treatment plants serving populations greater than 5,000. For smaller plants, recording and totalizing equipment will not be required. If sewage is pumped into the treatment works, it should be measured ahead of the pumping station, if practicable, in order to record the hourly variations in the rate of flow In plants requiring the recirculation of sewage it is also desirable to provide meters with means for indicating the rates of recirculation. Venturi meters, weirs, and Parshall flumes have been found satisfactory for the measurement of sewage, the Parshall flume being generally preferable for military projects. Measuring devices will be designed with a view toward obtaining their maximum accuracy of measurement throughout the expected range of flows.

(3) Primary-Settling Tanks

Primary-settling tanks normally will be of the flat-bottom type, either rectangular or circular, with mechanical sludge moving equipment. Hopper-bottom tanks, if used, will be confined to small installations. Primary-settling tanks will have sufficient volume to provide a detention period based on average hourly rate of flow through the tanks including recirculation as follows:

In activated-sludge plants	1.5 hours
In all other types of plants	2.5 hours

For plant, port, and storage projects, where the contributing population is largely nonresident, the detention period to be used in design is 2 hours, based on the hourly rate for the 8-hour period of maximum use.

The optimum side-water depth of a settling tank normally will be from 8 to 10 feet. The inlet and outlet channels will be designed for a minimum velocity of 2 feet per second at average rate of flow and with corners filleted to prevent the deposition and collection of solids. The prevention of channeling of the sewage in a settling tank is essential to good settling. This requires that the inlets to rectangular tanks be carefully designed and the overflow weirs of rectangular and circular tanks be adjustable for leveling. Serrated weirs are preferable to straight weirs. For rectangular tanks, partially submerged rectangular ports properly sized and closely spaced in the distribution channel are effective means of providing uniform distribution. Means for the collection and removal of scum are required for primary-settling tanks. For this purpose rectangular tanks are usually provided with scum troughs with the crest about 1 inch above maximum water-surface elevation. Circular tanks are provided with a scum baffle ahead of the overflow weir and with suitable means for collecting the scum. To minimize the accumulation of sludge film on the sides of sludge hoppers, a side slope of 1-1/2 vertical to 1 horizontal is the minimum recommended. Visual sludge wells, into which sludge is withdrawn from the sludge hoppers and from which the sludge is pumped, are considered preferable to direct pump connections with the hoppers.

(4) Trickling Filters

The design of trickling filters will be based on the following:

(a) Determination of Applied Biochemical Oxygen Demand

In determining the amount of BOD applied to trickling filters, the amount of BOD in the raw sewage may be assumed to be reduced by 35 percent by prior settling in the primary-settling tanks.

(b) Standard Rate Trickling Filters

Standard or low-rate trickling filters when followed by final settling tanks usually will produce complete treatment under an applied load of 600 pounds of BOD or less per acre foot per day. Figure 23 indicates the removal that may be expected under various loadings. For instance, under a loading of 600 pounds per acre foot per day, an average removal of 81.75 percent is indicated. Assuming a removal of 35 percent of the BOD by primary settling, this would indicate an overall plant reduction averaging 88 percent with a minimum reduction of 85 percent reasonably assured. Higher percentages of reduction could be obtained with lower loadings. The recommended depth of a standard-rate filter is 6 feet.

(c) High-Rate Trickling Filters

High-rate filters will provide an intermediate degree of treatment under conditions of the usual loadings and recirculation ratios. Figure 24 indicates the remov hat may be expected under various loadings and at various rates of recirculation. For instance, under a load of 3,000 pounds of BOD per acre foot per day and with recirculation in the ratio of 1.5 to 1.0, an average removal of 74.7 percent is indicated. Assuming a removal of 35 percent of the BOD by primary settling, this would indicate an overall plant reduction averaging 83.5 percent with a minimum reduction of 80 percent reasonably assured. Higher percentages of reduction could be obtained under lighter loadings or with higher recirculation ratios, but the cost would be increased. For the same degree of treatment, it is very probable that standard rate filters would be as economical and, therefore, preferable in view of their greater

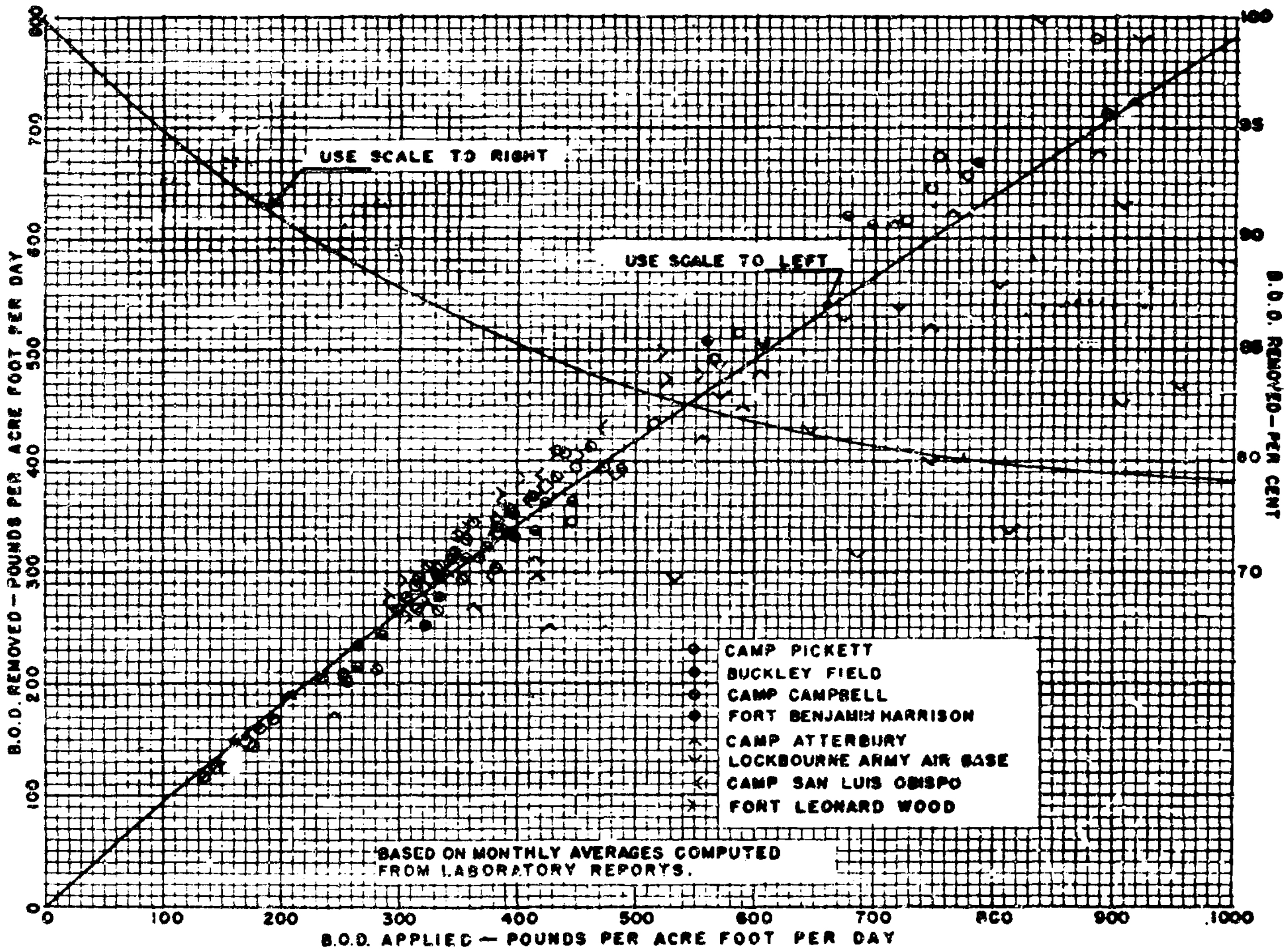

Figure 23. Trickling Filter Performance Curve - No Recirculation

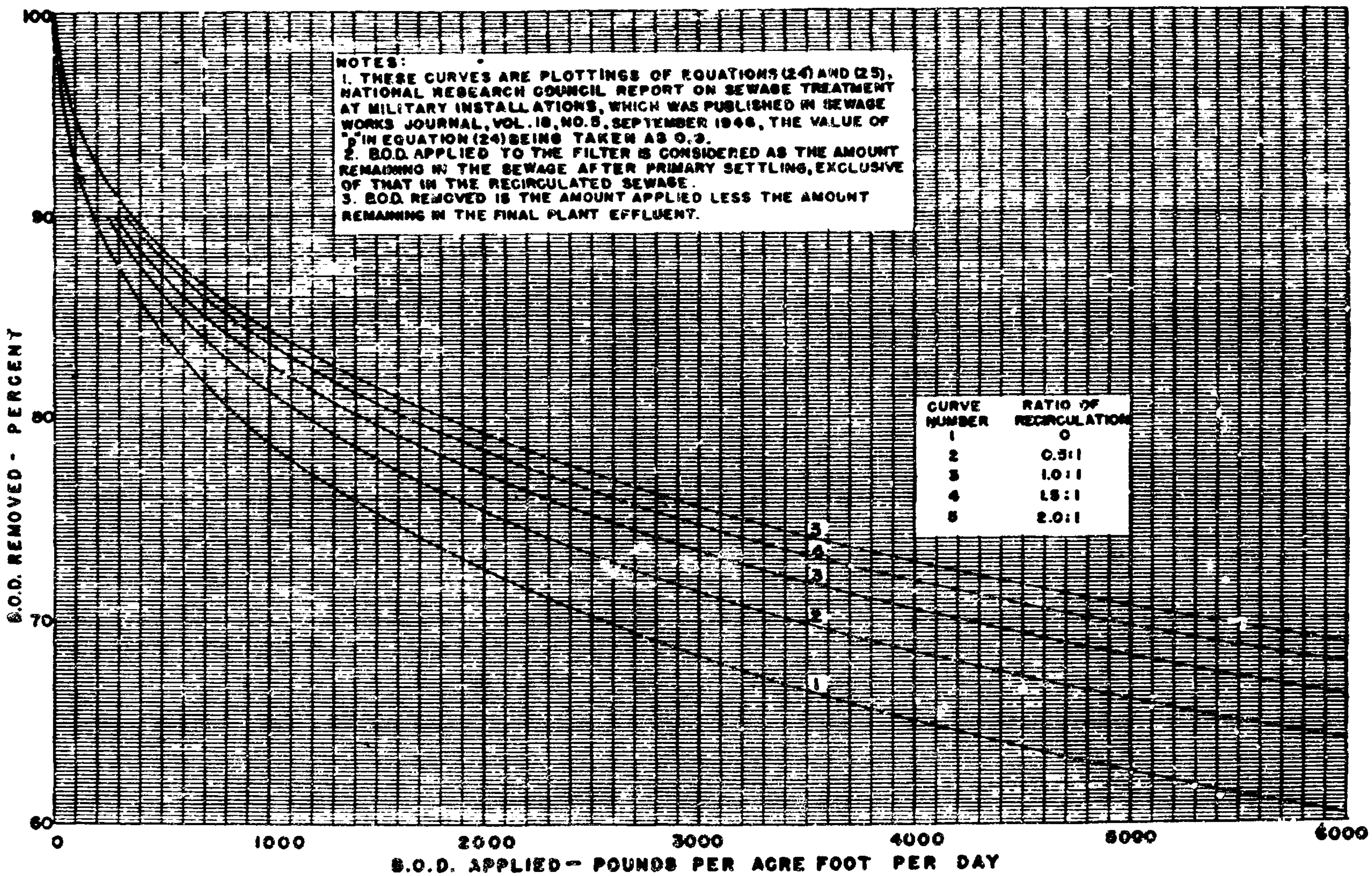

Figure 24. Trickling Filter Performance Curves - Comparison for Various Ratios of Recirculation

dependability for performance under the suddenly and widely varying conditions that develop at military establishments. The depth of high-rate filters will normally be not more than 6 feet and not less than 3 feet.

(5) Activated Sludge Process

The activated sludge process has not proved to be as efficient in treating sewage at Army plants as in municipal plants where the contributing population is less subject to sudden and wide fluctuation. However, where local conditions are such that trickling filters would not be practicable, consideration may be given to the use of this process. Where the process is to be used as the principal method of secondary treatment, the design will be based on the use of compressed-air diffusers. Mechanical aeration, which depends upon entrainment and surface absorption, has not proved entirely satisfactory for activated sludge in Army plants. When used in auxiliary treatment with other methods of biological treatment, mechanical aerators have given satisfactory service in some of the Army installations and may be considered for such purposes.

(a) Aeration Tanks

Aeration tanks for activated sludge plants using diffused air should have sufficient volume to provide for an aeration period as determined by the use of figure 25, and as computed for the average daily rate of sewage flow to which is added an allowance of 25 percent for return sludge. Figure 25 indicates the required aeration time based on parts per million of 5 day BOD in the sewage entering the aeration tank, exclusive of return sludge. The number of parts per million normally will be determined on a basis of 30 percent removal by primary settling. The water depth may be from 10 feet in small tanks to 15 feet in large tanks, preferably about 12 feet as an average. The tank bottom should slope along the longitudinal axis to a sump, and the sidewalls should be shaped so as to promote spiral action of the sewage. This can be accomplished by providing a 45-degree projection extending a few inches above the water surface and about 2 feet 6 inches from the wall. For correct cross-flow conditions it is recommended that the width be approximately 15 feet 8 inches in tanks of 10-foot side water depth, and as determined by direct interpolation between these widths in tanks of intermediate side water depths. The tank inlet port should be near the side along which the diffusers are placed. A water header and spray nozzles should be installed along one of the long sides of the aeration tank to control frothing.

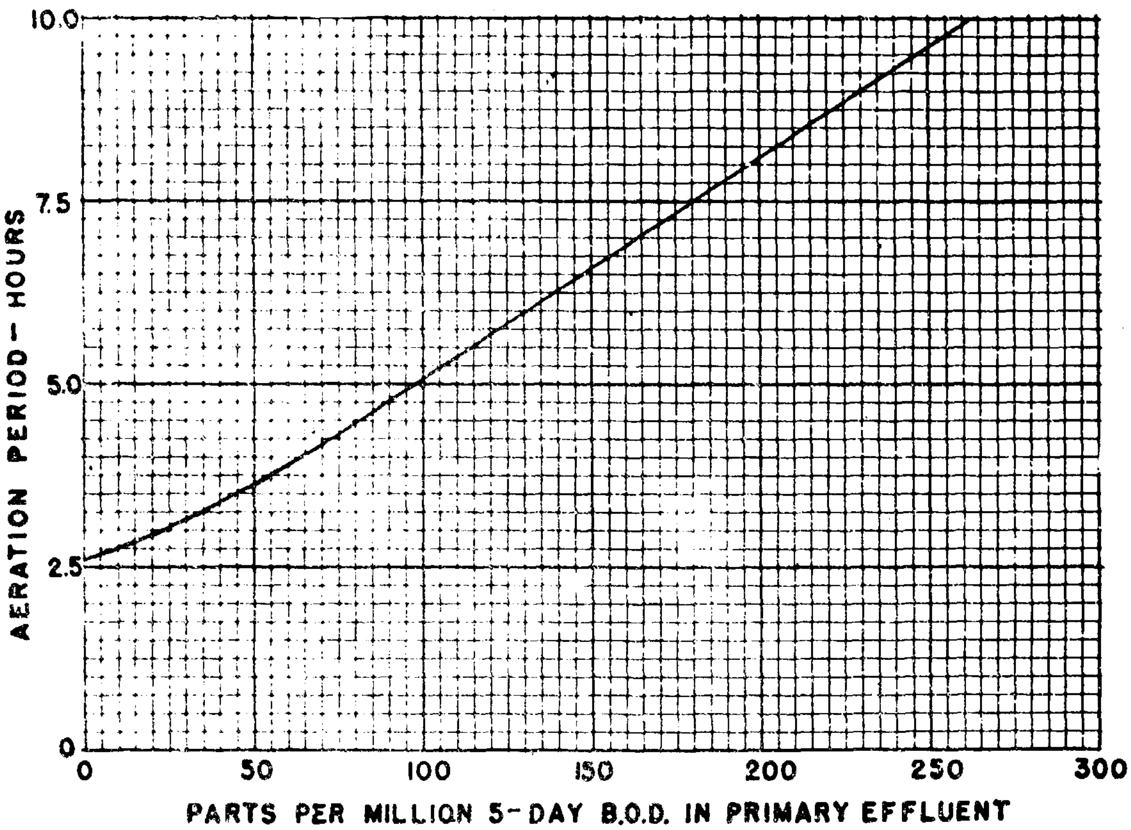

Figure 25. Aeration Requirements Curve for Activated Sludge

(b) Quantity of Air

The equipment for supplying air through the diffusers should have a capacity of 1,500 cubic feet of air per pound of BOD to be removed in the aeration tank and final settling tank, computed on a daily basis. At least 3 cubic feet of air per minute per linear foot of tank for its entire length will be required in order than a minimum cross velocity of 2 feet per second may be maintained. It is desirable to distribute the greater portion of the air along the first third of the tank length. The number and spacing of diffuser tubes or the total area of diffuser plates will depend upon the required amount of air and the rates of distribution. The maximum spacing recommended for diffuser tubes is 2 feet.

(c) Blowers

The air blowers for aeration tanks may be either the centrifugal type or the positive-displacement type. Each has its peculiar advantages. Accurate determination of the operating pressure is of prime importance in the selection of blowers, particularly in the case of centrifugal blowers. The location and type of control valves are also of major importance in view of the fact that throttling affects different types of blowers in different ways. The design will provide for operating flexibility and standby service. Blower manufacturers will be consulted regarding specific needs. In order that responsibility for correct correlation and for proper operation may be fixed, it is desirable that all aerating equipment be furnished through one manufacturer.

(d) Air Mains

The air mains will be designed so that, regardless of lengths, the pressure loss will not exceed 1 ounce per square inch from one end to the other in order that uniform distribution through each square foot of diffuser surface may be obtained. Mains connected to a manifold will be provided with an orifice, a slope gage, and a blast or butterfly valve, and means will be provided for indicating and integrating total air flow.

(e) Return Sludge

Duplicate sludge pumps having a combined capacity of approximately 50 percent of the design sewage flow will be provided for returning sludge to the aeration tanks and to the primary settling tanks. A sludge division box and suitable means for measuring the return sludge should also be provided.

(f) Flow channels

All sewage flow channels will be designed for a minimum velocity of 2 feet per second at average flow and with the corners filleted so as to prevent the collection of solids.

(6) Intermittent Sand Filters

The use of intermittent sand filters will, in general, be confined to small installations requiring a high degree of secondary treatment and to plants having other means of secondary treatment, but requiring additional treatment of the effluent. When sand filters are used, the design loadings, expressed in gallons of various types of sewage per acre per day for various effective grain sizes of sand, are indicated in table 19. The sand should have a uniformity coefficient that does not exceed 5. The effective size and uniformity coefficient are determined by plotting a sieve analysis curve of the sand, using dimensions of the clear openings of the sieves and percentages by weight of material finer than each sieve as coordinates. The size of grain corresponding to the point of intersection of the curve by the 10-percent line is the effective size of the sand. The uniformity coefficient is the ratio of the size corresponding to the point of intersection by the 60-percent line to the effective size. At least three beds will be used and preferably more. It is important that the sewage be spread as uniformly as practicable over the entire bed in order that maximum efficiency may be obtained. This will require that the dosing tank be carefully designed with respect to the size of the beds and that the distributing pipes or flumes be properly arranged and provided with valves or gates. Splash plates are required at the points of discharge to prevent excessive disturbance of the sand. Alternating siphons, operating from a common dosing tank, will be used to dose the beds in rotation. The siphons and piping will be sized for a dosing rate of about 0.1 gallon per minute per square foot of bed area. The beds will be about 3 feet thick exclusive of the layer of gravel or similar material surrounding the underdrains. The spacing of underdrains is usually about 30 feet center to center.

(7) Sewage Ponds

Sewage ponds are considered to be of two types, namely, oxidation ponds and raw-sewage lagoons. Oxidation ponds are for providing secondary treatment following primary treatment. Raw-sewage lagoons are used for the complete treatment of raw sewage. Sewage ponds may be used under the conditions outlined

Table 19

Intermittent Sand Filter Loading

	Gallons per acre per day		
	Effective size of sand (mm)		
Type of sewage	0.2	0.3	0.4
Effluent from septic tank	40,000	60,000	80,000
Effluent from plain settling tank	75,000	100,000	125,000
Effluent from chemical precipitation tank	150,000	175,000	200,000
Effluent from final settling tank following trickling filters or their equivalent	225,000	250,000	275,000

hereinafter in subparagraphs (a) and (b). They can be formed by damming low land or by grading and surrounding an area with earth dikes. All trees and shrubs will be removed and other vegetation will be cut close to the ground. The pond bottom will be reasonably level and not vary more than 1 foot in elevation between high and low points, and preferably not more than 6 inches. The dikes will have a top width of about 8 feet and will be of a height that will provide a freeboard of at least 3 feet above maximum water level. Inner slopes will not be steeper than 1 vertical to 4 horizontal, nor flatter than 1 vertical to 7 horizontal. Outer slopes will not be steeper than 1 vertical to 3 horizontal. The dikes will be stabilized with turf or other protective cover.

(a) Oxidation Ponds

Time, sunlight, and air are the controlling factors in effective purification in oxidation ponds. Such ponds will not be used in areas where they would be subject to being frozen continuously for longer periods than 10 days. Under favorable conditions, the effluent will be comparable to that from a standard rate trickling filter. They will be sized for a detention time of not less than 30 days based on the average daily sewage flow and for an organic loading that does not exceed 50 pounds of biochemical oxygen demand per acre per day. Shallow ponds are more effective than deep ponds because of the relatively greater surface through which sun rays and oxygen can be absorbed and because of the greater mixing that would be produced by wind. In mosquito areas, the minimum depth will be 2-1/2 feet in order to reduce the growth of vegetation, but no more than 4 feet will be considered in computing the detention time except in localities where strong winds and a great deal of sunshine are prevalent.

(b) Raw-Sewage Lagoons

Lagoons normally will be single-cell units designed for a minimum depth of 3 feet and a maximum depth of 5 feet. When topography is such that construction of a single-cell lagoon would not be economically practical, two cells may be provided in series or in parallel. The size of lagoons that are subject to prolonged freezing, as in some of the northern states, normally will be less than 1 acre per 20-pound loading of biochemical oxygen demand per day and will be larger if and as required by local conditions. The depth of lagoons in these areas will be 5 feet. Ponds that are not subject to lengthy periods of freezing may be sized for higher loadings as determined from local experience to be suitable for the local conditions, but not in excess of 40 pounds of BOD per acre per day without prior approval by the Chief of Engineers or by the Chief of Staff, US Air Force. The required additional size of ponds without overflow to a water course would depend upon evaporation rate, annual rainfall, and length of time that the ponds would be covered with ice. Ponds provided with discharge connections to a water course will have capacity for complete storage when the ponds are forzen over, and discharge piping will be appropriately valved. The inlet pipe to a lagoon will terminate at approximately the center of the lagoon. Overflow or outlet pipes and surface overflows of adjustable-level type will be properly baffled to prevent overflow of scum and will be arranged to maintain the design minimum depth. The baffle will extend approximately 12 inches below overflow level.

(8) Sludge Digestion Tanks

The required digester capacity will be provided in two stages, primary and secondary in series, unless a single-stage digester would be less costly. A comparative cost analysis will be made. The primary digester is the principal unit in two-stage digestion and will be provided with suitable facilities for thoroughly mixing the total contents to effect as homogeneous a mixture as practicable throughout the entire tank. This may be accomplished by recirculating gas through diffusers, by impellers and draft tubes, or by other suitable means, properly located in the digester. Digestion is continued to some extent in the secondary digester, but the principal function of this unit is to provide for settling, concentrating, and storing digested sludge before transferring it to drying beds. Where single-stage digestion is to be utilized, mixing facilities mentioned above will be so arranged and located as to provide a zone of relative quiescence in the bottom of the tank for the accumulation and concentration of digested sludge. Greater total volumetric capacity will be needed for single-stage than for two-stage digestion.

(a) Capacities

The volumetric capacities to be used in design are indicated in table 20. Where two-stage digestion is to be provided in designs for the expansion and/or conversion of existing facilities, the existing facilities will be utilized to the best economic advantage, but the capacity of neither stage will be less than that indicated in table 20 without approval of the Chief of Engineers.

Table 20

Digester Capacities

Type of sewage	Capacity, cubic feet per capita: Two-stage digesters: Primary (heated)	Two-stage digesters: Secondary (unheated)	Single-stage digesters: Heated	Single-stage digesters: Unheated
Plain primary sedimentation followed by sand filters or without secondary treatment	0.75	0.75	2.0	3.0
Chemical precipitation without secondary treatment	1.0	1.0	3.0	4.5
Activated sludge	1.2	1.2	4.0	6.0
All other forms of secondary treatment	1.0	1.0	3.0	4.5

(b) Heating

Normally, digesters equipped with facilities for heating the sludge are preferable to unheated digesters. In two-stage digestion the primary digester will be heated and the heating facilities will be designed to maintain the temperature at approximately 95°F. In single-stage digestion the heating facilities will be designed to maintain the temperature at not less than 70°F. Heating will be by means of external heat exchangers. Effective insulation can be obtained by providing a closed air space between the digester wall and an outer brick shell or by earth embankment. The determination of whether or not insulation is required and of the type to be provided depends upon local conditions. Under favorable climatic conditions, unheated digesters may give satisfactory results if extra capacity is provided as indicated in table 20. Generally, however, heated digesters will be more satisfactory and will, except in small plants, be less costly to construct.

(c) Disposal of Supernatant. The supernatant liquor displaced by sludge pumped into the digester is normally returned to the inlet of the primary settling tank. As this liquor is very high in biochemical oxygen demand, it is advisable to treat it in sand filters before returning it to the system or to the plant outlet sewer. This applies particularly to primary treatment plants and to activated sludge plants. A bed area equivalent to 0.2 square foot per capita of resident personnel and 0.1 cubic foot per capita on nonresident personnel is recommended for such filters. Sludge drying beds specially reserved for this purpose could be used. Special filters of this type will not be provided at Air Force installations, unless specifically authorized.

(d) Piping

Piping is required for the input, withdrawal, transfer, and recirculation of sludge, the withdrawal of supernatant liquor, and the collection and utilization or disposal of gas. A reasonable amount of flexibility in the system is essential to normal operation, but complicated designs for remote possibilities are not necessary and are to be avoided. Six-inch pipe is the minimum size recommended for sludge piping. Sludge lines for the input of raw sludge, transfer of sludge from one digester to another, or circulation of sludge through an external heat exchanger will terminate at approximately the geometric center of the digester. Transfer lines from primary to secondary digesters will be from the side of the primary digester to a convenient point near the bottom and will be properly valved. Pipe lines will be provided for the withdrawal of sludge from the center of the bottom of single-stage and secondary digesters for transfer back to primary digesters. Similar lines will be provided for withdrawing accumulated grit from primary digesters. The sludge line to an external heater will be from a suitable point at the side of a digester near the bottom of a primary digester in two-stage digestion and above the zone provided for the accumulation and concentration of digested sludge in a single-stage digester. Supernatant lines will be arranged for withdrawing supernatant at different elevations according to the location of the clear stratum and at a point sufficiently far from the sludge input line to prevent the withdrawal of a mixture of sludge and supernatant. Gas lines will be designed with adequate flame protection and sized on a basis of a peak rate of gas generation of 3 cubic feet per day per capita of resident personnel and 1-1/2 cubic feet per capita of nonresident personnel and as may be necessary when gas is circulated for mixing the contents of the digester.

(e) Covers

Floating covers for digesters have many advantages over fixed covers and are preferred in general. However, fixed covers may have economic advantage in the primary digester of two-stage digester systems and may be necessary in climates where the accumulation of ice and snow might interfere with the free movement of floating covers. When fixed-cover digesters are used, adequate means will be provided for the automatic and simultaneous refilling of the tank either with gas or with liquid when liquid contents are being withdrawn. This is to prevent the admission of air and the creation of an explosive mixture that could be ignited accidentally. Floating covers will be provided with sufficient gas seal to maintain a gas pressure equivalent to that of a 1-inch water column or higher. All covers on primary and single-stage digesters will be provided with at least three sampling wells--one near the center, one about midway between the center and the wall, and one near the wall. The cover may be omitted from a secondary digester if the plant is located sufficiently distant from habitation that odors would not be objectionable and if in a climate where, according to reliable weather records, temperatures of 20°F or less would not be sustained for more than 10 days more frequently than once in 5 years.

wooden stop gates for the entrance of trucks. If the natural soil is sufficiently pervious to absorb the liquid and there is no danger of polluting an underground water supply, the underdrains and layer of gravel may be omitted. The required area in this case will depend upon local conditions, but 3 square feet per capita will be required under average conditions. Beds without underdrains can be prepared by building small earthen dikes around leveled areas.

(11) Chlorination

The impression that chlorine will remove all the health hazards from sewage seems to prevail among the general public and to some extent among engineers and sewage treatment plant operators. There is a danger in this sense of false security. Although chlorine is an effective disinfectant when in actual contact, the possibility always exists that the chlorine may not come in contact with organisms that are inside the organic matter. It is, therefore, essential that the design of the various elements of the treatment plant be such that effective treatment will reduce the need for chlorination to a minimum.

(a) Rates of Application

Chlorination facilities will be provided only to the extent necessary to safeguard health and to prevent a nuisance. If conditions are such that, through failure of power or of equipment, there would be a possibility of contaminating a water supply with raw sewage, capacity for chlorinating at a rate of 200 pounds of chlorine per million gallons of sewage at the 4-hour maximum rate of flow is desirable, the 4-hour maximum flow rate being considered as 175 percent of the average hourly rate of flow. In other cases where chlorination is required, capacity for chlorinating at a rate of 125 pounds per million gallons at the 4-hour peak rate of flow is considered sufficient.

(b) Points of Application

When chlorination of the final effluent is required, the design will include a baffled tank of sufficient volume to provide a contact time of 15 minutes at the average 4-hour peak rate of flow unless there is sufficient length of outlet sewer to provide this contact time. Other points of application are as follows: ahead of primary settling tank, ahead of trickling filters, ahead of final settling tanks, and in wet wells of pumping stations from which the discharge or overflow could at times bypass all other points of chlorination and contaminate a water supply.

(12) Septic Tanks

The use of septic tanks normally is confined to small or scattered installations where connection to a sewage collection system for more conventional treatment and disposal would not be economically feasible. The tanks are designed to provide the detention periods hereinafter indicated plus 15 to 25 percent additional volume for sludge space. However, tanks of less than 500-gallon capacity are of questionable value. Manholes are required for fixed-cover tanks and, in the larger tanks, are located over both the inlet and the outlet pipes. Tank length of about two or three times the width and liquid depths of at least 4 feet in the smaller tanks and 4-1/2 to 6 feet in the larger tanks are recommended.

(a) Effluent Disposal

A thorough study of local conditions will be made to determine the proper means for disposing of the effluent from septic tanks. Disposal will usually be into the subsoil through tile fields of leaching wells. The use of tile fields will be limited to installations serving populations not appreciably greater than the preferably less than 50. In isolated areas where a nuisance or health hazard would not be created and where conditions are otherwise favorable, the effluent may be effectively disposed of by spraying or flowing over sloping areas or into evaporation ponds. A seepage basin may offer possibilities. In some cases flowing streams may be utilized. In other cases, secondary treatment in subsurface sand filters, open sand filters, or oxidation ponds may be necessary prior to discharge into streams or drainage courses.

(b) Detention Period

Where the effluent from a septic tank is to be disposed of either by surface or subsurface irrigation, design will be for a detention period of 24 hours based on the average rate of sewage flow. An 18-hour detention period would usually be satisfactory if secondary treatment in a subsurface sand filter or oxidation pond is provided. With secondary treatment in open sand filters, the detention period might be further reduced to 10 or 12 hours. When the effluent is to be discharged into a flowing stream, evaporation pond, abandoned mine, or seepage basin, the detention period will be as the local conditions indicate to be appropriate, but not less than 10 hours.

Where the effluent from septic tanks treating sewage from 20 or more persons is disposed of in tile fields or subsurface filters, dosing tanks with automatic sewage siphons are advisable. They are not necessary where the effluent is discharged into leaching trenches or leaching wells. Dosing tanks will be designed to discharge a volume equal to about 80 percent of the capacity of the disposal lines in the tile field or filters. Where this would result in an excessively large dosing tank, alternating siphons discharging into separate tile fields could be used. The dosing tank can usually be constructed the same width and adjacent to the septic tank.

(13) Subsurface Irrigation

Subsurface irrigation can be used as a means of disposing of the effluent from septic tanks where the soil and site conditions are suitable. It is used, however, in the vicinity of shallow water or springs or where the pollution of the ground water would be objectionable and is possible. Tile fields should not be located in areas that may be subject to future pavement or deep filling or to the movement of vehicles. Proposed sites are investigated to determine absorptive characteristics of the soil and whether seasonal ground water level or impervious substratum would interfere with satisfactory and continuous absorption.

(a) Tile Fields

In tile fields the sewage is applied to the upper layers of pervious soil by means of open-joint agricultural tile of 4-inch or 6-inch diameter, laid in trenches about 18 inches wide and preferably not over 2 feet deep. The tile will be completely surrounded with crushed stone, gravel, or similar material the full width of the trench and about 12 inches deep, the invert of the tile being about 6 inches above the bottom of the trench. The upper half of each tile joint will usually be covered with a strip of tar paper to prevent the entrance of sand or gravel. The tile lines will be spaced from 5 to 10 feet apart, depending on the soil absorption, and will not exceed 100 feet in length. Equal distribution of the sewage over the entire tile field is essential. For this purpose the grade of the laterals should be about 0.3 percent when dosing tanks are used and 0.5 percent when not used. The outside boundaries of a tile field will be clearly defined with posts or suitable markers, as warnings against the entrance of vehicles.

(b) Leaching Wells

The use of leaching wells is not advised if tile fields are feasible. When used, the wells will be lined with masonry blocks having lateral openings, field stones, or rubble, laid without mortar below the high water elevation. If the soil is very sandy, gravel placed outside the walls may be necessary to prevent entry of sand into the wells. Also prevention of flooding by surface runoff is essential. A distance equivalent to twice the well diameter between wells is recommended as the minimum spacing of the wells.

(14) Subsurface Sand Filters

Subsurface sand filters may be used in connection with septic tank installations where conditions are unfavorable to the use of tile fields, leaching wells, or open intermittent sand filters for the disposal of the tank effluent. Subsurface sand filters are usually costly to construct, and the cost of repairs would be high in case of clogging. For these reasons, careful consideration is given to other facilities before this type of facility is finally selected for a project. The filters may be constructed as individual trenches or in the form of rectangular beds. In either case they consist of distribution tile, filter medium, effluent collecting tile, and effluent discharge line. Subsurface sand filters are similar to intermittent sand filters as previously described, the principal exceptions being that the sand beds are covered with a layer of gravel, a layer of straw, and then a layer of soil and that the sewage is distributed to the surface of the sand by means of tile surrounded by gravel. It is recommended that the sand bed be at least 30 inches thick and that design be based on an application of 1 gallon per square foot of filter surface per day. The distribution tile and the effluent collecting tile are adequately vented for filter aeration. The outside boundaries are clearly defined with posts or similar markers as warning against the entrance of vehicles.

(15) Sewage Treatment Plant Laboratory

Each plant will be provided with facilities for making the necessary tests for control and record purposes. The tests prescribed are included in US Army Technical Manual TM 5-665, Operation of Sewerage and Sewage Treatment Facilities at Fixed Army Installations, and in AFM 85-14 for Air Force installations.

(16) Industrial Waste Treatment

There is apparently no standard method for treating industrial wastes. Each industrial plant effluent presents a special treatment problem. Industries manufacturing identical products and employing the same processes, but located in different regions, probably will not require the same type and extent of waste treatment, because availability of dilution water and water uses vary from area to area. Separate treatment plants might be necessary for preliminary treatment of these wastes before further treatment of the effluents in a station sanitary treatment works. Certain industrial wastes sometimes not only hinder but greatly damage the biological-treatment processes of a treatment plant by excessively acidity or alkalinity which may alter the pH of the sewage. Some of the basic treatment methods utilized by the Military are: (1) solids separation--racks and screens, grit removal, sedimentation (batch sedimentation, coagulation chemicals), flotation (gravity separators and dissolved air flotation); (2) biological oxidation of organic substances--trickling filters, activated sludge; (3) neutralization; (4) absorption; (5) ion exchange; (6) evaporation; (7) chlorination; (8) incineration; (9) catalytic oxidation; and (10) lagooning.

Air Force Manual, Industrial Waste, AFM 88-11, Chapter 6, describes the various methods of control, treatment, suggested water quality criteria, and standards for this type waste. The text is general, as it was written for Air Force-wide usage (Ref. 81). Research is being conducted but on a specific type waste, and not a general solution to a varied problem. An example of a specific waste problem study is the work being conducted by the Air Force Weapons Laboratory on photographic processing waste which utilizes ozone as an oxidant. It has resulted in apparent success on a small-scale laboratory experiment (Ref. 82). Kelly Air Force Base has a conglomerate of industrial wastes. The base has contracted the city of San Antonio to treat and dispose of the base domestic sewage and has converted the base sanitary sewage plant into an industrial waste treatment plant. P. N. Albright, in a paper published in the Air Force Civil Engineer (Ref. 83), describes the various modifications to the plant and processes of treatment of over 2 million gallons per day of industrial waste before the effluent is released to a public stream.

Another industrial waste that is common to every Air Force station is from aircraft washracks. An accumulation of oils, greases, dirt, and metal oxides collects on all aircraft surfaces. To remove these films an aircraft is washed at periodic intervals or when other maintenance operations are to be performed. The aircraft washing procedure involves spraying of specified cleaners on prescribed skin surfaces to loosen and emulsify the collected films. The surfaces are then brushed and rinsed off with hot and cold water. Following the aircraft washing the clad aluminum surfaces may be sprayed with an acid skin brightener designed to remove corrosion products and to improve the appearance of the aircraft. The brightener is applied with a nonatomizing spray, is left for 5 to 12 minutes, and is then rinsed off with water. The wastes normally derived from the washracks are composed of free-floating oils and greases, settleable solids, and a milky, soap-like emulsion containing suspended oil and grease particles. The milky emulsion is extremely stable and resistant to many methods of cracking. Investigators have observed that the untreated emulsions can stand for months without any tendency to separate, retaining their milk-like appearance. Excluding free-floating oils, the oil concentration in the emulsion may vary from several ppm to several thousand ppm with most of the oil concentration falling into the 100 to 1,000 ppm range. The discharge of untreated washrack wastes which can be (1) high in biochemical oxygen demand, (2) toxic to stream life, and may (3) reduce surface reaeration, (4) cause taste and odor problems in drinking water supplies, and (5) cause offensive and unsightly conditions along stream banks which may, but not necessarily, create pollution problems. In states where oil-concentration limits exist, the acceptable limit of oil concentration in streams varied from 15 to 30 ppm (Ref. 84). Table 21 was prepared to illustrate the method of disposal of washrack wastes, method of treatment, number of aircraft serviced, and chemical tests on the waste water as practiced at various Air Force bases.

f. Package Treatment Plants

A number of manufacturers market predesigned factory assembled components which may be used to assemble a complete plant at a desired site. These range in size from the capacity required for a single residence to that of a small town. Intermediary sizes are finding widespread application in shopping centers, highway rest areas, institutions, and housing developments.

A portable sewage treatment plant designed and constructed by the Infilco Company was tested at the Naval Civil Engineering Laboratory during 1953 and 1954. The data from these tests indicated good performance, but certain design changes were recommended. Subsequently, the Navy Bureau of Yards and Docks purchased a

Table 21

Aircraft Washrack Waste History by Random Choice o Air Force Base

Base and Location	Method of Treatment: 1 Gravity Separation Only	2 Air Flotation Only	3 Combination of 1 and 2	4 Other	5 No Treatment	Final Disposal of Waste Water: Stream or River	Leaching or Evaporation	Municipal Sewer	Other Practices	Number of Aircraft Washed per Month	Use of Skin Brightener	Chemical Tests Performed on Washrack Wastes	Remarks
Bergstrom AFB, Austin, Texas	X					X				60	No	No	Oil & grease not removed from waste water
Bolling AFB, Washington, D. C.					X	X				54	No	--	Potomac River receives the wastes
Carswell AFB, Fort Worth, Texas			X			X				23	No	--	Grit buried, trapped oil burned
Castle AFB, Merced, California		X				X				20	No	No	Infilco Air flotation unit, oil burned
Craig AFB, Selma, Alabama					X	X				--	--	--	Untreated waste dumped into Alabama River
Dyess AFB, Abilene, Texas		X				X				--	--	Yes	Air flotation unit by F. S. Gibbs. Inc.
Ent AFB, Colorado Springs, Colorado					X		X			15	--	No	Waste via industrial waste system thru trap
Glasgow AFB, Glasgow, Montana					X	X				4	Yes	No	Skin brightener on 2 aircraft/month
Grand Forks AFB, Grand Forks, N. D.				X	X				X	45	No	No	Grease trap only treatment
Grenier AFB, Manchester, N. H.					X	X				18	Yes	No	Merrimac River receives waste
Hill AFB, Ogden, Utah			X					X		+50	--	Yes	Grit buried, oil & grease burned
Holloman AFB, Alamogordo, New Mexico					X				X	20	Yes	No	Via storm sewer to desert lake
James Connally AFB, Waco, Texas				X	X	X				20	--	Yes	Stream originates at base thru sanitary effluent and swimming pool water
Kelly AFB, San Antonio, Texas			X			X				20	Yes	Yes	Grit to sludge drying bed, oil waste reclaimed
Kincheloe AFB, Kinross, Michigan					X				X	--	No	No	Waste into swamp via storm sewer
Kirtland AFB, Albuquerque, New Mexico					X		X		X	20	No	No	Via storm sewer to arroyo
Luke AFB, Phoenix, Arizona	X						X		X	200	No	No	Grit buried, reclaimed oil used as dust palliative, effluent to arroyo
Mac Dill AFB, Tampa, Florida					X				X	--	--	No	Tampa Bay receives waste

redesigned plant for in-service testing at Guantanamo Bay, Cuba. Construction and testing were to be done by a construction battalion at that location, but before construction was completed, the battalion was no longer available for this work. The redesigned plant was then shipped to Port Hueneme, California, for installation by the Laboratory at the Marine training camp at Bridgeport, California. This construction proved to be too expensive and the project was terminated (Ref. 85).

The American Society of Civil Engineers, November 1962, produced an extensive study on packaged plants. Experiments at the University of Michigan have given much more information on the subject. The Civil Engineering Branch at Kirtland Air Force Base is now trying to obtain information concerning this type treatment plant from the manufacturers and will correlate the information to obtain an efficient plant by standards of economy, proficiency, and maintenance. For this information see AFWL-TR-69-121, Summary of Commerical Waste Water Package Treatment Plants.

Tables 16 and 21 reflect the fact that some of the air bases in the United States do not treat their wastes at all but dispose of them directly into an available carriage medium. These bases have been included in the Air Force Military Construction Program and Congress will have to appropriate the necessary construction funds. It is assumed that the Navy and Army also practice the same disposal method at a number of their establishments.

Table 22 is presented to show a cross section of the various package treatment units available, the manufacturer's name, the trade name, the capacity, and the type of treatment afforded. The information for this table was extracted from The 1968 Sewerage Manual and Catalog File (Ref. 86).

Package treatment plants may be designed to handle various types of industrial wastes. The following type industries utilize package plants: pulp and paper, industrial use of oil, brine treatment for the rubber industry, alkali-chlorine production, canning plants, milk and cheese processing, distilleries, breweries, and soft drink bottling plants (Ref. 87). Military installations having industrial waste treatment problems might investigate this area as a possible solution to their problem.

Table 22

Packaged Sewage Treatment Unit Information

Manufacturer	Trade name	Capacity	Remarks
Link-Belt	Contac-Pac	5-600 persons	Aeration & vertical contact plates
Smith & Loveless	Oxigest Model R	30,000-500,000 gpd	17 sizes - aerobic sludge digestion
	Oxigest	40-5,000 persons	Extended aeration - diffused air
Dravo Corporation	Aeropack	200-10,000 persons	Diffused air aeration & aerobic sludge digestion or contact stabilization.
	Mobilpack	10,15,20, & 30,000 gpd	
Yeomans Bros.	Cavitette	Single residence sizes	Modified activated sludge or extended aeration with final settling tank.
	Yeo-Wave	3,000-18,000 gpd	10 sizes, compressed air aeration
Dorr-Oliver	CompleTreator	15,000-240,000 gpd	Uses Bio-filter, DuoClarigester screening, and chlorination.
	CompleTreator-aeration plant	100,000-500,000 gpd	Extended aeration or contact stabilization.
Chicago Pump	Rated aeration	---	Contact stabilization or extended aeration.
	Competaire	15,000-75,000 gpd	Activated sludge and aerobic digestion.
Walker Process Equipment	Sparjair	50-10,000 persons	Contact stabilization-aeration, re-aeration, & aerobic digestion.

Table 22 (cont.)

Manufacturer	Trade name	Capacity	Remarks
Lakeside	Spira-Pac	---	Compact high-rate trickling filter, w/Spriagestor for primary treatment & sludge digestion.
Can-Tex Industries	Tex-A-Robic	500-25,000 gpd	Diffused air extended aeration.
	Tex-A-Robic	20,000-500,000 gpd	Diffused air contact stabilization.
Infilco Inc.	Accelo-Biox	75-3,000 persons	Extended aeration w/combination of mechanical & compressed air aeration.
Hays Process Co.	Hays Submerged Contact Aeration	10-400 persons	Contact aeration by diffused air.
Sydnor Hydrodynamics	Centri-Swirl	1,000-20,000 gpd	Total oxidation using diffused air.
Permutit	Ameodyne Products	1,000-30,000 gpd	23 sizes - extended aeration, diffused air, controlled continuous sludge return & contact stabilization.
Eimco Corporation	Type ADR	1,000-15,000 gpd	Aerobic digestion.
	Type ADC	2,000-1,000,000 gpd	Aerobic digestion.
	Type CSC	20,000-1,000,000 gpd	Contact stabilization.
Komline-Sanderson	---	Up to 5,000 persons	Extended aeration, aeration & settling tank integral.
American Bowser Corp	Oxy-Pak	10-3,000 persons	Extended aeration, diffused aeration w/"Aircomb" diffusers.

Table 22 (cont.)

Manufacturer	Trade name	Capacity	Remarks
Aer-O-Flo Corp.	---	1,000-100,000 gpd	Extended aeration, Aer-O-Flo comminutors optional.
American Radiator & Standard Corp.	Bio-Con	20,000-30,000 gpd	Extended aeration.
Suburbia Systems Inc.	Suburbia	50-1500 homes	Predesigned steel components.
Water Pollution-Control Corp.	Sanitaire		
	Mark I	10,000-40,000 gpd	Factory assembled.
	Mark II	Up to 10,000 gpd	Factory assembled, cylindrical.
	Mark III	100,000-400,000 gpd	Field erected.
	Mark IV	Up to 100,000 gpd	Field erected, can be operated as extended aeration conventional activated sludge, contact stabilization, or step aeration.
	Mark V	---	Shipboard installation.
	Mark VI	Over 400,000 gpd	Field erected.
	Mark VII	Up to 10,000 gpd	Factory assembled, rectangular.
Marolf Hygienic Equipment Inc.	---	2,000-35,000 gpd	Extended aeration w/air diffusers, return sludge by air lift & separate aeration & final settling tanks. Parallel hookup to increase capacity.

3. SPECIAL INSTALLATIONS

a. Discussion

World War II records show a total of 1,000,000 hospital admissions for filth-borne diseases during that period, even with relatively good sanitation practices by the American Army Camps (Ref. 74). Little or no changes have occurred in the method of field-type latrine construction since then. Better disinfectants and disinfecting practices are available now and are being used. Temporary sanitary methods are required for field troops but it is a matter of good housekeeping to keep the filth-bearing flies, rats, and other vermin to a minimum.

There is no real reason for development of a mobile-type sewage treatment system for field troops as there was for the purification of water. The old standby straddle trench or deep-pit latrine can be constructed rather rapidly and kept in a sanitary condition without too much trouble.

Some fixed installations are constructing Imhoff tanks, which is a costly and time-consuming method. The use of lagoons is increasing as a practical and economical treatment method at this type of installation.

A considerable amount of research has been accomplished, however, on improving comfort stations in the Arctic and Antarctic areas. Most of these outposts are permanent or semipermanent. Remoteness alone is a sizeable problem, which when combined with temperatures ranging from -60°F to 40°F with summer temperatures averaging 13°F any improvement in comfort is a worthwhile effort.

b. Quantity of Waste

Quantities of wastes (generally collected, liquid or solid) whether combined or individually defined are hard to establish. There are no requirements nor methods for measuring the quantity of human waste and refuse in the field. The solid waste and refuse of field troops is much greater than for barracked troops in the States as materials utilized in their profession are cased for shipping which contributes to the per capita total. Packaging of supplies for transportation and protection to field troops as well as for personnel stationed in the polar regions would also account for a greater amount of refuse.

The total weight of wastes of all kinds, including liquid wastes, produced under field conditions approaches 100 pounds per man per day (Ref. 74). In the polar regions the total quantity of water-borne sewage will be close to the amount of water supplied. If nonwater carriage disposal is used, the quantity of waste from each 10-man group will be about 6 gpd (Ref. 88). Table 23 shows the quantity of human wastes from a 25-man polar barracks; it does not include garbage or refuse.

Table 23

Quantity of Human Wastes from a 25-Man Polar Barracks

Waste	Weight in pounds per day	Percent water content	Volume in gallons per day
Fecal	11.55	75.0-80.0	
Urine	76.97-138.52	95.0-96.0	9.2-16.85
Combined	88.90-150.45	93.3-94.4	10.65-17.97

The strength and quantity of sewage at military installations varies somewhat from normal domestic sewage. A National Research Council report concluded that, in comparison with municipal sewage, the military sewage (1) tended to be more concentrated, (2) had a greater proportion of volatile matter relative to total solids, (3) contained a higher proportion of grease, and (4) exhibited larger and more rapid variations in diurnal flow. The strength of polar military sewage tends to be even greater than that of temperate regions (Ref. 89).

In the polar areas the per capita quantities of garbage are subject to some possible decrease because of greater preshipping preparation than in normal climates. Offsetting this factor are the somewhat greater food allowances so that total quantities are not likely to be significantly different than in temperate climates (Ref. 88).

c. Treatment Requirements

The military forces, while guests of an allied or friendly country, carry along with them their own customs and practices. With the exception of combat troops in the field, sanitation is practiced at fixed installations very similar to that practiced by our cities. Even the combat troops conduct certain field sanitation practices to help reduce filth-borne diseases

There is no set effluent standard as such, but the military does honor the standards of a friendly country if it has requirements. The Services are also very conscious of the health hazard from possible pollution of its water supply. The US Military is also cognizant of the beneficial uses to be affected and the adverse effects to be created by the discharge of the sewage effluents.

d. Collection, Treatment, and Disposal

One method of sewage disposal is by burial. Collected wastes of field troops are eventually buried, no matter what method is used to collect the waste. Methods of human waste disposal will vary with the situations in the field. On the march, the "cat-hole" latrine is used. The individual digs a hole about a foot deep, then after use replaces the earth over the feces. In bivouacs and in overnight camps, urine and feces are disposed of by the use of straddle trenches. In temporary camps, usually deep-pit latrines and urine soakage pits are constructed. Until the construction of deep-pit latrines has been completed, straddle trench latrines are used. Each unit is responsible fo its own latrine construction, maintenance, and closure. Other types of latrines that are used are mound, bored-hole, and pail latrines. The use of these various latrines is dependent upon the type soil, height of ground water, equipment on hand, and the duration of stay of personnel in the area.

The following general rules apply to the construction of all type field latrines (Ref. 74):

(1) To make sure that food and water will be protected from contamination, latrines should be built at least 100 yards from the unit mess and the nearest water source. Also, the latrine should not be dug below the water level in the ground nor in a place where it may drain into a water source. Usually, latrines are built at least 30 yards from the end of the unit area but within a reasonable distance for easy access. At night, if the military situation permits, they should be lighted. If lights cannot be used, a piece of cord or tape may be fastened to trees or stakes to serve as a guide to the latrine.

(2) A canvas or brush screen should be placed around each latrine, or the latrine may be enclosed within a tent. In cold climates this shelter should be heated. The screen or the tent should have a drainage ditch dug around its edges to prevent water from flowing over the ground into the latrine. For fly control, these shelters should be sprayed twice weekly with an approved insecticide.

(3) On the outside of each latrine enclosure a simple hand-washing device should be installed. This device should always be kept filled with water and should be easy to operate.

(4) Latrines should be policed every day. Certain unit personnel should be assigned the responsibility of ensuring that the latrines are being properly maintained.

(5) When a latrine has been filled to within one foot of the surface, or when it is to be abandoned, it should be closed in the following manner: The contents of the pit, the side walls, and the ground surface to a distance of two feet from the side walls should be sprayed with a DDT residual solution or other insecticide. Then the pit should be filled to the ground surface with successive, 3-inch layers of earth. Each layer is packed down and its surface is sprayed with insecticide before the next layer is added. Then the latrine pit is mounded over with at least 1 foot of dirt. The purpose of this method of closing is to prevent any immature fly that may hatch in the closed latrine from getting out. The location of the latrine should then be plainly indicated with a sign which is marked CLOSED LATRINE and is dated.

A straddle-trench latrine is dug 1 foot wide, 2-1/2 feet deep, and 4 feet long. This will accommodate two men at the same time. The number of trenches provided should be sufficient to serve at least 8 percent of the unit strength at one time. The trenches should be separated at least 2 feet. There are no seats in this type of latrine, but boards, if available, may be placed along both sides of the trench to provide better footing. Toilet paper should be placed on a suitable holder and protected from bad weather by a tin can or other covering. A limb or forked branch stuck in the ground, fork up, is suitable for a paper holder. The earth removed in digging is piled at the end of the trenches and a shovel or paddle is provided. Each man can then promptly cover his excreta and paper. When the unit leaves the area, or when the trenches are filled up to 1 foot of the surface the trench or trenches should be closed.

The deep-pit latrine is dug 2 feet wide and 7-1/2 feet long. The depth of the pit will depend on the estimated use time. As a rough guide, a depth of 1 foot is allowed for each week of estimated use, plus 1 foot of depth for the dirt cover. Generally, it is not desirable to dig the pit more than 6 feet deep because of wall cave-in danger. Rock or ground water level often limits the depth of the pit. Over the pit a box is installed. The standard type latrine box provides four seats and is 8 feet long and 2-1/2 feet wide and has a depth of 16 inches. A unit of 100 men requires 16 feet of latrine space or two latrine boxes. The holes should be covered with flyproof, self-closing lids. A metal deflector should be placed inside the front of the box to prevent urine from soaking into the wood. The use of lime in the pit, or the burning-out of the pit contents, is not effective for fly or odor control and is not recommended. For fly control, the interior of the box and the contents of the pit should be sprayed twice weekly with a residual fly spray. The box and seats should be scrubbed daily with soap and water. When a unit leaves the area, or when deep-pit latrines are filled to within 1 foot of the ground surface, the latrines should be closed.

A mound latrine may be used when a high ground-water level, or a rock formation near the ground surface, prevents the digging of a deep pit. A mound of earth having a top at least 6 feet wide and 12 feet long should be constructed so that a four-hole latrine box may be placed on its top. The mound should be high enough to meet the pit requirements for depth, allowing 1 foot from the base of the pit to the water or rock level. Before the mound is built, the area where it is to be placed should be broken up or plowed in order to aid seepage of liquids from the pit. The mound is then built in 1-foot compacted levels. When the desired height has been reached the pit is dug into the mound or if the soil is such that bracing is necessary, walls of wood, sand bags, or other suitable material might be used to prevent cave-ins and the pit is developed as the mound is raised in 1-foot increments. The same standard box and flyproof covers are used as in the deep-pit type latrines.

A bored-hole latrine consists of a hole, about 18 inches in diameter and from 6 to 20 feet deep covered by a one-hole latrine box. A metal drum with both ends removed may be sunk into the ground for use as the box. A self-closing lid is made to fit the top of the drum. This type of latrine is satisfactory for small units, provided the necessary mechanical equipment for boring the hole is available.

A pail latrine may be built when conditions (populated areas, rocky soil, marshes) are such that other types of latrine cannot be used. A standard four-hole latrine box may be converted for use as a pail latrine by placing a floor, hinged ends, and a pail under each hole. Pails should be cleaned at least once daily; more often if necessary. The contents may be buried, burned, or disposed of by other sanitary methods.

Urine disposal facilities should be provided to accommodate at least 5 percent of the command at any one time. When trough urinals are used, 10 feet of length should be allowed for every 100 men. Five pipe urinals should be allowed for a unit of 100 men. In permanent or semipermanent camps, urine disposal facilities are usually connected into the water-borne sewage system. When in the field, separate devices for the disposal of urine might be necessary. These should not drain into a pit latrine unless the soil is sufficiently porous to absorb the additional liquid. The best device for urine disposal in the field is the urine soakage pit. This pit is dug 4 feet square and 4 feet deep; it is then filled with rocks, flattened tin cans, broken bottles, or other coarse contact material. Depending on the materials available either pipe or trough urinals may be used with this pit. Small stone or pea gravel is then placed on this coarse material in about a 4-inch thickness. Pipe urinals should be at least 1 inch in diameter and should be placed at each corner of the pit. A funnel of tar paper, sheet metal, or similar material is placed in the top of each pipe, the upper rim extending about 30 inches above the ground surface. The funnels are filled with grass or straw to keep flies out. The grass or straw filler should be changed daily. The trough urinal may be either U- or V-shaped and made of sheet metal or of wood. If made of wood, the trough should be lined with heavy tar paper. The four sides of the trough, each about 6 feet long, slope slightly toward one corner where a pipe is connected to carry the urine into the soakage pit. The trough end of the pipe should be filled with grass or straw which should be changed daily.

Liquid wastes from mess operations normally pass through a grease trap which drains into a sewer in a fixed installation. In temporary camps, however, this waste must be absorbed by the soil; and here, too, grease traps must be installed to take the grease from the liquid to prevent clogging of the soil and stopping absorption. These grease traps must be cleaned frequently and the removed grease either burned or buried. In these camps a soakage pit, constructed like a urine soakage pit, normally will dispose of liquid kitchen wastes for a total of 200 men. The only difference in construction of a kitchen liquid waste pit is that a grease trap is substituted for the pipes or trough of a urine soakage pit. If the camp is to be occupied for several weeks, two pits should be constructed, alternating days for pit usage (Ref. 74).

Many of the fixed-installation bases in Vietnam use a standard sewage collection system with various methods of treatment. Septic tanks and leaching fields have been a prime method of treatment and disposal. However, the high water-table condition during the monsoon season makes this system a health hazard. At the present time, disposal of the centrally collected sewage flow in Vietnam is normally into some water course such as a stream, river, or estuary. The BCEs are giving treatment priority considerations to areas which affect such uses as water supply intakes, recreational beaches, and the requirements of the local community (Ref. 90).

Tan Son Nhut Air Base just outside Saigon uses lagoons for its sewage treatment which then drains into a ditch. At Da Nang an Imhoff tank is used for the processing of the Air Force collected sewage, while some of the waste is collected in the Air Force version of the pail toilet. In this version, one or two sets (back to back) of latrine box-type toilets are installed on a latrine floor. Underneath the floor the earth is excavated so that 55-gallon drums which are cut in half can be placed on pallets. The drums are replaced with the aid of a forklift under each opening above. Once a day these pallets supporting the drums are removed and taken to a suitable place where diesel oil is mixed with the waste and fired. The ash is then buried. However, the native Vietnamese troops stationed in their own compounds at Da Nang dispose of their sewage raw, directly into an irrigation ditch. Much of the fresh water resources in South Vietnam are polluted because of what appears to be a national practice.

In Osan Air Base, South Korea, the treatment uses septic tanks and surface disposal of the effluents (Ref. 91).

The air base at Korat, Thailand, utilizes an Imhoff tank and logoons for treatment and the effluent is chlorinated before it is discharged to a small water course. The American compound at Don Muang RTAFB, Thailand, consists of two areas. Both areas utilize septic tanks with no secondary treatment. The septic tanks in the cantonment area discharge to a klong--a drainage canal or pond. The septic tanks in the Don Maung proper area are pumped and trucked away. A package sewage treatment plant is being considered for the cantonment area. At the U-Tapao RTAFB, the Air Force installed a new 1.6-mgd sewage treatment plant which was placed in operation August 1967. The plant consists of two primary sedimentation tanks, two primary and two secondary sludge digesters with four sludge-drying beds, three trickling filters, two final sedimentation basins, and a chlorine contact chamber. The effluent is discharged into the ocean. At the Ubon RTAFB, Thailand, the Air Force has installed a treatment system consisting of Clarigestors followed by trickling filters, final sedimentation, and chlorination basin with a total plant capacity of 600,000 gpd. An Air Force Red Horse Squadron built a raw sewage lagoon at Nakhon Phanom RTAFB, Thailand. Design BOD loading is 100 pounds per day with a total capacity of 650,000 gallons per day.

An oxidation ditch with mechanical aerators treats 0.74 mgd of sewage at the Ching-Chaun Kang Air Base, Taiwan. At the Shu Linkou Air Station in Taiwan, sewage treatment is provided by an Imhoff tank and two trickling filters. The capacity of this plant is 109,000 gallons per day. Final chlorination is not provided. Effluent discharges to a small pond or klong outside the compound and is used by local farmers for crop irrigation.

In the Philippines at Mactan Air Base a new sewage plant has been installed consisting of an Imhoff tank, sludge-drying beds, two trickling filters, final sedimentation tanks, and a chlorine contact basin. The effluent is discharged into the ocean passage between Mactan and Cebu Islands. Clark Air Base has a sewage treatment plant which provides primary treatment only. The plant consists of two Imhoff tanks and two chlorine contact tanks. Capacity of the plant is approximately 1.92 mgd. An estimated 4.3-mgd treatment capacity is required. No secondary treatment is provided and the effluent is discharged to the Bamban River. The river has been degraded from a Class A to a Class C stream as a result. A sewage treatment plant addition is included in the FY 70 Military Construction Program (Ref. 92).

In the polar regions a water- or oil-carriage sewage system should be used where practical. A minimum of about 30 gallons per person per day water supply is needed. Sewers can be laid either above or below ground, depending on terrain and weather conditions. Treatment of sewage may be required in some localities. If installation of sewers is impractical, limited water-carriage waste systems may be designed on the basis of retention tanks and vehicular hauling of collected sewage. Much less satisfactory is the use of bucket latrines. Clark and Groff (Ref. 89) in their study of existing practices of sanitary waste disposal in the polar regions for the Navy describe the methods used for temporary camps and advanced camps as being very similar to the methods used by the field forces in combat areas, explained in earlier paragraphs. Pit privies, vaults, bored holes, straddle trenches, and urination funnels are of this type. Box latrines with pail are used in many arctic and polar installations. The situation of McMurdo Sound Naval Station, Antarctica, is described as follows (Ref. 93):

> The disposal of human waste and garbage is extremely primitive. The six head buildings are equipped with "honey-buckets" to take care of fecal material. The seats are vented to the outside and are extremely cold and uncomfortable to use. The "honey-buckets" are emptied into a "honey wagon" three times a week, and the contents are hauled to the bay and dumped into the water. Garbage from the galley is collected and dumped in the same manner. During the winter months, a large heap collects which goes out with the ice every spring.
>
> The heads and various other buildings are equipped with crude tin-can and sheet-metal urinals. Some urinals empty into 55-gallon oil drums which are ultimately hauled to the bay and dumped. Other urinals empty directly to the outside and discharge at grade; in winter, small "amber glaciers" develop. They become quite offensive during the spring melt, when temperatures may range as high as 40°F.
>
> Waste from the galley is discharged at grade in the general direction of the bay.

McMurdo is in the process of constructing a collection line which will utilize flush toilets in the latrines. Fresh water from the 16-stage flash evaporator Aqua-Chem desalinization will be used as the flushing medium. The installation of this system is going rather slowly as construction can only be accomplished during the summer, about five months duration, have average temperatures of about 13°F.

Low temperatures of the polar climates provide problems that do not exist even in our northern states in winter. Before a sewage collection and disposal system is designed, the effect of the sewage on the receiving body of water or land area must be estimated. Because of the low temperatures, the rate of biological activity and self-purification is slow so that organic pollution can be carried very far away from the point of discharge and enteric organisms can be widely distributed. The slow rate of organic oxidation can result in little oxygen demand in a receiving body of water. In a flowing stream, this effect can mean that little or no oxygen demand will occur before the sewage is so diluted as to be an insignificant cause of stream oxygen depletion. In lakes, however, or where sewage is discharged to a normally dry water course, organic deposits occur that will cause serious oxygen depletion when spring or summer temperatures result in rapid biological activity. Fortunately, spring runoffs frequently disperse and dilute winter accumulations before nuisance conditions arise. If sewage discharge is to a body of sea water, the year-round low sea water temperature in polar regions will result in very low oxidation rates. Consequently, if tides and currents are adequate to cause dispersion, no nuisance conditions should result. However, practically no experience records are available for these conditions (Ref. 88).

The above conditions might be true for the coastal shoreline of the Arctic; however, there has been a great amount of work written on the subject. The US Navy Hydrographic Office published a special document titled An Annotated Bibliography of Flushing and Dispersion in Tidal Waters (Ref. 94). It represents a survey of the published literature dealing with the subject. This document constitutes the first phase of a comprehensive study directed toward the development of formulas and methods for predicting the time required for contaminated sea water in tidal areas to be replaced by uncontaminated water.

Bacteriological contamination is more persistent in low temperatures. Organisms remain viable for much longer periods than in temperate climates. Because of this, physical factors such as dilution and sedimentation become relatively more important in reduction of bacterial counts.

In general, the need for treatment or disinfection is much lower than in temperate climates. However, discharge of untreated sewage should be undertaken only after careful consideration of the effect in the receiving area of the longer duration and wider dispersion or organic and bacterial contamination. In the Arctic, recognition of the possible effects on the food chain of the native population can be an important consideration.

Halton and Nehlsen (Ref. 95) have conducted studies on the survival of the Eschesechia coli in sea water at 0°C. The bacteria is a common indicator organism found in sewage. They found that from the time of inoculation about 70 percent of the organisms survived for 8 days, 34 percent for 15 days, and 1 percent for 35 days. They concluded that low sea-water temperatures favor the survival of large numbers of sewage bacteria.

The Naval Civil Engineering Laboratory conducted low-temperature tests on viruses in frozen sewage. The results of this preliminary study showed that viruses in sewage frozen at temperatures as low as -40°C remain viable and may even increase in number. After 4 months of storage at temperatures as low as -33°C, 10 to 20 percent of the viruses remained infective. That any viruses remained for any period of time is significant since very minute amounts of enteroviruses can initiate diseases in humans (Ref. 96).

A literature review was made by NCEL on viruses in polar sanitation to collect information on the survivance of bacteria. The object was how to base an estimate of the threat to the health of polar camp personnel posed by viruses in human waste (Ref. 97).

A water-borne sewage system, used wherever water is available, improves living conditions, and is a factor contributing to the high morale of the personnel from a sanitary and aesthetic viewpoint.

Sewage installation and maintenance is one of the most difficult problems in polar station construction. Circumstances permitting direct burial of uninsulated sewers are rare. The only alternative may be above ground, insulated and heated, or utilidor construction. Utilidor is defined as a conduit placed in the ground or supported on the ground to protect electrical or telephone cables, water, steam and/or sewer pipes (Ref. 88).

Whenever unstable conditions exist, it is necessary to provide support and thermal protection to fit the local conditions. Thermal protection to prevent freezing should be designed to make maximum use of available heat and existing sewage flows. Sewage treatment can be predicted on the basis of soil conditions, sewer location, sewer pipe materials, and anticipated flow conditions (Ref. 88). If freezing is indicated, means of decreasing heat loss and adding heat must be considered. Insulation with a mixture of asphalt and vermiculite has proven to be practical in a number of installations. Heat can be added with heating cables, steam, or hot water; however, the method depends on local conditions. Sewers transversing relatively flat terrain can require pumping stations at frequent intervals. Lift stations of the enclosed storage single-chamber type offer advantages of reduced heat loss, ease of installation, and minimum ventilation problems.

If soil or environmental conditions prevent direct burial of sewers, some type of utilidor must be utilized. In regions of deep snow cover or in undersnow stations, large diameter, bolted corrugated steel pipe or plate could be used to construct walk-through utilidors if this concept is necessary. Since utilidors are expensive, particular care should be used in locating buildings and sewers in order to minimize construction. For undersnow stations, insulated and heat-traced sewer pipes are preferable to the utilidor concept.

An investigation was conducted at NCEL on rigid and flexible pipe and hose materials with electric heat tracing and thermal insulation pre-applied. The information obtained will be used in the development of prototype systems for the distribution of freezable liquids at low temperatures. Results of an availability study of electrically heat-traced rubber hose, and the results of a low-temperature evaluation of a commercial piping system with pre-applied electric heat-tracing elements, insulation, and protective outer cover was documented. This work includes assembly at -30°F and tests of the heat-tracing system at temperatures to -45°F.

Results of these studies indicate that the manufacture of insulated and electrically heated rubber hose is feasible. It was also found that the pre-insulated commercial piping system is well suited for assembly and use at low temperatures, but improvements are required at joints in the heating element, insulation, and outer jacketing (Ref. 98).

Baumgartner (Ref. 99) reports that Northwestern University, under contract to the Arctic Aeromedical Laboratory, has developed an oil-carriage/sewage-incineration system for disposal of human wastes at Point Barrow, Alaska. The toilets are flushed with fuel oil, supplied under pressure by a pump when the user throws a switch to open a solenoid valve. Adequate flushing has been obtained with as little as two quarts of oil, although the average use was greater during the trial runs. The fuel pump switch also actuated a household garbage grinder installed directly under the toilet. The waste slurry flows by gravity to a storage tank where it remains until it is needed as fuel for the boiler. Before use as boiler fuel the waste slurry is mixed by the storage tank mixer that is operated for 10 minutes to ensure a homogeneous feed. In a test run the system operated for 20 hours on waste slurry and for 80 hours on fresh fuel before the diaphragm valves in the system failed and clogged the burner parts.

Boyd (Ref. 100) states that the system reported on by Baumgartner was first installed in 1957 and that the system was still in operation in 1965. It has been used continuously except when it is necessary to clear a clogged burner in the boiler. The oil used is diesel oil with a density of 0.18 and a pour point of -70°F. The heat generated during the operation is used to heat a boiler for other work. This boiler is a 100-hp water-tube firebox boiler handling a waste load of about 300 pounds per day. Therefore, using an estimated 3 pounds per man per day, the unit can take care of about 100 men.

Very cold climates will generally have a more pronounced effect on biological processes than on physical processes. Pretreatment units such as screens and shredders must be housed to prevent freezing of mechanisms and to permit suitable maintenance; sedimentation units should operate at normal efficienty, but again, housing to prevent icing of tanks and mechanisms is necessary. Grit chamber design should be 50 percent greater than normal to offset the increased viscosity of sewage. If the treatment units are housed and heated, normal-sized units may be used.

The need for secondary treatment with a biological process must be carefully studied with regard to the great expense that may be entailed. To achieve normal efficiencies, unit sizes should be increased by 50 to 70 percent (unless housed and heated) for either trickling filters or activated sludge units, and housing of units is necessary; however, high-rate, solid contact units offer great advantages in compactness. Because of these difficulties, it is desirable to consider chemical coagulation with disinfection as a means of primary treatment to eliminate any need for secondary treatment.

Extended aeration systems have been used with some success in cold areas. These systems can be simple and effective when properly designed. Heating of the air supply may be necessary.

Oxidation lagoons is another alternative. Experience has so far indicated that seasonable performance can be expected in the Arctic, although a nuisance period in the spring will probably occur. Recent developments of aeration techniques should broaden the application of oxidation lagoons, as it is now possible to aerate lagoons. Low population densities favor the availability of suitable sites. Such lagoons do not appear to be practical in the Antarctic because of permanent freezing.

The Air Force Arctic Aeromedical Laboratory issued a report concerning observations of sewage oxidation ponds in south-central Alaska. The ponds measure 80 to 85 feet square and are surrounded by 10-foot dirt dikes. There are two of them in the system. The population served by the ponds during the course of the study was 36 people. Sewage discharged by the facility was a household type and excluded laundry wastes. The facility appeared to handle readily a BOD burden of 40 pounds per acre per day as was evidenced by the ease with which the phytoplankton metabolized ammonium and phosphorus compounds. The ponds maintained a vigorous dissolved oxygen gradient and pH; both are indicative of good stabilization. Recovery from an oxygenless state (ice removal in the spring) showed that the ponds rallied within a week from an anaerobic situation to an aerobic one, where the algae demonstrated an accelerated growth and the dissolved oxygen became supersaturated (Ref. 101).

Digesters must be heated and all appurtenances enclosed to prevent freezing. High-rate units will decrease the heating load considerably. A large area of sludge drying beds or lagoons is necessary. When water supplies are scarce and there is a need to conserve manpower, a recirculating activated sludge system should be considered. The Arctic Aeromedical Laboratory operated such a system in their laboratory to confirm field investigations. The investigations indicated that a 423-gallon recirculating activated sludge system could adequately treat the undiluted human wastes from 10 men for at least 6 months and provide an effluent acceptable for use as a flushing fluid. In addition, the level and the effects of overloading were noted. The effect of high pH on odor production was observed, and the importance of pH control between 6 and 7 was demonstrated. The feed COD of 44,000 mg/l (BOD = 21,000 mg/l) was reduced by about 90 percent and the estimated water savings for toilet flushing was estimated at greater than 90 percent (Ref. 102).

At stations located on or beneath the surface of glacial areas, sewage treatment may be omitted and the wastes disposed of by placing in subsurface ice cavities. The lateral collection system may discharge directly into the cavity or into a retention tank. Discharge from the retention tank may be automatically controlled and effected in large quantities. The collection and discharge lines and the retention tank should be insulated and heated by electrical tracing or other means to prevent freezing. The receiving cavity may be either a horizontal or a vertical shaft, which may be dug by boring or by melting with steam. When a water well is abandoned, it may be used as a disposal pit. Disposal of liquid wastes in glacial cavities is both economical and reliable; however, such a disposal point should be separated from a water source in the same aquifer by a minimum of 1,000 feet.

At stations situated on the snow, untreated sewage may be disposed of by drilling a hole into the snow. If the amount of liquid waste is sufficient, the warmth of the discharge will tend to perpetuate the opening and even enlarge it.

If a Rodriguez well is used for water supply, a minimum of 1,000 feet separation is required between it and the sewage disposal hole.

Discharge of untreated wastes at other polar locations is sometimes used. At coastal stations, the sewage is discharged above the tidal crack between sea and shore ice.

The Boyds (Ref. 100) write that people who live on the Arctic coast can collect sewage in 55-gallon oil drums and dispose of them by putting them out on the ocean ice. These drums are easy to obtain because much fuel still comes north in drums that remain because of the prohibitive cost of return. It is a primitive disposal method, but one of the cheapest. One disadvantage is that the ice may go out only to come back in later in a bulldozer fashion, pushing the barrels back up on the beach, where they might remain or even burst. The situation is undesirable from an aesthetic as well as a public health viewpoint.

Retention tank systems of several types have been devised both for small and large stations in an effort to provide some of the conveniences of a water-flush system in areas where installation of sewers is impractical. Most types have been unsatisfactory and maintenance is usually very high. Odors and mechanical breakdowns cause great inconvenience.

One typical system incorporates a toilet, a waste separation tank, and a waste retention tank. All showers and basins drain to the separation tank and the toilet is flushed with this liquid by a marine hand pump. The separation tank is equipped with a float-switch-operated sewage sump pump that draws from the bottom of the tank and discharges to the main retention tank. Usually, no fresh water is required and the float positioning maintains a minimum waste liquid level in the separation tank. Accumulated wastes in the main retention tank are tank-trucked to a disposal area.

The chemical toilet system has proven more satisfactory in operation than the system mentioned above. The toilet is a specially designed stainless steel fixture with a drain outlet valved for retention purposes. Draining of the toilet is accomplished when the valve is opened and waste is drained to a retention tank. After use by each individual, a chemical is added, as required, to the toilet by means of a dispenser. Approximately 0.5 gallon of water is needed for charging. All shower and lavatory wastes are drained or pumped periodically into a tank-truck for disposal, or moved directly to a waste field. This system is recommended for use at small remote polar stations only, where water is at a premium.

Retention tank systems should be located within buildings. Special protection from freezing can then be limited to providing for drainage in case of a shutdown, and for protection of any outside valves or other appurtenances. Designs should stress ease of maintenance and reliability.

Odor control should be ensured by powered ventilation of toilet rooms. Retention tanks should be sized for at least once-a-day emptying but some reserve capacity must be included. The tanks should be equipped with two pumps to ensure service if one pump fails. The tanks should be inspected internally for signs of corrosion.

The Navy tested the McPherson, Inc., "Sanitoi Sewerless Toilet System" that was developed by the manufacturer for use in localities where water scarcity or sewage disposal problems prevent use of conventional methods. The system consists of a toilet, compartmented aeration and settling tank, diaphragm-type air compressor, and a water pump. For flushing, the water pump is switched on; drawing water from the settling compartment of the tank operates the toilet. The pump delivers the water at a pressure of approximately 30 psi to the toilet, where it is ejected from a nozzle against a turbine wheel in the lower section of the toilet. After leaving the turbine the water passes up into the bowl of the toilet, circulates around and flushes the bowl, and then drains down through a grinding unit which is driven by the turbine. The effluent from the grinder drains by gravity to the aeration compartment of the tank. The pump is operated only long enough to clear the toilet bowl (Ref. 103).

NCEL developed a mechanical-flush chemical toilet to satisfy the need for a simple, reliable, low-cost, sanitary toilet at advanced polar bases where water is in short supply and where logistic support is limited. The main part of the unit consists of an endless belt on rollers attached by means of a simple frame to the underside of a conventional toilet seat. The seat is attached to a circular tank cover, and the entire device is then inserted into a baffled retention tank, with the tank cover resting on the rim of the tank. The tank, rollers, bearings, belt, and frame hardware are fabricated from highly corrosion-resistant materials, such as polyethylene, nylon, fiberglass, or polyvinylchloride (PVC).

The toilet is operated as follows: First, the tank is partially filled with a solution of copper sulfate pentehydrate and sodium bisulfate. Waste is deposited by the user on the endless belt. After each use, the toilet is "flushed" by turning a hand crank which causes the belt to move through the chemical solution. Solids fall off the belt and are contained in a baffled area within the tank. As the cranking continues, the belt is cleaned by a brush. The function of the belt is to prevent splash and to mask unsightly conditions. Compression springs are provided to keep the belt taut. The unit is equipped with a ratchet device to prevent the belt from being turned in the wrong direction. In the bottom of the tank is installed a paddle wheel to provide mechanical disintegration of the solids so as to aid chemical penetration of the waste, and to facilitate draining of the tank. The shaft of the paddle is connected by means of a chain to the belt drive so that flushing and disintegration can be accomplished in one operation by the user.

The units may be used individually, or many may be manifolded for use by large numbers of people. The tank may be gravity drained through the bottom and the effluent discharged to a subsurface pit, or it may be pumped to a nearby incinerator (Ref. 104).

Application of incinerating toilets is similar to chemical and bucket systems. Ultimate cost is high and service has usually been unsatisfactory. A number of incinerating toilet systems have been experimented with but with little success. Table 24 was taken from NCEL Technical Note N-406, Incinerating Toilets, and appears to be the most complete summary on this type system (Ref. 105).

The Aero Medical Laboratory, Wright Air Development Center, tested an oil-fired, ground, incinerator toilet developed by the Tokheim Company. The toilet had a liner bag which collect the waste; the bag is released upon operation of the "flush" handle and drops into the oil-fed fire pot. The tests were inconclusive because replacement parts for repairing the toilet could not be obtained (Ref. 106).

Other areas to consider are the waste disposal of naval vessels anchored in a harbor or dockside, flying aircraft, and space waste management.

As a consequence of increasing public awareness of water pollution and augmented recreational use of tidal waters, the Navy is having to face the problem of discontinuing the practice of direct discharge of sewage by naval vessels in confined waters. A shipboard survey to determine the quantities of human waste produced per capita and the physical, biological, bacteriological, and chemical properties was conducted to establish the degree of pollution of harbor waters by naval vessels and to provide design criteria for a treatment system.

Table 24

Summary of Information on Incinerating Toilet Systems

Unit	Collection system	Burner type	Fuel consumption	Odor control	Operational problems	Present status
Incinomode electric	Cellophane cone Gravity drop	Resistance heaters - Natural draft	1.5 lb fuel per lb waste	Catalytic grid - not effective	Element burnout High fuel consumption	Limited commercial marketing
Incinomode oil burning	Cellophane cone Gravity drop	Multifuel low pressure	Not available	Not tested	Not tested	Limited commercial marketing
Tokheim oil burning	Cellophane cone Gravity drop	Pressure atomizing	0.25	Brief period of odor	Hot exhaust - sparks - poor collection system	Unknown
Research Product electric	Cellophane cone Gravity drop	Resistance heaters - Induced draft	Not available	Not available	Element burnout	Limited commercial marketing
Dri-Flush oil burning	Paper strip transport	Pressure atomizing	Not available	Not tested	Not tested	Under development
Pierce Foundation oil burning	Paper bags (no integral toilets)	Vapor generating	0.7	Good	Fuel consumption high	Development abandoned
Northwestern University oil burning	Oil-flush	Rotary cup	Not available	Good	Burned feed stoppages Oil fumes	Under development

The data show that between 10 and 20 gpd of sewage are produced per capita on ships following a normal workday routine. A maximum of twice this amount can be expected if the operation is on an around-the-clock basis. The sewage produced contains an average of 236 mg/l of suspended solids and an average biochemical oxygen demand of 102 ppm. The geometric average coliform density index was found to be 4.8×10^5. Data were also documented for the concentration of settleable solids, total solids, and volatile solids present. The pH of the sewage and the dissolved oxygen present and the concentration of nitrogen present in various forms were determined.

The survey showed that the water in the vicinity of a vessel from which sewage is being discharged is not polluted to any adverse degree in terms of the commonly used parameters. Virtually no suspended solids were found in the river water and the coliform density was within the range permitted at most bathing beaches in the United States (Ref. 107).

Another area of concern is the collection and disposal of human waste from crew and/or passengers of the large aircraft, such as the transport, cargo, and bomber type. Prior to 1930, most flights were of short duration (2 hours or less) and those that flew over 2 hours had facilities for passengers' comfort. These toilet facilities simply discharged overboard.

In 1931, Howard Bell, M. D., in an article in the American Public Health Associates Journal, urged public health officials to take immediate action on aircraft disposal practices. The 78th Congress passed Public Law 410, giving the USPHS the authority to prepare regulations for the prevention of transmission or spread of communicable disease. Commercial airlines installed bucket-type toilets for both fecal wastes and urine. The Army Air Corps also installed bucket-type toilets but continued to vent urine overboard (Ref. 108).

Over the years the commercial airlines were forced to install odorless, clean and comfortable toilet facilities in their aircraft at the expense of additional weight which in some manner reduced the payload. The Military could not afford this type of luxury which would place in jeopardy some of the aircraft firepower.

Many schemes have been tried to develop a lightweight, simple operating, odorless, contained toilet system for aircraft but an optimum device has yet to be found. Investigations have begun to develop equipment to jettison the waste overboard. But even if such a device were developed that would produce a safe effluent and overcome any health hazard, the public would have to be sold on the idea.

Sanitary systems have been developed for sustaining men on long space journeys. Aerospace stations for docking, supplying, maintaining, and servicing space vehicles are no longer a Buck Rogers or Flash Gordon fantasy, but are soon to become a reality. The Biomedical Laboratory at Wright-Patterson Air Force Base in 1964 conducted an engineering evaluation to select an optimum waste management system for collection, storage, and/or disposal of human waste in a space station under weightless conditions. Based upon this study, a detailed design of an optimum waste management system was prepared for a 7-man, 15-day mission. Tests performed on a mockup model of the feces collector demonstrated the feasibility of the selected approach (Ref. 109).

4. CONCLUSION

> Experience in the cantonments of 1917 and in the sanitation of active troops convincingly showed that war is today, as much as ever 75 per cent an engineering and sanitary problem and a little less than 25 per cent a military one. Other things being approximately equal, that army will win which has the best engineering and sanitary services. The wise general will do what the engineers and sanitary officers let him. (Ref. 110)

The above quote is definitely pointed at the Military, but pollution of land, surface, and ground water and the air is a people problem, be they Military or civilian. Being aware of this, the Federal Government in unison with State agencies is now trying to do something to correct the pollution problem. The Air Force has a 5-year plan on water pollution control; the other Services have similar plans. Through the Military Construction Program an earnest attempt will be made to update the various substandard treatment systems used by the Services and to build new sewage treatment works where presently there are none.

Items that should be investigated include light-weight, modular, efficient, and transportable package sewage treatment plants; piping and fittings for collection systems and building service lines; and new innovations for handling solid wastes.

Somebody once said something about the world beating a path to the door of the man that would invent a better mousetrap. I believe this same thing would occur to the persons responsible for solutions to the waste problems caused by human activity.

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SECTION IV

SOLID WASTES

Not counting industrial and agricultural wastes, we discard more than 165 million tons of solid wastes every year in the Unites States (Ref. 111). As the population increases, so does the quantity of solid waste. L. M. Rhodes in his article, "Trash Explosion" (Ref. 112), puts it a little more startlingly:

> Every day, each American throws out about 5-1/2 pounds of waste, a figure that collectively adds up to a mind-rattling 400 plus billion pounds a year. In 1968, for example, Americans tossed away 55 billion cans, 26 billion bottles, 60 billion metal and plastic bottle caps, 30 million tons of paper, and unbelievably, junked 7 million automobile carcasses and 100 million rubber tires weighing a million tons. Put it another way, currently we produce enough trash annually to fill the Panama Canal four times over. That amount will triple in 10 years.

This material is disposed of by landfill, dumping, burning, incineration, and occasionally by disposal into bodies of water. A large portion of this refuse provides the junk yard eyesores which surround most American urban areas. The statistics are frightening--"a national disgrace" according to Health, Education and Welfare's Bureau of Solid Waste Management. The trouble is, notes a special report by the National Academy of Sciences, "As the earth becomes more crowded, there is no longer an 'away.' One person's trash is another's living space. San Francisco dumps so much trash into its Bay that conservationists fear the famous body of water will one day simply cease to exist. Already the Bay has lost some 250 square miles of its original 700. 'If we put another layer out there,' predicts Leonard Steffanelli of the Sunset Scavenger Company, 'it's going to look like a mountain.'"

Human activities are bound to create wastes and, like people of any community, the Military contribute their share. At an average troop cantonment, the per capita waste will approximate 1.5 pounds of rubbish, 0.50 pound of nonedible garbage, and 2.0 pounds of edible garbage per day (Ref. 113). O'Rourke (Ref. 114) states that the average civilian metropolitan area will produce approximately 0.69 pound of garbage and 0.41 pound of rubbish per day per capita. Seelye (Ref. 115) states that each 1,000 population produces approximately 1 ton of mixed garbage and refuse per day (including stores, restaurants, hotels, etc.); high-class residential sections alone produce 1 pound per capita per day while poorer class residential sections produce 0.75 pound per capita per day. The per capita per day, including businesses, would average 2.0 pounds per person. A chart produced by Seelye using the maximum per capita output which is qualified by economic conditions, locality, climate, and method of collection states that 1.23 pounds of garbage and 0.41 pound of rubbish per day are produced. Peak short periods can raise these estimates 140 to 200 percent over the average. Time of the year also has an influence on any design considerations for handling refuse because the design must include peak conditions.

Solid wastes attributed to human activities may be classified as garbage, debris and rubbish.

Garbage is the solid waste resulting from the preparation, cooking and serving food. Garbage is classified as either edible or nonedible:

a. Edible garbage is that part of the garbage which is suitable for animal food. It includes scraps of meat, vegetables, and other material which may be eaten by swine.

b. Nonedible garbage is that garbage which cannot be used for animal food. It includes coffee grounds, bones, eggshells, skins of citrus fruit, etc. A kitchen usually produces an average of from one-half to one pound of garbage per person per day. About half of this is edible garbage (Ref. 113).

Debris includes both combustible and noncombustible wastes, such as, ashes (the solid noncombustible remains of burned materials), waste materials resulting from construction or maintenance and repair work and leaves, grass cuttings and tree trimmings (Ref. 116).

Rubbish or trash consists of wastes which originate at kitchens, barracks, wards, quarters, and offices. It includes such items as emptied containers, waste paper, wood, metal, glass, and crockery. Rubbish is divided into classes: combustible--that which can be burned; and noncombustible--that which will not burn. Table 25 is included as a summary of the Navy classification of refuse wastes.

Handling of refuse should not be taken lightly. Due care must be exercised in lifting and handling collection containers to preclude injuries such as sprains and strains. When weight of collection cans is excessive, sufficient manpower

Table 25

Classification of Refuse Wastes

Class designation	Type	Subtype	Principal components	Source	Moisture %	Weight p.c.f.
1.....	Rubbish:					
A...	..... do	Combustible .	Paper, cartons, rags, wood scraps, floor sweepings.	Domestic. Commercial. Industrial.	25...	12
B...	..... do	Non-combustible.	Glass, cans, metal, pottery, building, and construction rubble.	....	.....	Varies with compaction, shape, etc.
2.....	Refuse.......	....	Mixed garbage and rubbish in varying proportions (20% - 65% garbage; most commonly about 50%).	Most frequently from domestic sources - with larger quantities segregation is easier to maintain.	50...	Varies with compaction. 10-20 uncompacted.
3.....	Garbage:		Animal and vegetable wastes from handling, preparation and consumption of foods.	Subsistence buildings. Cafeterias. Stores. Hospitals. Prisons, clubs, etc.	70...	55
A...	..... do	Hog food	All garbage not in sub-types B, C, and D.	...... do	.do..	Do.
B...	..... do	Non-hog food.	Citrus fruit rinds, corn husks, onion hulls, eggshells, tea and coffee grounds.	...... do	.do..	Do.
C...	..... do	Grease.		...... do	.do..	Do.
D...	..... do	Bones.		...... do	.do..	Do.
4.....	Animal solids and organic wastes.	....	Carcasses, organs, solid organic wastes.	Hospitals, laboratories, abattoirs, animal pounds.	85...	55
5.....	Flammable by-product. Organics.	Liquid, semi-liquid.	Petroleum sludge, crankcase oils, greases, tars.	Industrial processes, motor pools. A and R hangars. Oil separator skimmings.	Variable	55-60
6.....	Miscellaneous solids and semi-solid wastes.	....	Variable - may contain rubber, plastics, woodwastes, etc.	Industrial	.....	....
7.....	Trash........	....	Disintegrated combustible rubbish such as paper, sawdust, leaves.	Same as rubbish..	25...	20
8.....	Ashes	....	Solid, inert remains of burned materials.	Coal furnaces, incinerators, power plants.	.....	48

should be utilized to assure personnel safety. Average weights of various wastes are given in the following table as a guide to handling collections.

Table 26

Weights of Refuse

Material	Weights (lb)	
	32 gal can	Cubic foot
Garbage	150 - 225	35 - 53
Refuse, without garbage or ashes	18 - 36	6.5 - 8.5
Refuse, including garbage	39 - 47	9 - 11
Refuse, including garbage and ashes	56 - 64	13 - 15
Ashes	141 - 158	33 - 37

The two most common methods of refuse disposal are landfill and incineration. Another method used is composting of wet refuse. With an increasing population density, refuse disposal is becoming more and more a problem. There are many industrial organizations studying the problem and their studies have brought about such ideas as high-rate composting and making building blocks from rubbish. These ideas are complicated by collection practices. Separation of wet garbage from dry rubbish might cause extra expense by using different pickup vehicles, extra house calls, and possibly two methods of disposal. Some areas have even separated the rubbish into two collections, combustible and noncombustible.

Sanitary landfill has advantages and disadvantages. If properly executed, a sanitary landfill will help restore land that is useless for building purposes, farming, or grazing. On the other hand, sanitary landfills require a large amount of land, and unless properly compacted when placed it takes years before the land may be used for building purposes. Also there is a certain amount of odor and windblown debris that might be offensive to nearby property owners. An Illinois firm is investigating the possibility of compacting rubbish and garbage obtained from a regular general catchall collection into self-contained bales which by its very dense nature would provide a much denser burial material. This burial material could be more easily transported to the fill, could be handled with less mess, and would possibly eliminate much of the odor.

The military requirements for sanitary landfills are that fills will be confined to localities where the frost will not extend below a depth of 2 feet and where percolation or runoff from the fill will not endanger a water supply. Selection of a site for sanitary fill must take into consideration the following: type of soil, total area required (it is estimated that disposal can be made of 12 tons of mixed garbage and rubbish per day for 1 year on an area of one acre filled to a depth of 6 feet), drainage conditions, length of average haul, access roads, proximity of inhabited buildings (desirable to be at least 750 feet from buildings), and the prevailing winds.

The usual method of making a sanitary fill is to dump the waste into a previously dug trench measuring 2-1/2 to 6 feet deep. After thoroughly compacting the waste, it will be covered with earth obtained in preparing the next trench. A ramp will be made out of the earth obtained from the first excavation. Compaction of the waste will not only aid in confining it to the least practicable space but also will provide satisfactory support for the final earth cover over which trucks will operate in making subsequent fill. The top coverage of the fill must never be less than 18 inches of compact soil and preferably will be 24 inches in thickness. The thickness of the coverage on the outside slope will not be less than 12 inches. The top and side cover is to be placed within 24 hours after the refuse has been deposited. It is not necessary to seal off the end of the fill each day but it will be sealed off at least twice a week. The seal completes the cell which acts as a firebreak in case refuse and garbage in any one cell should become ignited (Ref. 118).

Incineration of garbage and rubbish is a widely practiced method of disposing of the refuse. The refuse is reduced to ashes which require less volume than that of a sanitary landfill. The operation of an incinerator is more expensive because of attendant time, construction costs, double hauls (for the collected refuse and removal of the ashes to a fill), and cost of the disposal area and attendant. The incinerator may also pose an air pollution problem. One firm, the Pan American Systems, Inc., of Albuquerque, New Mexico, has a patented incinerator process which is desinged to put an end to air pollution by capturing the gases produced by the burning material. Through a process not made public, certain gases are recirculated while some are extracted, processed, and bottled for commercial use. This could be a very economical method for a large scale operation but cost of operation figures are not presently available.

The Army, design and construction consultants for the Air Force, has three types of incinerators available for Army and Air Force use: Type I garbage and rubbish incinerators, Type II wet garbage incinerators, and Type III rubbish incinerators. Type I incinerators have a capacity of 1,250 and 2,500 pounds per hour. Type II have a capacity range of 3, 5, and 10 tons in 8 hours; the first two use natural draft while the largest has a forced draft.

Type I of these standard designs is a general-purpose incinerator and is the most suitable for the present-day needs at most installations. It will burn refuse consisting of all rubbish or, by proper control of the damper, a mixture of 65 percent rubbish and 35 percent garbage by weight. Type II will burn a mixture of 65 percent wet garbage by weight and 35 percent rubbish without the use of auxiliary fuel. However, this type is not designed to withstand the high heat release that would result from burning refuse containing a high percentage of rubbish and will not be constructed except when the conditions are definitely unsuited to the use of Type I. Type III is to be used only when the refuse contains less than 15 percent moisture and, since a special design would be required, will be used only when economy will result in its use over that of Type I.

Capacity will be provided for 25 percent excess over the average hourly needs to make allowances for irregularity in the delivery of refuse to the incinerator. Capacity factor for troop expansion will not be used, as the incinerator can be operated 16 hours per day if necessary, 8 hours remaining for cooling and cleaning. Little or no economy results in designing incinerators of sizes intermediate between the sizes already indicated.

The design of rubbish incinerators will normally be based on the use of a natural draft. When waste consists of wet, bulky material in appreciable proportion, auxiliary forced-draft facilities will be provided. When an incinerator must be located where the chimney could create a hazard to airplanes, forced draft will also be used. In placing an incinerator, convenience with respect to the housing area to be served and for accessibility from the existing road net must be considered. In general, the length of an average one-way haul should not be more than 3 miles and it should be located at least 1000 feet from the nearest inhabited building taking into consideration the prevailing wind (Ref. 119).

Composting of garbage requires a separation of refuse and at least two pickups, one for dry and one for wet refuse. It also will require the use of an incinerator and/or a burial place for the ashes or rubbish.

> Compost was known to the Romans; the Greeks had a word for it, and so did the Tribes of Israel. Much of the agricultural wisdom of the ancients survived the blight of the Dark Ages, to reappear--along with other fundamental scientific knowledge--in the writing of learned Arabs. Ibn al Awan, variously assigned to the 10th and 12th centuries, goes into extensive detail on the processing and use of compost, and other manures, in his Kitab al Falahah or Book of Agriculture. (Ref. 120)

Obviously composting of refuse is not a new idea but it normally is associated with farming and not in engineering use. It usually takes up to six months to produce a useable product; however, the market for fertilizer does have a limit and since the quantity of refuse for disposal is ever increasing, other uses will have to be developed for the product. One of the potential uses of the compost material is the placement of the material in a controlled, compacted landfill. D. M. de Blonk (Ref. 121) at the University of Pittsburgh, ran a series of soils tests on a compost product produced by a method developed by the Westinghouse Research and Development Division. The Westinghouse process produces compost in 6 days and the end product has the appearance and smell of a rich humus soil. From de Blonk's studies the engineering behavior of the compost material produced the following information: (1) the best method of placement, (2) the allowable bearing capacity, (3) the slope stability, and (4) the expected settlement of the material placed in a landfill.

Another method of garbage disposal is the use of the edible portion as hog fodder. Prior to World War II a number of service installations maintained farms adjacent to the military reservation. Feed for military horses was grown, grazing was provided, facilities for breeding were on hand, and always a number of pigs were raised to utilize the edible portion of the mess hall wastes. The Veterans Hospital in Albuquerque for years had a contract with a local hog raiser to haul away the edible trash. The Army Field Manual FM 21-10 has the following to say concerning this aspect of disposal: At permanent or semipermanent installations, edible garbage may be sold or given to civilians for use as animal food. The contract covering such sale or gift is made by the Quartermaster Corps and must conform to all military and local health department regulations. Before such a contract is awarded, an Army Medical Service officer should inspect the location where the garbage is to be used to make certain that it will not constitute a hazard to the health and welfare of the troops. The person who receives the waste should provide a truck with a watertight body for the transfer of the garbage at the garbage stand. For the sake of maintaining sanitary conditions at the dining halls, persons collecting the garbage should make the collection at regular intervals and take every precaution to prevent spillage (Ref. 113).

Prior to San Francisco's Bay Area Air Pollution Control District (BAAPCD), established in 1955, which includes nine counties in the Bay area, open burning of refuse was practiced. Of the ten Naval stations that were included in the area, several used the open burning method. As a first step in air pollution reduction, the BAAPCD issued a regulation banning open burning of all types of refuse. Effective around the first of January 1960, a second regulation concerning stack emissions was made. This affected a Naval supply center, a Naval hospital, and a Naval ammunition depot.

The Naval Civil Engineering Laboratory at Port Hueneme evaluated various refuse disposal equipment in an attempt to find a solution to their disposal problems. The first piece of equipment to be investigated was the Lantz Converter, a device designed to extract useful products from municipal and other types of refuse. The basis of the process is destructive distillation of refuse in a retort that is regeneratively heated by burning the gaseous or charred residue of the distillation. It was originally used to produce marketable charcoal from sawmill wastes. The disposal process heats combined refuse and garbage in a retort at a low temperature until all breakdown products have been distilled off. The charred residue is cooled before removal from the retort. The gaseous products produced by pyrolysis in the retort pass through a condensing section to remove water and various other condensable vapors. Methane and other gases discharged would be suitable for use in almost any combustion device. The cooled, charred residue of the waste could be processed for removal of metallic materials and briquetted for sale as charcoal. The condensed pyrolysis products resemble coal tars in composition and might be sold for extraction of useful chemicals; otherwise, they would probably require disposal in a fill or incinerator. The tests at NCEL showed that charring could be obtained by heating scraps of refuse at 300°C for a period of two hours.

The process was not adopted by the Navy for several reasons, the probable economic dependence of the process on sale of the by-products and possible difficulties with the retort-heating fires in regard to air pollution (Ref. 122).

The Navy also investigated a refuse grinding operation established by the USPHS at Chandler, Arizona. The operation was intended to use municipal refuse for composting in which the grinding would prepare the material. A gain of density to about 600 pounds per cubic yard was achieved by grinding in comparison to the average density of 150 pounds per cubic yard for open truck collection and 300 to 400 pounds per cubic yard for compaction truck operation. The USPHS research personnel devised a method of using a grinder in municipal collection. By utilizing a magnetic separator which extracts ferrous material from the ground material a potential source of revenue is provided. The system proposed by the personnel at Chandler is based on establishing central grinding stations in the collection area. Collection trucks unload at the grinder, ferrous materials are extracted, and the ground refuse is then hauled by larger trucks to the sanitary fill. They estimate that financial savings in labor and hauling and the revenue from sale of salvaged iron will justify the grinding station costs. The USPHS men at Chandler regard about 100 tons per day as the minimum economically practical capacity. Needless to say, the Navy did not adopt this scheme as the most productive Bay Naval station produces about 40 tons of refuse per 8-hour day.

Some of the Bay Naval stations have practiced landfills similar to that of the City of Berkeley, California. Berkeley collects 110 tons of refuse per day in city trucks and an additional 130 tons per day is brought to the city fill by private haulers. The fill site is prepared by diking off a large tidal area. After the area is enclosed a pump keeps the water level down in the fill area and the level of the mud flat is raised about 25 feet by filling in 12-foot lifts. A painted wooden fence surrounds the area and additional fencing is used in the area to control blowing paper. But in both Naval and municipal operations the main problem of bayside fills is the lack of cover material. The Navy has a number of contracts to deliver excavated material to their various fill sites to stockpile and use as cover when needed.

As an example, Kirtland Air Force Base, at Albuquerque, New Mexico, uses the sanitary landfill method to dispose of its wastes. It might be said that the base is lucky to have within its borders a portion of Tijeras Canyon. The area is a natural erosion excavation, and over the years much of this land has been reclaimed and put to use. The refuse is dumped and the cover used is acquired in leveling the surrounding hilly land.

Under provisions of the Solid Waste Disposal Act, the Bureau of Mines, US Department of the Interior, supplements its own work on waste disposal by awarding grants and contracts for research. Under this act the responsibility for Federal efforts to control wastes of mineral origin has been given the Bureau. Work performed under the grants usually is directed toward developing specific uses for specific wastes (Ref. 123).

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13. ABSTRACT

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The information gained cf the United States Armed Forces effort, in the areas of water supply, waste water treatment and solid waste disposal is summarized. The report surveys the state of the art of environmental engineering associated with the military environment. The responsibilities of the military civil engineers and the service laboratories and their locations are discussed. Waste products produced by human activities, namely, sewage, its collection, treatment, and disposal are included. Solid wastes are also discussed.