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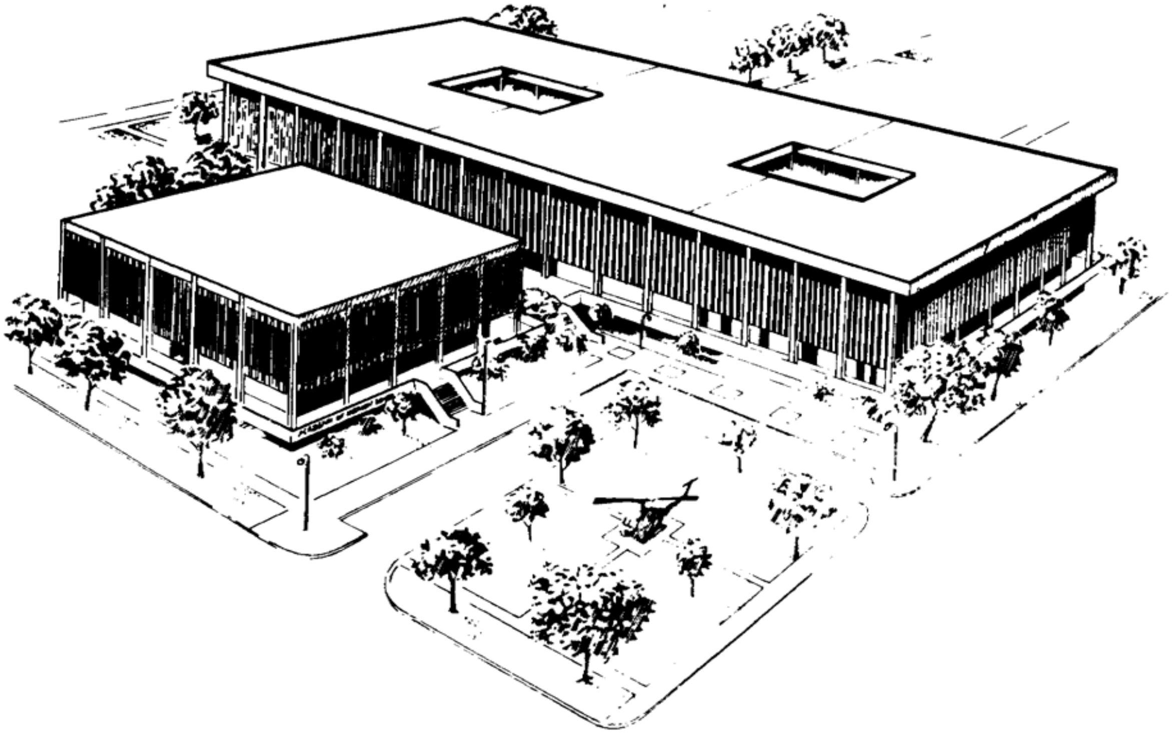

# MILITARY WATER SUPPLY

## SUBCOURSE MD0160 EDITION 100

## DEVELOPMENT

This subcourse is approved for resident and correspondence course instruction. It reflects the current thought of the Academy of Health Sciences and conforms to printed Department of the Army doctrine as closely as currently possible. Development and progress render such doctrine continuously subject to change.

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## CLARIFICATION OF TRAINING LITERATURE TERMINOLOGY

When used in this publication, words such as "he," "him," "his," and "men" are intended to include both the masculine and feminine genders, unless specifically stated otherwise or when obvious in context.

.

## TABLE OF CONTENTS

# SUBCOURSE MD0160

# MILITARY WATER SUPPLY

## INTRODUCTION

Water is essential to man. During peacetime or wartime, man needs to drink, cook, bathe, and relax. (In each of these events, water is in most cases a critical factor, just as food and shelter.) However, not faced with a shortage, the average American takes water for granted and consumes or uses more than is needed. What the average American does not realize is that over 97 percent of the water is in the ocean and that the other 3 percent is in atmospheric water vapor, surface fresh water, and ground water. Therefore, the fresh water that he thinks he is drinking is not fresh, so to speak, but reused water. About 25 percent of the fresh water is in soil formations located below the surface of the earth (aquifers), about 75 percent is permanently stored water located in the polar ice caps and glaciers, and less than one percent is located in our lakes and rivers.

Since our fresh water is not fresh, steps need to be taken to make it so. The surface water may appear to be drinkable but it is polluted with tiny particles, bacteria, and other chemicals, or microorganisms that make it undrinkable. This creates a water supply problem for our soldiers that the Army can rectify. The purpose of this subcourse is to help you better understand the military water system, its theories, and principles behind laboratory and field needs to test, treat, and protect installation and field water.

Subcourse Components:

This subcourse consists of six lessons:

Lesson 1. Introduction to Military Water Supply.

Lesson 2. Disinfection of Water.

Lesson 3. Bacteriological Tests and Standards.

Lesson 4. Physical and Chemical Tests and Standards.

Lesson 5. Field Water Treatment.

Lesson 6. Protection of Water Supplies.

Study Suggestions:

Here are some suggestions that may be helpful to you in completing this subcourse:

--Read and study each lesson carefully.

--Complete the subcourse lesson by lesson. After completing each lesson, work the exercises at the end of the lesson, marking your answers in this booklet.

--After completing each set of lesson exercises, compare your answers with those on the solution sheet that follows the exercises. If you have answered an exercise incorrectly, check the reference cited after the answer on the solution sheet to determine why your response was not the correct one.

Credit Awarded:

To receive credit hours, you must be officially enrolled and complete an examination furnished by the Nonresident Instruction Branch at Fort Sam Houston, Texas. Upon successful completion of the examination for this subcourse, you will be awarded 13 credit hours.

You can enroll by going to the web site http://atrrs.army.mil and enrolling under "Self Development" (School Code 555).

A listing of correspondence courses and subcourses available through the Nonresident Instruction Section is found in Chapter 4 of DA Pamphlet 350-59, Army Correspondence Course Program Catalog. The DA PAM is available at the following website: http://www.usapa.army.mil/pdffiles/p350-59.pdf.

# LESSON ASSIGNMENT

**LESSON 1** Introduction to Military Water Supply.

**TEXT ASSIGNMENT** Paragraphs 1-1 through 1-20.

**LESSON OBJECTIVES** After completing this lesson, you should be able to:

1-1. Define the basic terms used in military water supply.

1-2. Identify water supply responsibilities.

1-3. Identify the steps in the hydrological cycle, the principal sources of water supply, and the factors governing their selection.

1-4. Select the statements that best describe the major purification processes employed in military water treatment facilities and the principles governing these processes.

1-5. Select the statement that properly describes, water treatment facilities at municipal, garrison, and field locations.

1-6. Select the statement that best describes the water distribution systems.

**SUGGESTION** After completing the assignment, complete the exercises at the end of this lesson. These exercises will help you to achieve the lesson objectives.

# LESSON 1

# INTRODUCTION TO MILITARY WATER SUPPLY

## Section 1. GENERAL

### 1-1. IMPORTANCE OF WATER

a. **Uses**. No commodity finds so many uses in all lifestyles as does water. The following are some of the principal uses of water:

(1) Drinking.

(2) Personal hygiene (brushing teeth and shaving) centralized hygiene (showering), cooking, laundering, car washing, gardening, and so forth.

(3) Hospital medical treatment, construction, and industrial use to include virtually all kinds of manufacturing, distilling, brewing, mining, and so forth.

(4). Recreational use such as: swimming, fishing, boating, and so forth.

(5) Safety factors such as: Nuclear, biological, and chemical (NBC) decontaminating and fire fighting, and so forth.

b**. Military Importance**. Safe water in sufficient amounts is essential to an army. Polluted and bacterial-ridden water can cause an army to lose its effectiveness. Take for instance, Rommel, who just before a major tank battle with General Patton, contracted dysentery and had to fight it from a hospital bed. Had his water been properly treated, his men may have won the battle with him there. However, untreated water can spread diseases and infections. Cholera, typhoid, and paratyphoid fevers, bacillary dysentery, leptospirosis, and common diarrhea are a few of the diseases. In certain areas, water may also transmit infectious hepatitis, schistosomiasis (snail fever), amebic dysentery, and coliform bacteria (feces). Because units lack the capability of testing water for the presence of coliform bacteria, it must be tested, treated, and disinfected before distribution and use.

### 1-2. BASIC TERMINOLOGY

a. **Potable Water**. Potable water is water that is safe for human consumption. Potable water is free from pathogenic (disease-causing) microorganisms, poisonous substances, and excessive amounts of mineral and organic matter, and chemical, biological, or radiological substances.

b. **Contaminated Water**. Contaminated water is water which is unfit for human consumption, even though it may be palatable (see c below). Contaminated water contains microorganisms; wastes or sewage that render it unfit to drink; or chemical, biological, and radiological substances.

c. **Palatable Water**. Palatable water is water that is pleasing to the taste, significantly free from color, turbidity, taste, and odor, which may be unsafe (contaminated).

d. **Brackish Water**. Brackish water is unfit for drinking because of salty or unpleasant tastes that are caused by excessive amounts of undissolved chemicals, chlorides, sulfates, and alkalis.

e. **Polluted Water**. Polluted water is water that contains substances such as garbage, wastewater, mud, or other pollutants that make it objectionable because of appearance, taste, or odor. Polluted water is usually contaminated and may be easily detected, but may not contain disease-producing bacteria.

f. **Water Treatment**. Water treatment refers to the removal of undesirable constituents in water through means such as coagulation, sedimentation, filtration, and disinfect ion. Treated water is classified as palatable or potable.

g. **Disinfectant**. Any oxidants used to kill or inactivate most pathogenic microorganisms. Disinfectants are oxidants that include: chlorine, oxide, chloramines, and ozone added to water.

h. **Disinfection**. Disinfect ion refers to treating the water in order to destroy microorganisms by either adding chemicals, heat (boiling), ultraviolet light, ultrasonic waves or radiation.

i. **Chlorination**. Chlorination refers to the disinfect ion of water by the addition of a chlorine compound such as calcium hypochlorite, sodium hypochlorite, or gaseous chlorine.

j. **Parts Per Million**. Parts per million (ppm) is a unit of measurement for expressing the number of units of a substance in one million units of water by weight. Since 1 milliliter (ml) of water weighs 1 gram (g), this relationship may also be expressed as mg/l (milligrams per liter). Both terms are used interchangeably.

k. **Reverse Osmosis**. Reverse osmosis (RO) is a process that separates suspended and dissolved solids from filtered water, which is done by forcing raw water under very high pressure against a thin film called a membrane. The membrane allows purified water to pass through, while the suspended and dissolved solids stay on the other side

l. **Dissolved Solids**. The total amount of dissolved solids, organic and inorganic, contained in water or wastes.

m. **Total Dissolved Solids.** Total dissolved solids (TDS) are the amount of all dissolved impurities contained in a water sample determined by use of a TDS meter.

n. **Turbidity**. Turbidity is the suspension of impurities in water. Muddy water has a high turbidity.

o. **Backwashing**. Backwashing is the removal of accumulated solids from a filter by using a reverse flow of filtered water. The operation mayor may not be preceded by a reverse flow of compressed air.

p. **Brine**. Brine is very salty water.

q. **Desalination**. Desalination is the process of removing salt from sea or brackish water.

## 1-3. RESPONSIBILITIES.

a. **Commande**r. The unit commander is responsible for the adequacy and safety of the water used by his troops. He must enforce the rules of water discipline (see f below) and ensure that each individual thoroughly understands the danger of drinking contaminated water. When treated water is not obtainable, the commander must ensure that proper water treatment methods are used in his unit. The unit field sanitation team assists the commander in carrying out these responsibilities.

b. **Quartermaster Corps**. Personnel of the Quartermaster Corps (QM) are responsible for setting up and operating bulk water treatment equipment. The QM units procure, treat, and distribute the water. Sometimes water is transported by QM unit personnel to centralized water distribution points (dry points) for easy pick up by field units. However, the normal procedure is to erect standpipes adjacent to the water point for water trailer or container unit pick up.

c. **Corps of Engineers**. The Corps of Engineers selects sources of water and establishes water distribution points based upon information received from the Army Medical Department (AMEDD) and their own reconnaissance of the area.

d. **Army Medical Department**. Army Medical Department personnel are responsible for conducting bacteriological and chemical examinations of water, as well as chlorine residual and pH testing under certain situations, enforcing and establishing water quality standards, and inspecting water points and sources. Army Medical Department personnel advise commanders and engineers/QM as to the methods of purification that should be used to produce potable water. Once appropriate laboratory and field examination of water is complete, it is also the AMEDD responsibility to approve or disapprove the water for consumption.

e. **Field Sanitation Team**. The field sanitation team reports all water inadequacies to the unit commander. The team, with regards to military water supply, is responsible for:

(1) Instructing soldiers in sanitary methods of washing individual eating utensils.

(2) Assisting the commander in providing guidance to personnel and inspecting them and the facilities for proper water sanitation procedures.

(3) Supervising the disinfect ion of water in the unit area and instructing soldiers, as needed, in individual water purification methods.

f. **Individuals**.

(1) Water discipline. Whether in the field or in the garrison, each soldier is responsible for observing the rules of water discipline. These rules are:

(a) Drink potable water only.

(b) Prevent the waste of potable water.

(c) Protect water sources by using good sanitary practices. It is emphasized that water discipline does not imply doing without water. It means using water wisely and not wasting it.

(2). Water purification. Every individual must also be able to produce his own supply of potable water utilizing individual water disinfect ion techniques (see para 2-13).

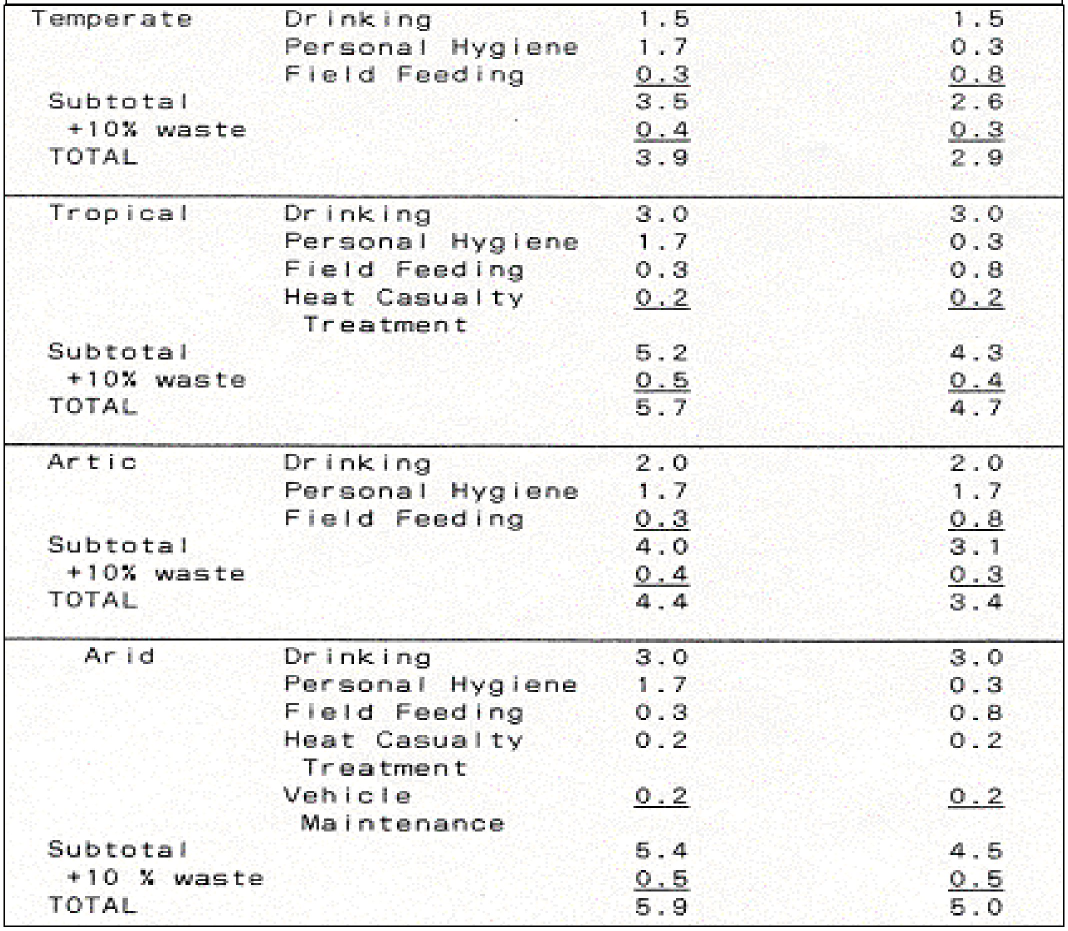
## 1-4. WATER REQUIREMENTS

a. **Fixed Installations**. Water requirements for fixed military installations vary widely depending upon the size of the installation and the activities conducted. Installations having industrial operations will require more water than those that have primarily training activities. Large installations will have greater water requirements than smaller installations, but the variation is generally greater at smaller installations. Per capita consumption under garrison (fixed installation) conditions varies from a minimum of about 40 gallons per person per day to a maximum of about 400. The average consumption at most installations is from 130 to 180 gallons per person per day.

b. **Field Operations**. The quantity of water required for troops in combat or under field conditions varies with the season of the year, the geographical area, and the tactical situation. Dehydration may be a problem in both extremely hot and extremely cold climates. In extremely hot climates, large quantities of potable water are required to replace body fluid losses. In extremely cold climates, body fluid losses are not as great as in hot climates; however, because perspiration evaporates very rapidly in cold air and because it is absorbed by heavy clothing, the individual is not aware of his fluid loss. Additional amounts of water are also required for maintenance of personal hygiene and food preparation. For planning purposes Table 1-1 shows the daily water consumption table requirements per person at company level, under various climatic conditions. Water requirements are essential for drinking, personal hygiene, and field feeding. Because there is a 10 percent loss of water through evaporation and waste, the total amount of water requested is increased by 10 percent to make up for this deficit. Therefore, in a temperate zone, the total daily water requirement per person is 3.9 gallons and this amount would be requested. In addition, international minimum potable field water standards must be met when our soldiers participate in mutual NATO (Standardization Agreement or STANAG) and Quadripartite (Quadripartite Standardization Agreement or QSTAG) force logistical operations in combat zones or in any other strict emergency-situations. There are agreements for short-term water consumption of seven consecutive days or less (STANAG 2136) and for all situations of more that 7 days (QSTAG 2885) where water purification units produce treated water. For example, the bacteriological standard for coliform of 1.0 per mg/l is the same for both long and short-term consumption. Requirements for conducting water quality analysis are contained in QSTAG 479.

**Gallons Per Man, Per Day, Per Climate**

**COMPANY LEVEL***



| Climate | Function | Sustain ** | Minimum*** |
|---|---|---|---|
| Temperate | Drinking | 1.5 | 1.5 |
| | Personal Hygiene | 1.7 | 0.3 |
| | Field Feeding | 0.3 | 0.8 |
| Subtotal | | 3.5 | 2.6 |
| +10% waste | | 0.4 | 0.3 |
| TOTAL | | 3.9 | 2.9 |
| Tropical | Drinking | 3.0 | 3.0 |
| | Personal Hygiene | 1.7 | 0.3 |
| | Field Feeding | 0.3 | 0.8 |
| | Heat Casualty Treatment | 0.2 | 0.2 |
| Subtotal | | 5.2 | 4.3 |
| +10% waste | | 0.5 | 0.4 |
| TOTAL | | 5.7 | 4.7 |
| Artic | Drinking | 2.0 | 2.0 |
| | Personal Hygiene | 1.7 | 1.7 |
| | Field Feeding | 0.3 | 0.8 |
| Subtotal | | 4.0 | 3.1 |
| +10% waste | | 0.4 | 0.3 |
| TOTAL | | 4.4 | 3.4 |
| Arid | Drinking | 3.0 | 3.0 |
| | Personal Hygiene | 1.7 | 0.3 |
| | Field Feeding | 0.3 | 0.8 |
| | Heat Casualty Treatment | 0.2 | 0.2 |
| | Vehicle Maintenance | 0.2 | 0.2 |
| Subtotal | | 5.4 | 4.5 |
| +10 % waste | | 0.5 | 0.5 |
| TOTAL | | 5.9 | 5.0 |

* For higher echelons examples, refer to FM 10-52.

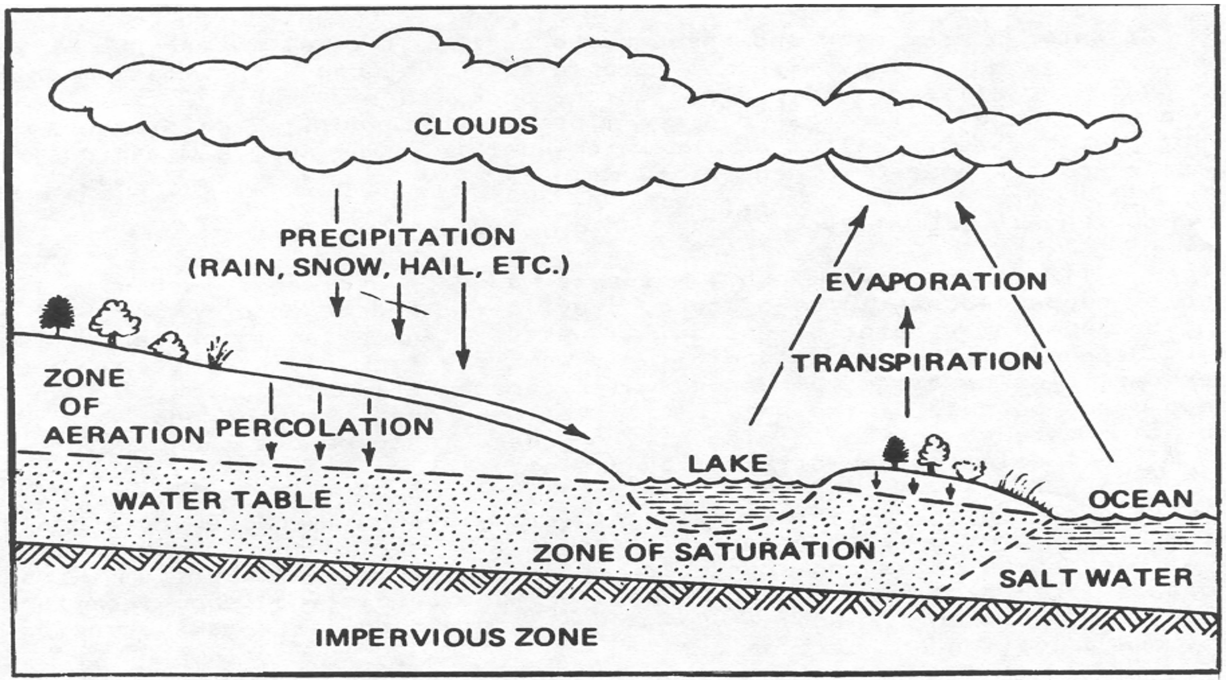
** Sustain refers to water requirements exceeding one week. In this case, after consumption includes nonessential events such as: laundry, centralized hygiene, and construction.

*** Minimum refers to the amount of water that needs to be consumed to survive for up to one week.

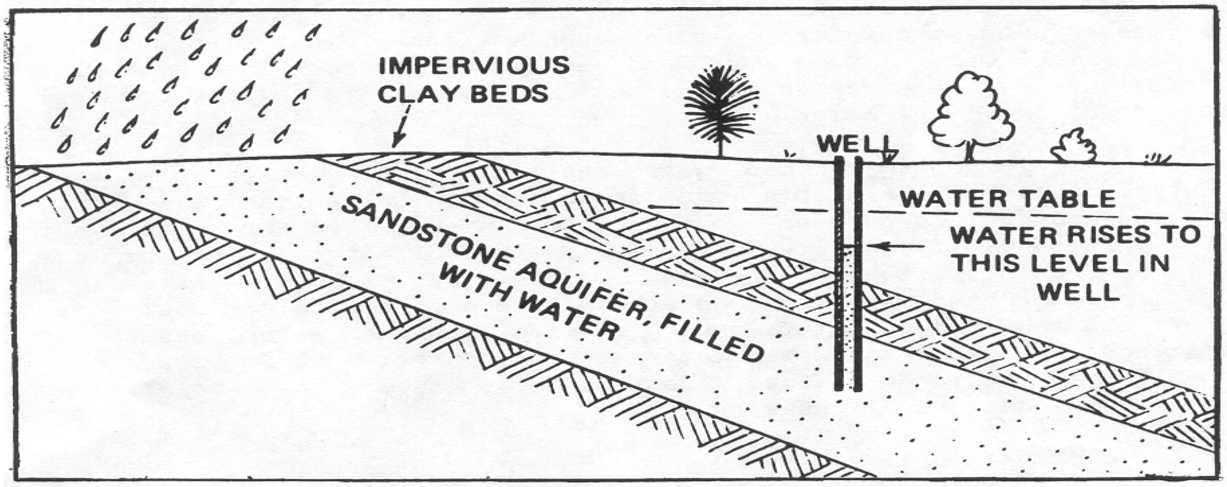
Table 1-1. Daily water consumption table requirements.

## 1-5. HYDROLOGIC CYCLE

a. The hydrologic cycle is the term used to describe the natural circulation of raw water in, on, and above the earth. (Raw water is classified as fresh, brackish, or salt (seawater) based upon the concentration of total dissolved solids). Water occurs in many forms as it moves through this cycle. Figure 1-1A is a simplified illustration showing the steps in the cycle.



Ⓐ Hydrologic cycle.



Ⓑ Aquifer under artesian pressure.

Figure 1-1. Basic hydrology

b. The steps in the hydrologic cycle include precipitation, evaporation, transpiration, infiltration-percolation, and runoff. Water is placed in the air by evaporation from water and land surfaces and by transpiration from plants. It is then condensed to produce cloud formations and returned to earth as rain, snow, sleet, or hail. A portion of the precipitation evaporates, some flow over the earth as run off into lakes and streams, and the remainder goes into the soil and thence into underlying rock formations by percolation (also called infiltration or seepage). Eventually, some of the water that has seeped through the earth will find its way to the surface through springs, or will flow through porous media until intercepted by streams, lake, or the ocean.

c. The cycle does not always progress through a regular sequence. Steps may be omitted or repeated at any point. For example, precipitation in hot climates may be almost wholly evaporated and returned to the atmosphere. In such an instance, the steps of infiltration, transpiration, and runoff are omitted. A large portion of the earth's fresh water supply is trapped below the surface and never gets into the hydrologic cycle.

## 1-6. SOIL FORMATIONS

As shown in figure 1-1 part a, the surface of the earth is divided into three zones, or layers: the zone of aeration; the zone of saturation; and the impervious zone.

a. **Zone of Aeration**. The zone of aeration is the uppermost soil layer. It is within this zone that the roots of plants are found. Water that does not run off into streams and lakes percolates through this earth layer.

b. **Zone of Saturation**. The zone of saturation is a pervious layer of sand, gravel, or rock that is capable of becoming saturated and storing water. Such soil formations are not always present. When they are present and contain usable quantities of water, they are spoken of as aquifers.

c. **Impervious Zone**. The impervious zone is a layer of rock that is so dense that no water will percolate through it.

d. **Water-Table**. The upper level of the ground water, or zone of saturation, is known as the water table. The depth of the water table depends upon the particular soil formation. When a depression in the surface falls below the water table, the result is a spring, swamp, or lake. Ground water, following the law of gravity and hydraulic principles, is constantly seeking a lower level. Sometimes a layer or several layers of impervious earth or rock extend to below the general level of the water table and confines a zone of saturation, or aquifer, below it (see figure 1-1 part b). This water percolates into the aquifer in a lateral direction through the water bearing strata rather than vertically. Since it is at a lower elevation than the water table, it is under pressure. This pressure is referred to as <u>artesian</u> pressure. When a well is dug or drilled into an artesian aquifer, the water in the well rises due to the artesian pressure to a level that is near the level of the water table. In rare cases, artesian pressure may be great enough to cause water to flow from a well.

## 1-7. CHARACTERISTICS AND STANDARDS OF QUALITY WATER.

As water passes over and through the earth, it takes on various characteristics that vary with the materials encountered. The most important water characteristics are turbidity, color, odor, taste, pH value, temperature, and dissolved gaseous and mineral substances. Each of these characteristics has an effect on the water quality. The Army's water quality standards are addressed, in general terms.

### a. **Physical Quality**.

(1) Turbidity. Turbid water is muddy or unclear. Turbidity is caused by suspended particles of sand, clay, silt, and organic material, including decaying vegetation and animal wastes. The size of the particles carried depends on the velocity of flow. When the flow of water stops, the larger particles settle out. Ground water (see para 1-6d) is clearer than surface water because of the natural filtration process it undergoes in percolating through the soil. The Army standard is to remove the particles to which microorganism may be attached by disinfect ion.

(2) Color. Organic substances in solution such as decaying vegetation, or inorganic substance such as manganese salts and iron usually causes the true color of water. For this reason, water taken from swampy sources is often highly colored. True color must be distinguished from the apparent color caused by turbidity. The color standard is to make drinking water more, appealing and palatable.

(3) Odor and taste . Algae (minute water plants), decomposing organic matter, dissolved gases, industrial wastes, and/or certain mineral substances most commonly cause the odors and tastes found in water. Mineral tastes usually come from ground water while organic tastes and odors come from surface water. Cold water has less taste and odor than warm water. To meet palability standards, remove odors and tastes. Palability does not affect the potability of water.

(4) Temperature. Cool water has less odor and taste than does warm water and is more palatable than warm water, which tastes flat. The water temperature of deep lakes and reservoirs is colder at the bottom in the summer. Therefore, if possible, draw relatively cool water during hot weather by shifting the intake to lower depths. On the other hand, cool water is more viscous (thicker) than warm water and thus filters more slowly. Cool water is also more difficult to coagulate and chlorinate than warm water because of slower reactions. When the water temperature drops below 45°F, water treatment rates should be reduced. Command decisions will be made based upon medical recommendations, if need be.

b. **Chemical Quality**.

(1) Total dissolved solids . The TDS of water is composed of small amounts of inorganic and organic substances or particles and mineral salts. The amount of each substance is proportional to the amount of time the water has been in contact with weathered rock, minerals, and other solids. The impure water may contain sulfate, magnesium, chloride, iron, manganese, and other ions as shown in Table 1-2. The TDS water quality standard is to prevent soldiers from getting chemically induced diarrhea.

(2) pH value. The pH value measures the acidity or alkalinity of water. The pH value midpoint is seven, which indicates a neutral solution. If acid substances in the water predominate, the pH falls between 0 and 7. If alkaline substances predominate, the pH is between 7 and 14. A value of seven does not necessarily mean that the water is pure, since acids and bases in solution neutralize one another. The pH value of water helps to determine the corrosiveness of the water, the amount of chemicals needed to disinfect the water, and the ability of the analyst to determine if contaminants are present. The various impurities in water, some of which are acids and some of which are bases, increase or decrease respectively, the hydrogen ion activity in the water. For a long-term (7 or more days) water source, the pH standard of water is between 5.0 to 9.2 units.

(3) Dissolved impurities.

(a) Oxygen. Rainwater contains large amounts of dissolved oxygen as does surface water where fish are plentiful. However, the amounts in surface water vary, as does its concentration of dissolved oxygen. Oxygen can, especially when carbon dioxide is also present, cause many metals to corrode. Therefore, use less oxygenated water for parts such as vehicular radiators

(b) Carbon dioxide. The atmosphere, decomposing vegetation, and underground sources cause carbon dioxide ($CO_2$) to enter water. When this happens, carbonic acid is formed. Carbonic acid aids in the formation of bicarbonates of calcium and magnesium.

(c) Hydrogen sulfide. Hydrogen sulfide ($H_2S$) is produced by the decomposition of organic matter and by the breakdown of certain compounds containing sulphur. It gives off an odor of rotten eggs and most likely is composed of large amounts of industrial or animal wastes. This gas is corrosive to metals. In small amounts, it is unpleasant; in large amount, it is also harmful.

c. **Radiological Quality**. Radiation can cause the body's defenses to weaken and should be avoided. Current water treatment methods are able to ensure that water is potable. The water quality standard is 1000 pc/L for gross beta activity and 10 pc/L for strontium 90.

| IMPURITIES | EFFECTS |
|---|---|
| **SUSPENDED IMPURITIES** | |
| Microscopic organisms | Some cause disease |
| Algae | Cause taste, odor, color, turbidity |
| All solids | Cause murkiness or turbidity |
| **DISSOLVED IMPURITIES** | |
| **SALTS** | |
| **CALCIUM AND MAGNESIUM** | |
| Bicarbonate | Causes alkalinity, hardness |
| Carbonate | Causes alkalinity, hardness |
| Sulfate | Causes hardness, evaporating scaling |
| Chloride | Causes hardness corrosive in boilers |
| **SODIUM** | |
| Bicarbonate | Causes alkalinity |
| Carbonate | Causes alkalinity |
| Sulfate | Causes foaming in steam boilers |
| Fluoride | Causes mottled enamel of developing teeth in children * |
| Chloride | Causes salty taste |
| **IRON** | Causes taste, red water, incrustations on metals |
| **MANGANESE** | Causes black or brown water |
| **VEGETABLE DYE** | Causes color, acidity |
| **GASES** | |
| Oxygen | Causes corrosion of metals |
| Carbon dioxide | Causes acidity, corrosion of metals |
| Hydrogen sulfide | Causes odor, acidity, corrosion of metals |
| Nitrogen | Causes no effect |

* Fluoride, if excessive (over 1 mg/L), may harm children's teeth. In lower concentrations, it increases resistance to dental decay.

Table 1-2. Common impurities in water.

d. **Microbiological Quality**. Transmitted waterborne diseases may be caused by bacteria, protozoa, viruses, or other higher organisms. They are not detected by the naked eye but can be microscopically detected or microbiologically tested to determine the kind and treatment required to make the water potable. However, the detection of many disease-causing microbes is difficult. Therefore, Preventive Medicine Specialists working at Division, Corps, or Theater may conduct certain tests (for certain coliform organisms, such as E. coli) to ensure that microbiological standards are met.

## 1-8. WATER SOURCES

a. **General**. Depending on the environment, one or more water sources may be more prevalent. Water for troop use may come from any of the following sources:

(1) Surface water (rivers, lakes, and streams).

(2). Ground water (springs and wells).

(3) Sea water.

(4) Rain, snow, and/or ice.

b. **Types of Water Sources**.

(1) Because of its easy accessibility, surface water sources are usually the most readily available, predictable, and visible. Surface water can be found in large quantities and can supply many soldiers. This water, as a rule, is low in mineral content, which makes it relatively palatable. However, surface waters have high turbidity from the particles of soil they have acquired during runoff. They are also probably contaminated for the same reason.

(2) Ground water usually has low turbidity because it has been percolated through the soil and undergone a filtration process. There are less chemical or biological contaminants in ground water than surface water; however, minerals which give off a bad taste, are present. Microorganisms, although reduced by filtration, are also present. Therefore, it is best to always assume that all water is contaminated and treat it accordingly. Springs yielding about 20 gallons of water per minute should be adequate for field units. However, ground water supplies are relatively inaccessible, requiring digging of wells or development of springs, and are usually of unknown quantity. Even when the quantity is sufficient, the depth of the water table frequently precludes extracting the water with the equipment available.

(3) Sea water is a source that, for all practical purposes, may be is regarded. The only practical process yet devised to treat salt water is

distillation/reverse osmosis. However, progress is being made with the development of new equipment for use by the engineer units. The use of seawater as a source of water supply should be considered only after an adequate supply of surface and ground water are not present.

(4) Rain, snow, and ice are not considered reliable for military purposes because of the unpredictability of the weather and the lack of suitable collection and storage facilities. It may be all right for small units to use for a short duration. Ice should be used rather than snow since it yields more water. Rain, snow, or ice are theoretically a pure source of distilled water; by the time it passes through the atmosphere and collects (thereby coming in contact with surfaces which mayor may not be clean), it becomes contaminated and needs to be treated as surface water would be.

c. **Selection of a Water Source**. Considering the advantages and disadvantages of each possible source, the surface water source usually best meets our requirements because of its quantity and accessibility. Although the quality is generally poorer than that of a ground water source, we can make the quality of water acceptable by treating it. The selection of a water supply source for a military unit depends upon several factors:

(1) Site conditions. Drainage, security, and adequacy of location are important factors to consider when selecting a site. The area should be checked for dead fish, frogs, and other animals; the condition of vegetation around the water's edge; and previous chemical or other agent use.

(2) Quantity. Because of the variances in the beds of streams, rivers, and lakes, the depth should be checked in several spots to make sure that sufficient water is present for the number of military involved and the duration of the operation. In colder regions, check the depth of water under the ice.

(3) Accessibility. The water must be accessible to personnel and vehicles. A good road network is needed along with parking to withstand all weather conditions. The water source should not be on the main supply route.

(4) Quality. The selected source of water should be of a quality that can be approved and readily purified with normal equipment in a specified amount of time. The water should be checked for turbidity, odor, taste, and color.

(5) Ease of treatment with available facilities. The capabilities of the available water purification equipment and facilities need to be considered and may be a determining factor if more that one water source is considered.

## Section II. WATER TREATMENT PROCESSES

### 1-9. GENERAL

The purpose of water treatment is to remove or destroy enough of the impurities in raw water to make it potable and palatable. The amount and type of treatment required, in a garrison or field environment, depends upon the quality of the raw water, the amount of water required, and the standards that must be met. A series of purification processes is generally employed. Complete water purification includes the following processes: coagulation, sedimentation, filtration, reverse osmosis (when required), and disinfection. In practice, the processes of coagulation and sedimentation are usually combined, so we will discuss these processes together. Reverse osmosis is required in the field when water is brackish or has salt (the process may also be used for fresh water purification). Disinfection is covered separately in Lesson 2.

### 1-10. PRETREATMENT

Water pretreatment is the partial clarification of water by coagulation and/or sedimentation done prior to filtration. Pretreatment prevents rapid clogging of filters and helps to ensure the production of filtered water with uniformly low turbidity.

a. **Plain Sedimentation**. Plain sedimentation is the natural settling of solids that are heavier than water. This sedimentation is caused by the force of gravity. Solids heavier than water are held in suspension in moving water, but they gradually settle to the bottom as the water velocity is reduced. The time required to clarify water by plain sedimentation depends upon the following factors:

(1) Size and specific gravity of the suspended particles. Large and heavy particles settle in a few minutes once the water has become still, whereas very small particles, such as clay and silt, may remain in suspension for several days.

(2) Turbulence of the water. Particles suspended in a rapidly moving stream will remain suspended much longer than the ones in a lake or a pond that is relatively quiet.

(3) Temperature of the water. The viscosity of water is affected by its temperature. The lower the water's temperature, the greater is the viscosity. (Remember viscosity is the property of a fluid that resists internal flow.) Consider 30-weight motor oil. Motor oil of this weight readily flows (that is, lower viscosity) at higher temperatures but difficult to pour (that is, has higher viscosity) at lower temperatures. The viscosity of water at temperatures above the freezing point is so slight and not noticeable to the touch. The effect on sedimentation is also slight. At temperatures below 45ºF, however, the increased viscosity of water is sufficient to retard the rate of sedimentation of suspended solids. Therefore, sedimentation is more efficient at higher water temperatures.

b. **Use of Plain Sedimentation**. Plain sedimentation is not ordinarily used by the military as a separate step in water treatment because the long period required for complete settling would call for an impractical number of settling tanks. However, in an emergency, such as the necessity of taking water that is heavily laden with silt from a swiftly flowing stream, special sedimentation tanks may be set up as a first step. This initial removal of turbidity reduces the load on subsequent treatment processes. Under normal conditions, plain sedimentation can be expected to remove about 55 percent of the nonfilterable residue and about 25 percent of the bacteria. Plain sedimentation is always followed by subsequent treatment of some form. The treatment may include chemically assisted sedimentation and/or filtration, but it always includes disinfection. In field water treatment, plain sedimentation and disinfection may be the only treatment given to water. In such cases, the raw water is allowed to stand in water cans, Lyster bags, or improvised tanks until the turbidity is reduced by sedimentation. The clear water is then drawn from the top and disinfected before use.

c. **Chemically Assisted Sedimentation**. Chemically assisted sedimentation incorporates three separate treatment processes: coagulation, flocculation, and sedimentation. Chemically assisted sedimentation can normally be expected to remove about 80 percent of the nonfiltrable residue, 50 percent of the bacteria, 75 percent of the color, and 25 percent of the taste. Compared to plain sedimentation, this clarification takes place in a relatively short time. Optimum results are usually obtained in about 30 to 40 minutes.

(1) Coagulation. Coagulation is the process of adding chemicals to water, rapidly mixing the solution, and causing the particles to cluster and settle out. The clustering of these particles causes them to increase in weight and settle to the bottom. Various chemicals, but most notably, ferric chloride and aluminum sulfate, are used and mentioned in paragraph 1-11.

(2) Flocculation. After coagulation, particles are assisted to cluster faster by the addition of chemicals that create an insoluble, jelly-like substance called floc. The floc/sticky or gelatinous solution entraps fine turbidity particles, which contain bacteria and other impurities, causes them to stick together, and settle as heavy clumps. Floc particles settle more rapidly and absorbs color. This process is called flocculation.

(3) Sedimentation. Sedimentation is the settling of the floc by gravity after the movement of the water has been retarded. It is essentially the same as plain sedimentation, but much faster.

## 1-11. CHEMICALS USED FOR COAGULATION

Several different chemicals may be used in coagulation, depending upon the characteristics of the water being treated. In some waters, combinations of two or more chemicals produce better results than any one chemical alone. In order to determine which chemical or combination and how much of it should be used, it is usually necessary to perform coagulation tests in the laboratory (see para 5-10). The pH of the water and the minerals present, which is combine with the coagulant, are the principal determinants as to which chemical is used. The following chemicals are some of the more commonly used coagulants:

a. **Aluminum Sulfate (Alum)**. Aluminum sulfate ($Al_2 (SO_4)_3$), commonly known as alum or filter alum, is one of the most commonly used coagulants in military water treatment. It is available commercially in solid form or as a solution called "liquid alum." Aluminum sulfate reacts with naturally occurring alkalinity in water to form aluminum hydroxide, a white precipitate that forms a floc and settles readily.

(1) Two chemical reactions showing the use of aluminum sulfate as a coagulant are given below.

(a) Aluminum sulfate added to water containing calcium bicarbonate.

| | | | | | |
|---|---|---|---|---|---|
| $Al_2(SO_4)_3$ •.18 $H_2O$ + | 3 $Ca(HCO_3)$ $\rightarrow$ | 3 $CaSO_4$ + | 2 $Al(OH)_3$ + | 6 $CO_2$ + | 18 $H_2O$ |
| aluminum | calcium | calcium | aluminum | carbon | water |
| sulfate | bicarbonate | sulfate | hydroxide | dioxide | |

(b) Aluminum sulfate added to water containing magnesium bicarbonate.

| | | | | | |
|---|---|---|---|---|---|
| $Al_2(SO_4)_3$ • 18 $H_2O$ + | $3Mg(HCO_3)$ $\rightarrow$ | 3 $MgSO_4$ + | 2 $Al_2(OH)_3$ + | 6 $CO_2$ + | 18 $H_2O$ |
| aluminum | magnesium | magnesium | aluminum | carbon | water |
| sulfate | bicarbonate | sulfate | hydroxide | dioxide | |

(2) Aluminum sulfate has an optimum pH range of 4.0 to 7.0, which is slightly acid. When treating water within this pH range, the usual practice is to add soda ash (see c, below) to provide sufficient alkalinity for precipitation of all the aluminum as aluminum hydroxide. Aluminum sulfate is desirable in that it is inexpensive; it is easy to store, transport, and apply; and it reduces the temporary (carbonate) hardness in the water. Disadvantages of aluminum sulfate are that it produces carbon dioxide (carbon dioxide is corrosive to pipes and other metals) and that the calcium or magnesium sulfate, which is, produced causes permanent hardness.

b. **Ferric Chloride**. Ferric chloride ($FeCl_3$) is available in liquid, crystal, or anhydrous form. Optimum results are obtained with ferric chloride under both acid (pH 3.5 to 6.5) and alkaline (pH above 8.5) conditions. The floc formed by ferric chloride is heavier than that formed by alum; therefore, it settles more rapidly. It also settles more rapidly in cold water than does alum floc. Ferric chloride is very corrosive, both because of the chlorine ion present and because carbon dioxide is formed in the coagulation process. The chemical reaction that occurs when ferric chloride is added to water containing calcium bicarbonate is as follows:

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| $2\ FeCl_3$ | + | $3\ Ca(HCO_3)_2$ | $\rightarrow$ | $2\ Fe(OH)_3$ | + | $3\ CaCl_2$ | + | $6\ CO_2$ |
| ferric chloride | | calcium bicarbonate | | ferric hydroxide | | calcium chloride | | carbon dioxide |

c. **Coagulant Aids**. These materials do not produce coagulation when they alone are added to water, but they improve the results when they are used with coagulants. The two coagulant aids commonly used in military water treatment are soda ash and limestone.

(1) Soda ash (sodium carbonate). Soda ash ($Na_2CO_3$) is used with alum to supply the necessary alkalinity for precipitation of the aluminum. It does not increase the hardness, but it does increase the corrosiveness somewhat. The chemical reaction is as follows:

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| $Al_2(SO_4)_3\ 18\ H_2$ | + | $3\ Na_2CO_3$ | $\rightarrow$ | $3\ Na_2SO_4$ | + | $2\ Al(OH)_3$ | + | $3\ CO_2$ | + | $15\ H_2O$ |
| Aluminum sulfate | | sodium carbonate | | sodium sulfate | | aluminum hydroxide | | carbon dioxide | | water |

(2) Limestone (calcium carbonate). Crushed or powdered limestone ($CaCO_3$) is used with ferric chloride in the same manner as soda ash and three aluminum sulfate. The reaction is as follows:

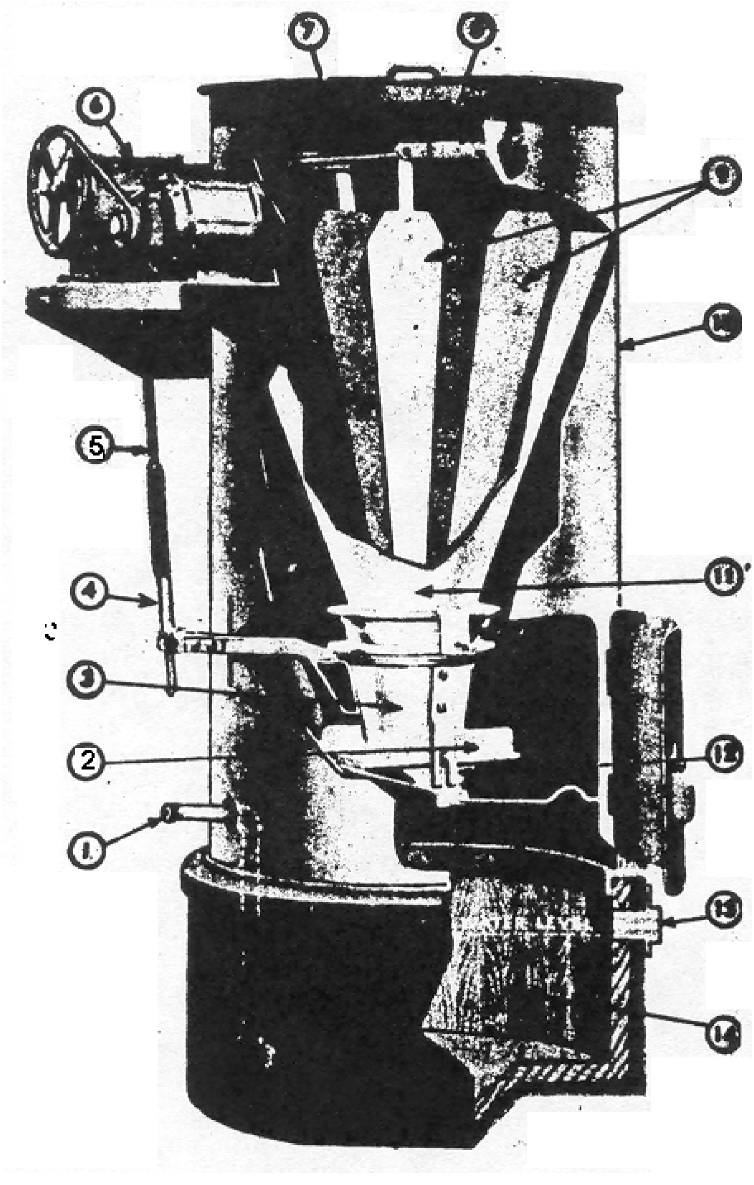
| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| $2\ FeCl_3$ | + | $3\ CaCO_3$ | + | $3\ H_20$ | $\rightarrow$ | 2 Fe(OH)3 | + | $3\ CaCl_2$ | + | $3\ CO_2$ |
| ferric chloride | | calcium carbonate | | water | | ferric hydroxide | | calcium chloride | | carbon dioxide |

## 1-12. CHEMICAL APPLICATION

a. **Feeding**. The amounts of chemicals added to the water must be carefully controlled to insure uniform treatment. Many types of chemical feeders are available, but dry feeders (see figure 1-2) are used most often because of their greater accuracy and simpler operation. They can be adjusted to feed automatically by connecting a flow measuring device, which proportions chemical feed to rate of water flow. The dry chemical is fed at the proper rate to a small tank or mixing chamber where it is suspended in water. The resulting slurry is added to the water to be treated.

b. **Mixing**. Mixing is necessary to provide rapid and uniform dispersion of the chemical throughout the water being treated. The mixing may be done either mechanically by motor driven propellers or hydraulically by baffled chambers or piping systems designed to create turbulent flow conditions. The fundamental principle is the violent agitation of the water and chemical together for a short time.

**NOTE**: Mixing is a very important step because improper mixing results in the wasting of chemicals and premature clogging of filters.



1. Water jet
2. Scraper
3 Oscillating hopper
4. Micrometer screw
5. Connecting rod
6. Speed reducer
7. Agitator shaft
8. Rocker arms
9. Agitator plates
10. Housing
11. Hopper
12. Receiving tray
13. Outlet
14. Mixing chamber

Figure 1-2. Dry-chemical feeder.

c. **Flocculation**. After mixing, flocculation takes place. This process is accomplished, usually, in a single tank, within a time span of between 15 to 45 minutes. During this period, the water is gently agitated to make floc particles. Bacteria and suspended solids meet and adhere together into large masses. This gentle agitation is essential for flocculation to be accomplished either hydraulically or mechanically. The most common hydraulic method is a baffled flocculation basin (see figure1-3) in which the water flows around the end of, or over and under, the baffles. A disadvantage in the use of baffles is that the degree of agitation is dependent upon the water velocity and is not easily controlled. The trend is toward mechanically driven paddles whose speed can be adjusted to give the optimum degree of agitation (see figure1-4).

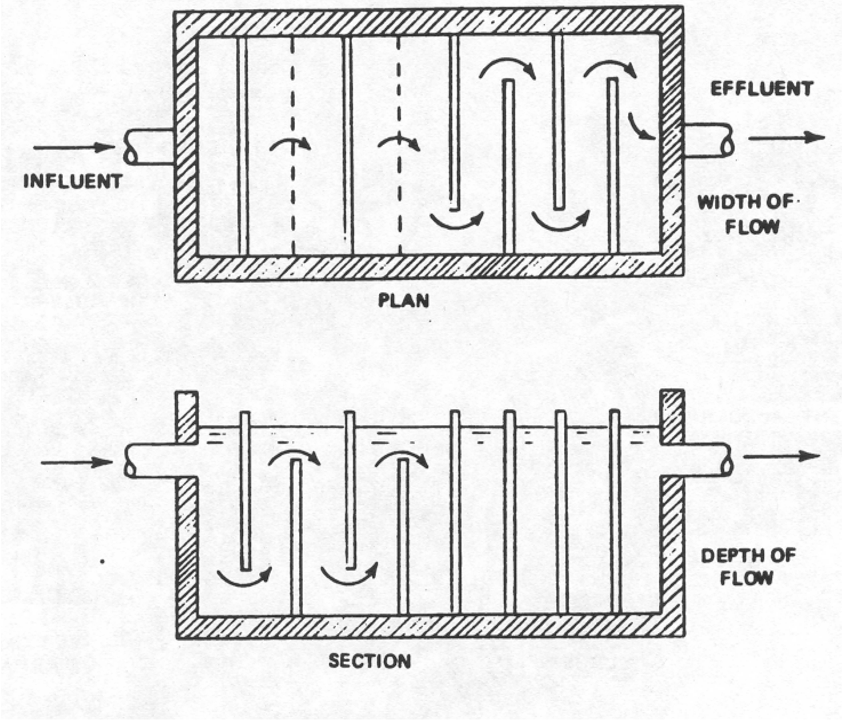


Figure 1-3. Battle flocculation basin.

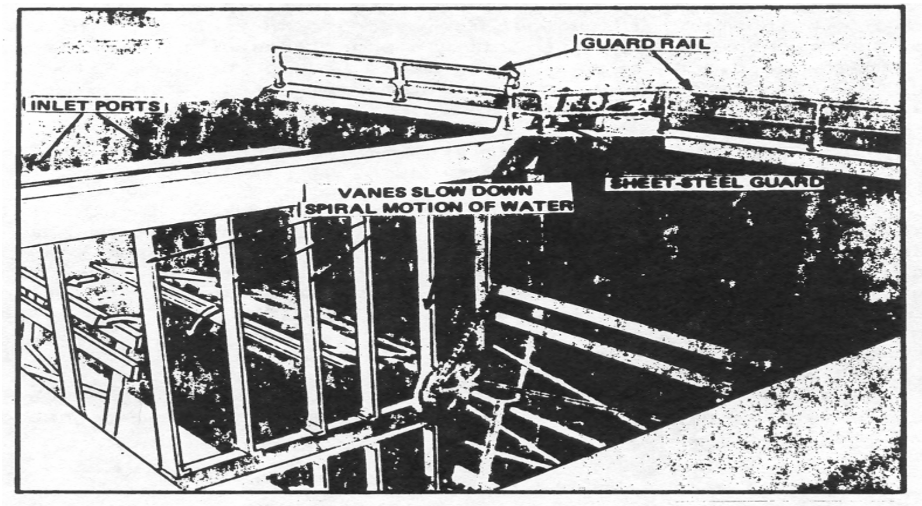


Figure 1-4. Paddle type flocculator.

d. **Sedimentation**. Sedimentation is the process of removing settleable materials. It is accomplished by decreasing the velocity of flow to lessen the ability of the water to hold particles in suspension. As the water flows through a sedimentation basin within a tank, at an extremely slow velocity, suspended material settles toward the bottom of the basin. The water passing out of the tank is relatively clear. Correct basin design keeps the water from flowing directly from inlet to outlet. Additional baffles are sometimes needed to control the flow. Best results are obtained when flow is evenly distributed, properly baffled, and enters the basin at about 1 foot per minute velocity. The process normally takes between 3 and 6 hours. Sedimentation basins may be separate units or they may be combined with flocculators. The latter is shown in figure 1-5.

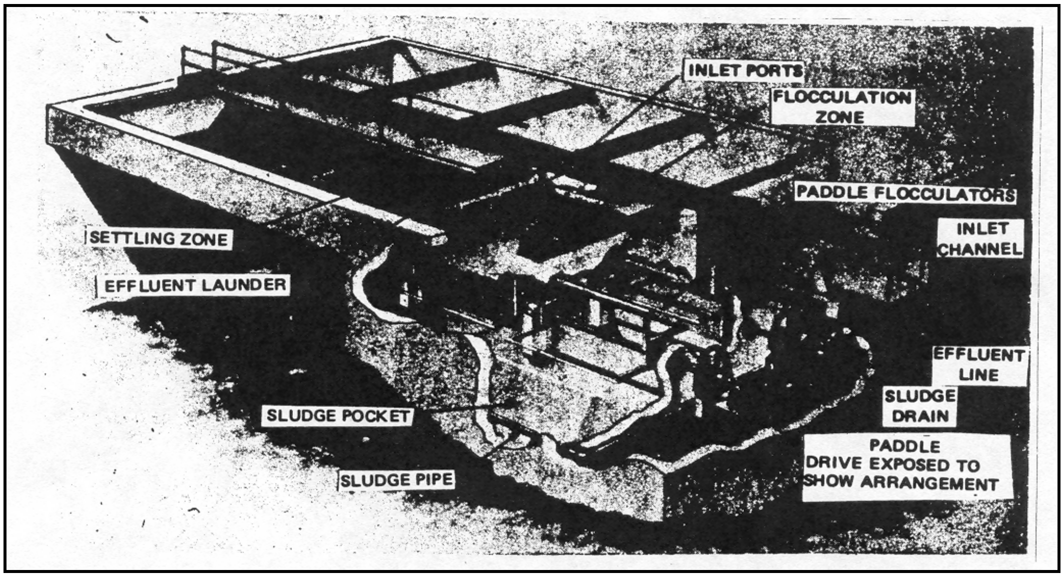


Figure 1-5. Combined flocculator and sedimentation tank.

e. **Solids Contact Process**. The solids contact process incorporates chemical mixing, flocculation, and sedimentation in a single tank referred to as an upflow clarifier (see figure 1-6). In the military version of the up flow clarifier, the process also includes disinfection (chlorination). A brief description of the process follows: The raw water enters through the mixing zone where it is mixed with coagulation chemicals and rotated at high speed by motor driven disks (impellers). The water flows downward through mixing zone, forming floc that absorbs colors and traps other impurities as it settles. The water passes through openings at the bottom of the mixing zone into the clarification zone where a counter rotary motion is imparted to the coagulated water and the speed of rotation reduced to a gentle agitation. As the coagulated water rises in the clarification zone, the floc (or slurry) remains in suspension so that the water at the top of the clarifier (separator zone) is clear and relatively free of floc. The clarified water flows from the effluent launder into the wet well tank from which it is pumped to filters for final treatment. The level of slurry in the clarifying chamber is maintained by the continuous withdrawal of slurry through a draw-off port into a sludge concentrator, which also acts as a small auxiliary clarifier. The solids contact process provides for retention periods of 1 to 2 hours.

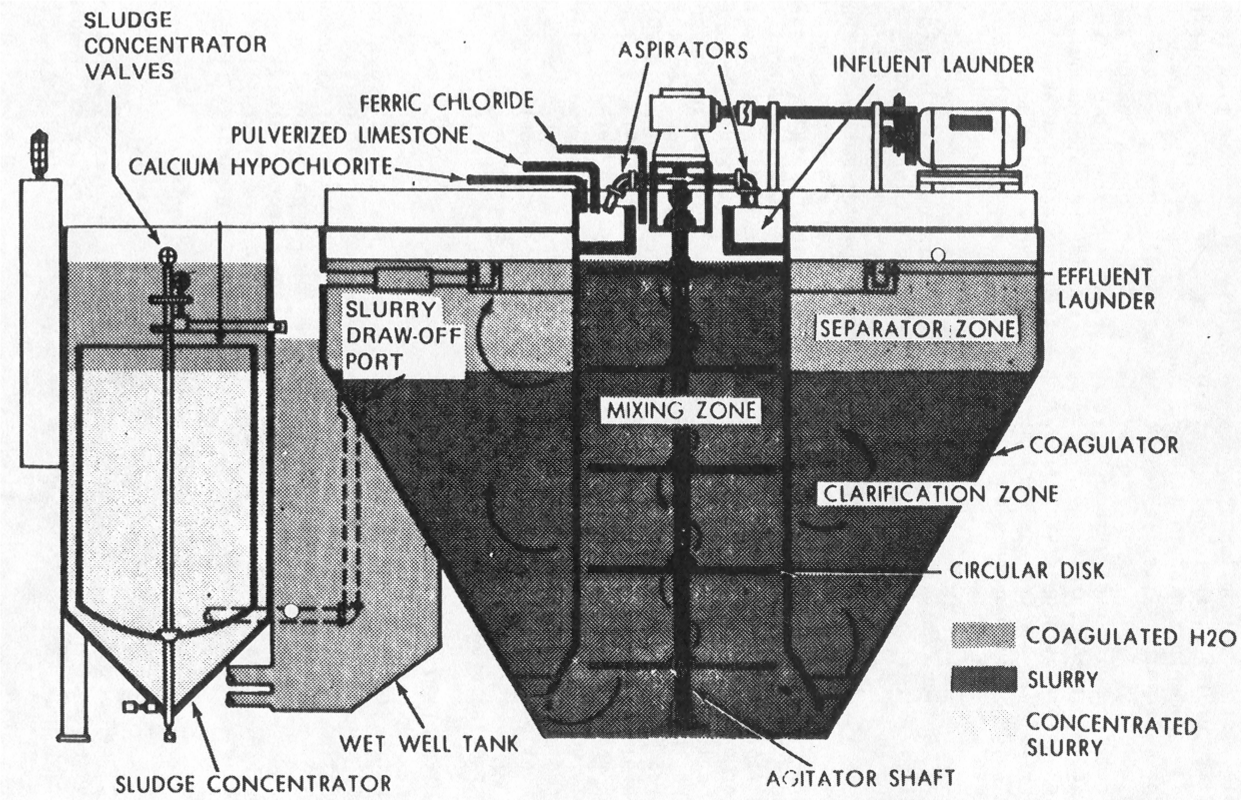


Figure 1-6. Upflow clarifier.

## 1-13. FILTRATION

Filtration is an important process in water treatment. This process can filter physical, chemical, and (to a limited degree) biological particles by separating suspended and colloidal impurities from water as it passes through the porous medium. The filter removes fine organic and inorganic materials, and, incidentally, reduces bacteria and impurities causing taste and odor. A typical filter consist of a bed of sand or other filter medium supported by graded gravel resting on an under drain system (see figure 1-7).

a. **Processes Involved in Filtration**. Filtration clarifies water by a combination of processes:

(1) Straining. Straining is a physical process by which particles too large to pass through the pores of the filter medium are strained out. It is the most important of the processes involved in filtration.

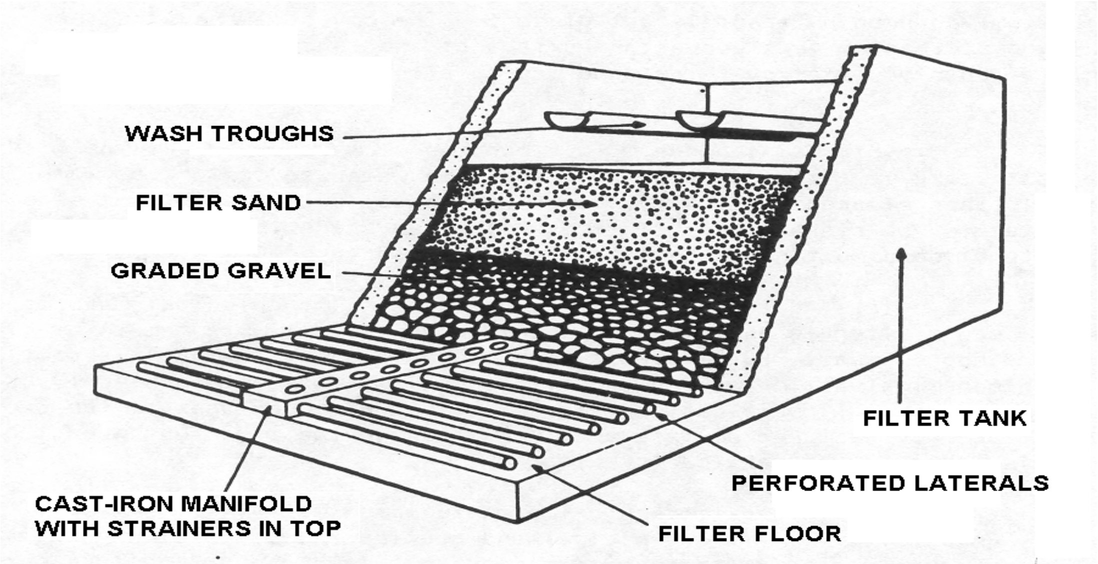


Figure 1-7. Typical sand filter.

(2) Adsorption. Suspended particles adhere to the grains of the filter medium and cover the surfaces with a sticky coating.

(3) Sedimentation. Void spaces between individual grains of filter medium act as tiny sedimentation chambers. Small-suspended particles settle out caused by gravitational forces.

(4) Biological action. Depending on the rate of flow through the filter, limited bacterial action may occur within the filtration mat. This action destroys bacteria and other microorganisms by oxidation.

b. **Types of Filters**. Filters used in municipal or fixed military installation water treatment facilities include slow sand filters, rapid sand filters, pressure filters, and diatomite filters.

(1) Slow sand filters. Slow sand filters are no longer being constructed because more-efficient methods have been developed. However, there are still many slow filtration plants in existence. Slow sand filters are usually used when coagulation is not included in the treatment process. Their capacity is about 2 to 10 million gallons per day (gpd) per acre. This rate of filtration requires about 500 square feet of filter surface to maintain a water production rate of 3,000 gallons per hour (gph), the capacity of the Army's largest standard mobile, field water purification unit.

(a) Construction. The slow sand filter is constructed as shown in figure 1-7, except that it does not have wash troughs. It consists of about 12 to 18 inches of graded gravel (the largest sizes on the bottom) covered by about three feet of sand. The cover of the structure should be at least six feet above the surface of the sand to provide for an adequate depth of water over the sand and to allow sufficient head room for cleaning.

(b) Maintenance. To clean the slow sand filter, the first step is to take it out of service and allow the water to drain from it. The filter is then cleaned by manually removing the top 3 or 4 inches of sand. The filter may be cleaned several times before any sand is replaced; however, the depth of sand must never be less than 24 to 30 inches.

(c) Advantages and disadvantages. The principal advantage of the slow sand filter is that, when properly operated, it removes amebic cysts and approximately 99 percent of the bacteria. This removal is partly due to biochemical action within the filter medium. Its action closely approximates natural purification. The principal disadvantages of the slow sand filter are the large surface area required and the time lost when the filter is taken out of service for cleaning.

(2) Rapid sand filters. The rapid sand filter is the most commonly used filter today in municipal and garrison water treatment facilities. Rapid sand filters are designed to filter about 2 gallons per minute (gpm) per square foot ($ft^2$), which is roughly equivalent to 25 square feet of filter surface for a 3,000 gph production rate. This is about twenty times the capacity of the slow sand filter. Because of the increased rate of flow, water must be pretreated before filtering.

(a) Construction. The construction of a rapid sand filter is as shown in figure 1-7. The under drain system supports 18 to 24 inches of graded gravel. The gravel is about 24 to 30 inches of filter medium. The sand used in a rapid sand filter is somewhat coarser than that used in the slow sand filter (0.35-0.55 mm in the rapid filter, as compared to 0.25-0.35 mm in the slow filter). The coarser sand permits a faster rate of flow. The rapid sand filter has a provision for reversing the flow of water in the under drain system for washing the filter, a feature not found in the slow filter.

(b). Maintenance. Cleaning of the rapid sand filter is necessary when the loss of head is 7 to 9 feet or when the filter has been operated continuously for 100 hours. By "loss of head," we mean a differential in the pressure of the influent and the effluent equivalent to the weight of 7 to 9 feet of water (3 to 4 pounds per square inch). Loss of head is measured by a gauge that can be read directly in feet of water (see figure 1-8). Washing is accomplished by taking the filter out of service, opening the waste valve, and running clean water through the under drainage system in a reverse direction at seven or eight times the rate of filtration. The clean water is forced upward through the gravel and sand. The water causes expansion that loosens and agitates the sand grains and washes accumulated floc and foreign matter off the grain surfaces. The wash water rises into the wash troughs (see figure 1-7) and is discharged through the sewer, carrying foreign matter with it. The filter is returned to service when the wash water is free of foreign matter.

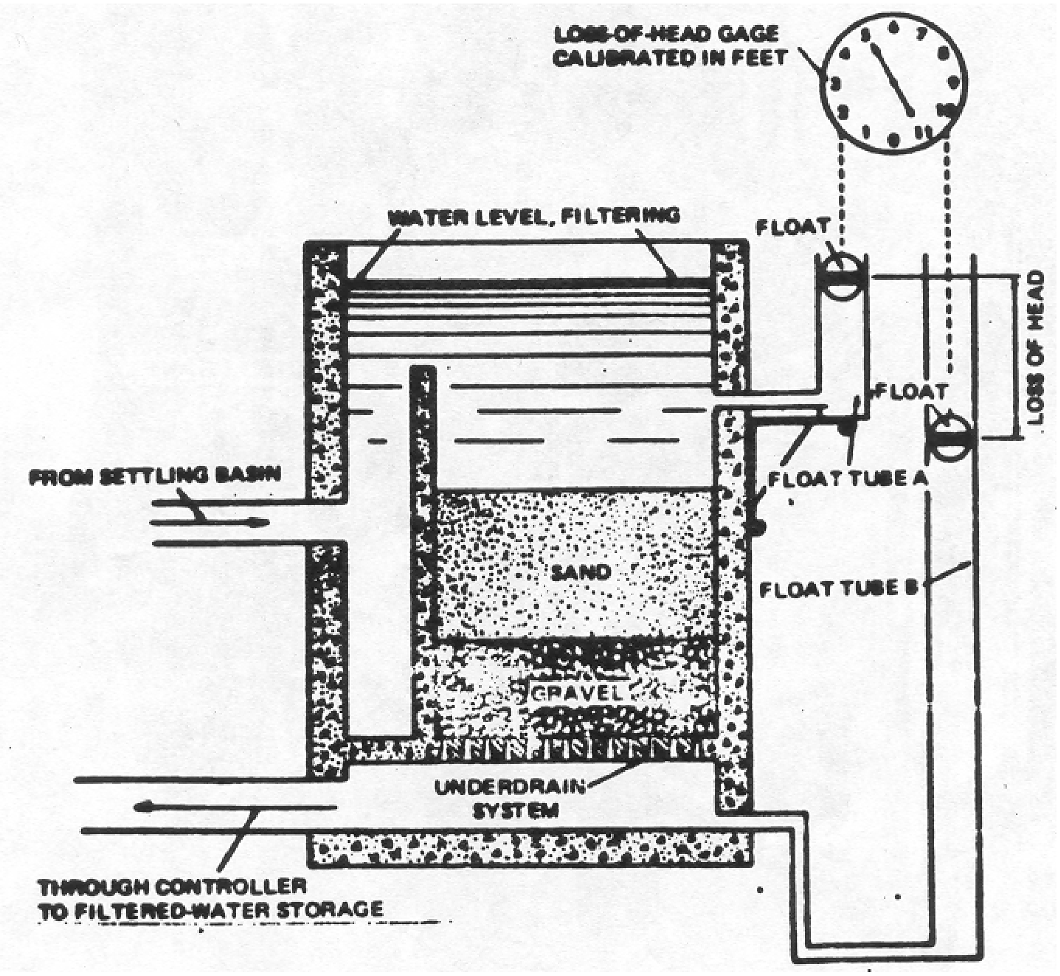


Figure 1-8. Loss-of-head measurement.

(c) Advantages and disadvantages. The principal advantage of the rapid sand filter is its economy of space in that it can process approximately twenty times the amount of water that can be filtered by a slow sand filter with the same surface area. Disadvantages are that pretreatment is required, that bacterial removal is less than in the slow filter (90 to 98 percent as compared to 99 percent for the slow filter), and that a skilled operator is required.

(3) <u>Pressure filters</u>. A pressure filter is essentially the same as a rapid sand filter except that it is completely enclosed in a steel tank and the entire unit is operated under pressure (see figure 1-9). The tank may be either vertical (as shown in the illustration) or horizontal. Its characteristics and flow rate are the same as the rapid sand filter except that .it operates under pressure instead of gravity. The pressure type filter is usually employed in small installations or swimming pools where the cost of a rapid sand filter plant would be prohibitive. It has the advantage of low initial cost and permits the use of one pump (rather than two pumps) to raise the water from a low elevation, through the filter, to a distribution system. Its main disadvantages are that the operator is unable to observe the filter operations and that it is not equipped with wash troughs.

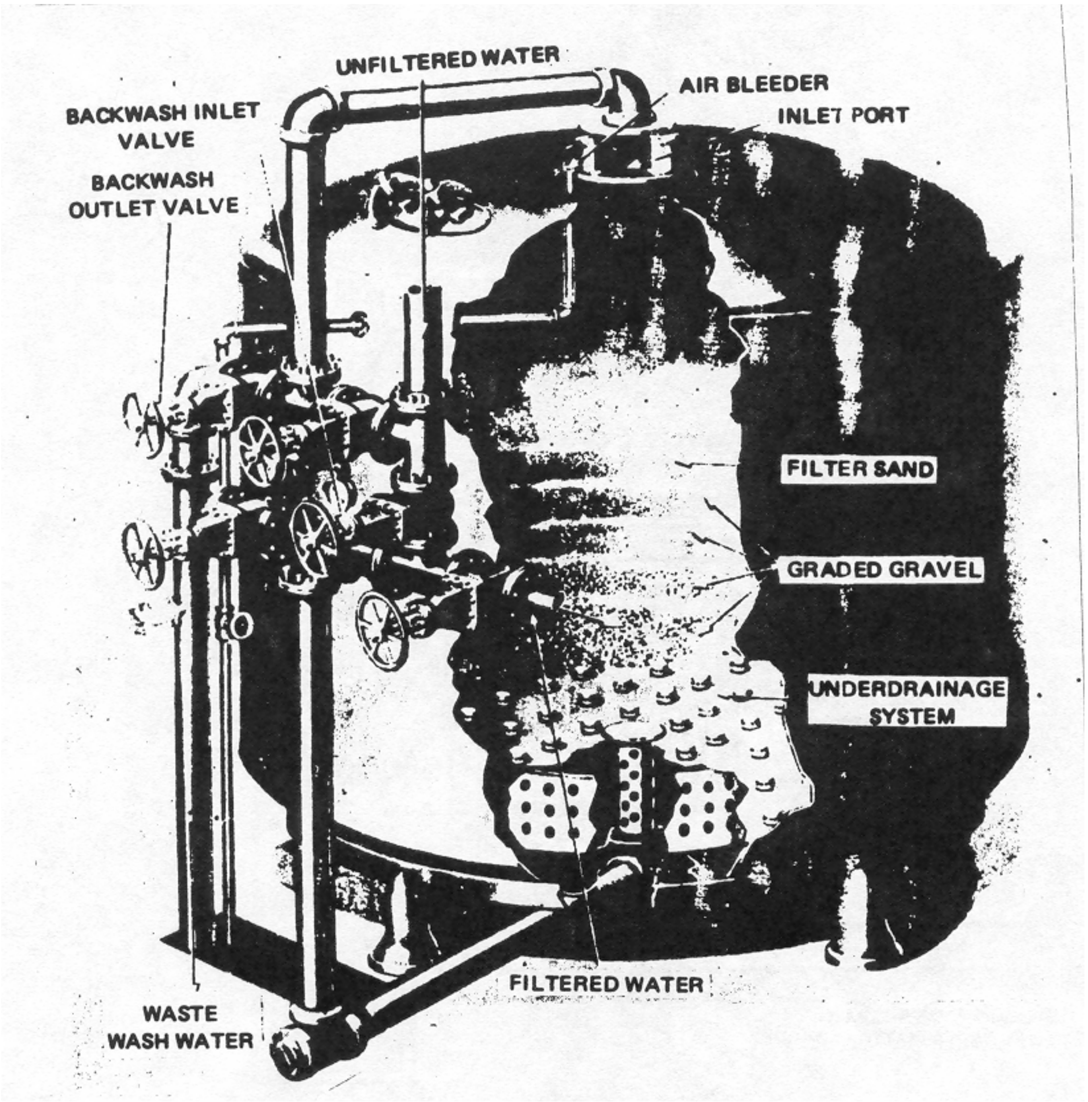


Figure 1-9. Pressure filter.

(4) Diatomite filters. Diatomite filtration is a unique process which was adopted by the United States (US) Army from the British during World War II and which is now incorporated in the standard field water treatment process. It is also used commercially in some small municipal systems and is used extensively in swimming pool filtration. It is not used in the reverse osmosis process. The principle of diatomite filtration is the remarkable absorptive property of diatomaceous earth, the filter medium used in this process. Diatomaceous earth is a white to gray powder made from the skeletal remains of algae known as diatoms. The particles making up the powder, being composed of silica, are high in strength, rigid, and abrasive. They are extremely small, averaging 10 to 200 microns (0.01 to 0.2 mm) in diameter. This size is approximately forty times smaller than that of the sand grains used in a rapid sand filter (0.35 to 0.55). Moreover, the diatomaceous earth particles are highly irregular in shape. This irregularity in size and shape gives the particles an extremely high porosity (about

90 percent) due to the high void space between particles. It also gives the particles property of clinging together to form a "bridge" across an opening larger than the particles themselves, but through which water passes (see figure 1-10).

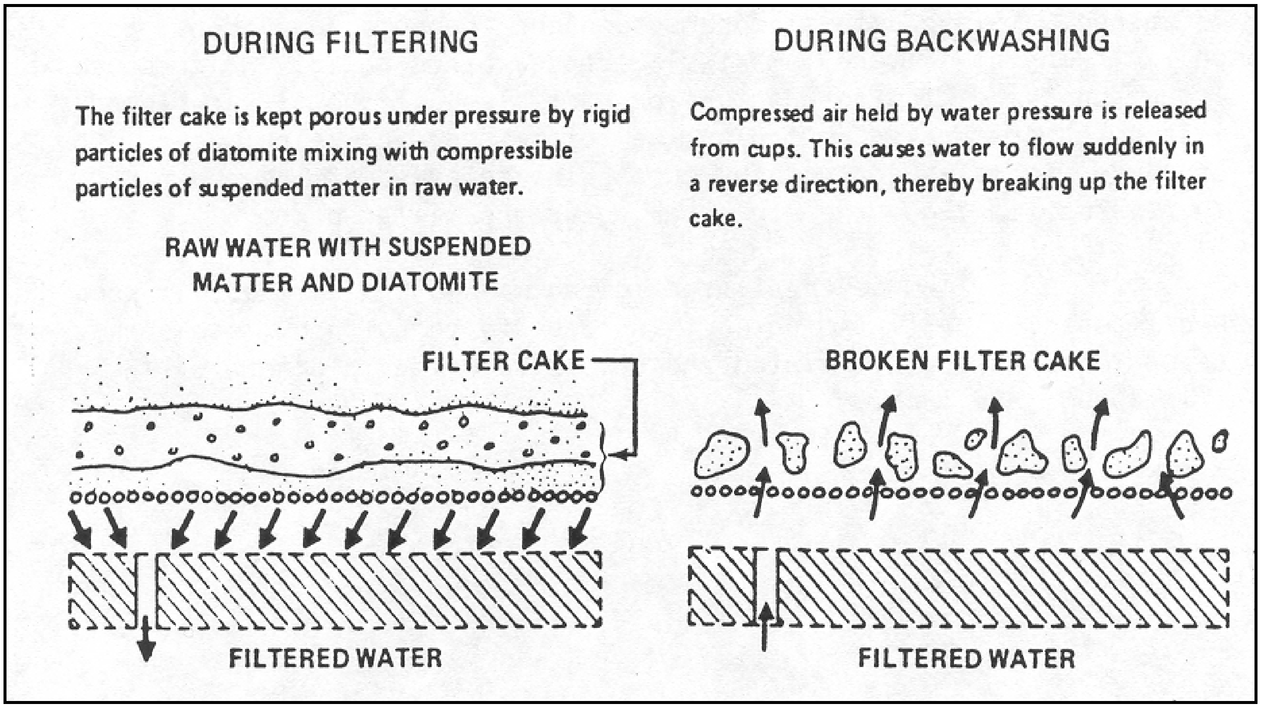


Figure 1-10. "Bridging" of diatomaceous earth particles across septum.

(a) Construction. Figure 1-11 illustrates the construction of a diatomite filter. It consists of a metal tank enclosing five or six filter elements (depending on the model). Each filter element is made up of a series of plastic cups fastened to a central tie rod. The cups are enclosed in a perforated metal tube that is covered by a plastic membrane sleeve (see figure 1-12). The plastic membrane provides a porous surface (septum) upon which the diatomite coat forms. This diatomite coat is usually called the "filter cake."

(b) Operation. The diatomite filtration process involves three separate operations: precoat, filtration, and backwash. The precoat operation is necessary to prepare the filter element with a coat of diatomite (also called filtraid). A slurry of water and diatomite are introduced to precoat the filter. The diatomite is held on the filter element by a pressure difference between the inside and outside of the filter elements. Unfiltered/raw water enters through the funnel, mixes with slurry water, and passes through the filtering element system (see figure 1-12). This liquid keeps the filter cakes porous as the rigid particles of diatomite mix with a small amount of continuous flow of slurry. The precoat filter allows water to pass but prevents passage of schistosome larvae, amoebic cysts, and about 90 percent of the bacteria. The flow rate of a diatomite filter is about 5gpm/ft$^2$ (see figure 1-13 for the flow).

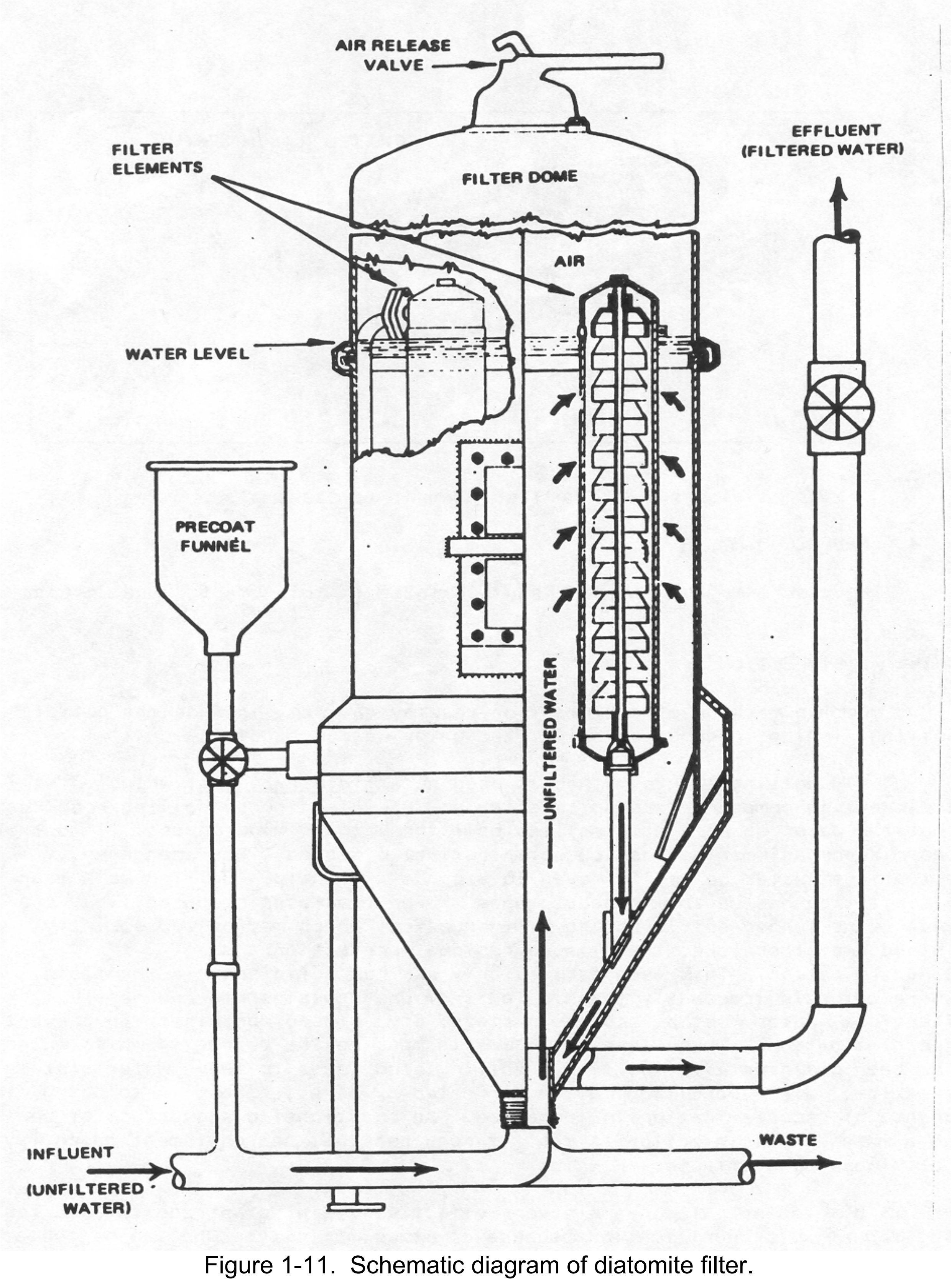


Figure 1-11. Schematic diagram of diatomite filter.

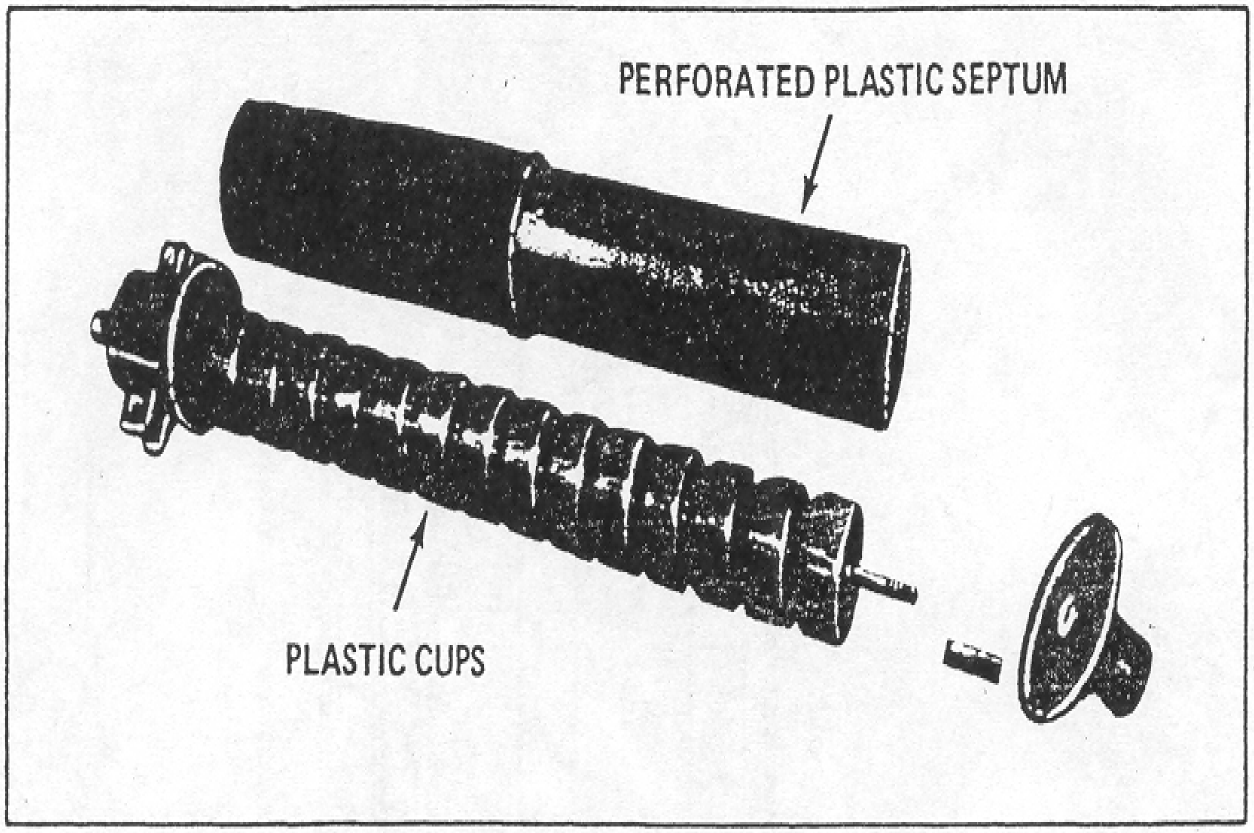


Figure 1-12. Filter element (disassembled).

(c) Maintenance. There will come a time when the filter elements become clogged by the constant build up of diatomite particles."

1 To clean or clear them, backwashing is necessary. The equipment needs to be taken out of service for this process. Backwashing occurs when compressed air, held by water pressure, is released as the air valve is opened. This causes air pressure under the dome to suddenly be released. Air in the filter element air traps expands rapidly which causes a "blast" that knocks diatomite and foreign particles off the filter elements. The filter cakes are broken up too as the compressed air, which was held by water pressure, is released from the cups. The released compressed air causes water to reverse its flow, thereby breaking up the filter cakes.

2 Once the filter is backwashed and drained, it should be washed/flushed. The filtering unit is ready to be put back into operation after precoating has been initiated and completed. The thickness of the precoat is about 1/16 inch.

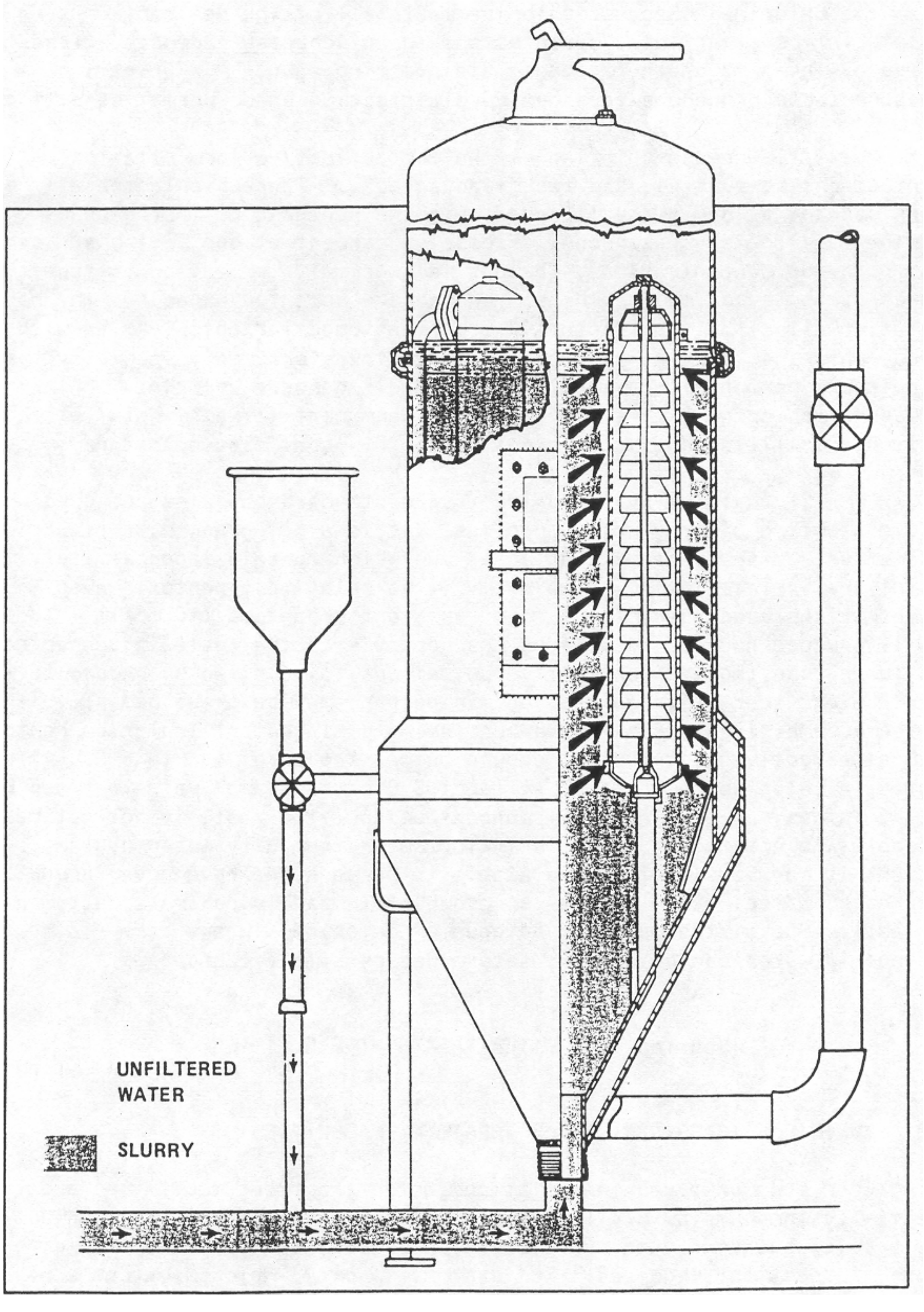


Figure 1-13. Flow of materials during the precoating process.

## 1-14. REVERSE OSMOSIS

Reverse osmosis will be discussed later in this chapter and in Chapter 5.

## 1-15. DISINFECTION

Common methods of disinfection used by the Army include the use of boiling, iodine, gaseous chlorine, and chlorine compounds.

a. **Boiling**. This method is used as a field expedient, when disinfecting compounds are not available. Disinfection by boiling requires that the water be held at a rolling boil for 5 to 10 minutes to kill most of the microorganisms that can cause intestinal diseases. For emergency situations, water boiled for even 15 seconds helps. Boiling as a means of disinfection has several disadvantages. Once the water stops boiling, the heat is no longer sufficient to kill organisms that may be subsequently introduced; therefore, there is no residual protection against decontamination. This is a particularly serious deficiency in the field, where water is frequently transferred from one container to another. Therefore, water must be stored in clean, dry, closed containers to prevent decontamination. There is also no way to measure the degree to which water has been disinfected by boiling. Boiling also tends to leave water flat and tasteless. This condition may be corrected by aeration, but in so doing, the chance of recontamination is increased. An additional disadvantage of boiling as a means of disinfection is that it requires fuel and equipment that may not always be available.

b. **Iodine**. Iodine is a very effective disinfectant and is used for individual water purification because of its simplicity. One iodine tablet is used to disinfect a canteen (1 qt/960 ml) of water or two tablets if the water is turbid or cold (40ºF). A total of thirty minutes is needed to do this process, as described in Lesson 2. As a principal means of disinfection, however, it has several disadvantages. Iodine tablets are not very stable; they decompose when exposed to, moisture in the atmosphere. The most serious deficiency of iodine as a disinfectant is that there is no current test for determining iodine residual in the field. In addition, iodine gives water a taste and color which many people find objectionable.

c. **Chlorine**. Because chlorine meets all of the desirable characteristics of an ideal disinfectant to an acceptable degree, it has been adopted by the Army as the standard disinfecting agent. Chlorination is the only acceptable procedure for routine disinfection under normal conditions.

(1) Gaseous chlorine is the most effective form of chlorine for disinfection, however, it has two disadvantages. Whereas chlorine at the proper concentration in the finished water is nontoxic to man, gaseous chlorine is extremely hazardous. Excessive concentrations in the air can be fatal. In low concentrations, the gas is extremely irritating to sensitive tissues of the eyes, mouth, throat, and nose. Repeated exposures may have a cumulative effect on lung tissues. Equipment used for chlorination with gaseous chlorine is relatively complicated; therefore, only specially trained and reliable

personnel are permitted to handle gaseous chlorine. Chlorination by means of chlorine gas is found only in permanent (fixed) installation water treatment facilities and is done only by highly qualified operators.

(2) Calcium hypochlorite is the standard chlorine compound used for disinfection of Army water supplies. It is a dry granule or powder which is relatively stable, readily soluble, and which contains approximately 70 percent available chlorine by weight. It is relatively nontoxic even in concentrations used against the most resistant organisms (10 mg/l). In fact, it produces nausea and is unacceptable to the taste in concentrations much lower than those that cause serious toxic effects. Added to water in sufficient quantities to destroy microorganisms (chlorine demand), it has some remaining to serve as a continuing disinfectant (chlorine residual). The most effective disinfection occurs between the pH of 5.5 to 6.5. After 30 minutes, chlorine residual of at least 5.0 ppm and a pH value between 6.5 and 7.5 is desirable. In normal concentrations, the taste is not noticeable to people who are accustomed to drinking water from city water systems; however, it may be slightly unpalatable to persons who have never drunk chlorinated water. Even the latter group will become accustomed to the taste. One of the major advantages of chlorine--in any form--is that its presence in water can be determined by simple tests.

## Section III. WATER TREATMENT FACILITIES

### 1-16. MUNICIPAL (GARRISON) WATER TREATMENT FACILITIES

Garrison, or fixed installation, water treatment facilities are essentially the same as civilian municipal facilities. The size and design of the facilities depend upon the population served, the space available, and the amount of treatment required. For example, a city, which services a metropolitan area of approximately 800,000 people (including an installation), treats its public water supply only by chlorination. This is because the source may have a deep underground aquifer from which water is obtained by drilling deep wells. Other smaller communities within a 35-mile radius test water from surface sources and require complete treatment. Garrison or municipal water treatment facilities uses one of the following combinations of processes.

a. **Slow Sand Filtration Plant**. The slow sand filtration plant is generally accompanied only by chlorination following the filtration process. This type of plant is decreasing in popularity and is seldom built today because of the ever-increasing scarcity of land and the large land requirement for this type of filter.

b. **Rapid Sand Filtration Plant.** The rapid sand filtration plant is the most common type of municipal or garrison water treatment plant. The rapid sand filtration plant requires some type of pretreatment to prevent excessive clogging of the filters and the resulting requirement for frequent backwashing. Pretreatment may consist of the standard coagulation, flocculation, and sedimentation process or, in some of the more modern plants, utilize the solids contact process. Filtration is usually accomplished by means of an open (gravity type) rapid sand filter in some small communities, although the pressure filter may be found. Crushed anthracite (hard coal) is sometimes used to replace the sand in a rapid sand filter, or a layer of fine anthracite may be placed as a cover for a sand bed. Graded anthracite may also be used to replace the gravel. Among the advantages claimed for anthracite are lower head loss, less wash water needed, a lower rate of application of wash water, a higher rate of filtration, and lower filter runs. Chlorination always follows filtration.

c. **Diatomite Filtration**. Diatomite filtration is not often found as the primary means of filtration in municipal water supply systems. They are, however, frequently found where (1) auxiliary means are needed to meet seasonal demands, (2) temporary facilities are needed while permanent facilities are being built; or (3) treatment by filtration is considered necessary, but chemical coagulation is not warranted. In municipal use, diatomite filtration is not generally used in conjunction with chemical pretreatment. Diatomite filtration is always followed by chlorination.

## 1-17. FIELD WATER TREATMENT UNITS

Field water treatment differs from municipal or fixed installation water treatment in that the equipment used must be portable so that it can be rapidly moved and set up to support tactical operations. It must also be capable of treating water from a poorer source than is generally available to a fixed installation or a municipality. Accordingly, field water purification equipment usually incorporates both chemical pretreatment and diatomite filtration. Although field water treatment is discussed in Lesson 5, the equipment w ll be described here in general terms

a. **Erdlator**. The term "erdlator" is a nickname for the standard Army field water purification unit that was coined by its developers (Engineer Research and Development Laboratories). The erdlator may only be used to purify fresh water.

(1) Principles of operation. All of the erdlators incorporate the following operational processes:

(a) A continuous flow solids contact process utilizing an upflow clarifier, are commonly referred to as the erdlator tank. In continuous flow equipment, water enters, is treated, and leaves at a constant rate of flow. This flow can be maintained for 24 hours a day, if necessary.

(b) Chemical pretreatment combined with disinfection, using ferric chloride as a coagulant, pulverized limestone as a coagulant aid, and calcium hypochlorites as a disinfectant.

(c) With the exception of the 10,000--gph WPU (see para (2) (f), below), filtration of coagulated water from the erdlator is done by means of diatomite filtration.

(2) Models. Erdlator models can be found in foreign systems and are available in the US Army for issue. However, the US Army is phasing them out and cannibalizing some for spare parts. Those models, in use for the time being, are:

(a) Water purification equipment set, 420-gph, skid mounted. It can also be dropped by parachute.

(b) Water purification unit, trailer mounted, 600-gph. This unit is mounted on a 2 1/2-ton, 2-wheel trailer, which can be either towed or air dropped.

(c) Water purification unit, van type body mounted, 1,500gph. This unit is mounted on a standard 2 1/2-ton truck chassis (see figure 1-14). The van is heated, giving it an all-weather capability.

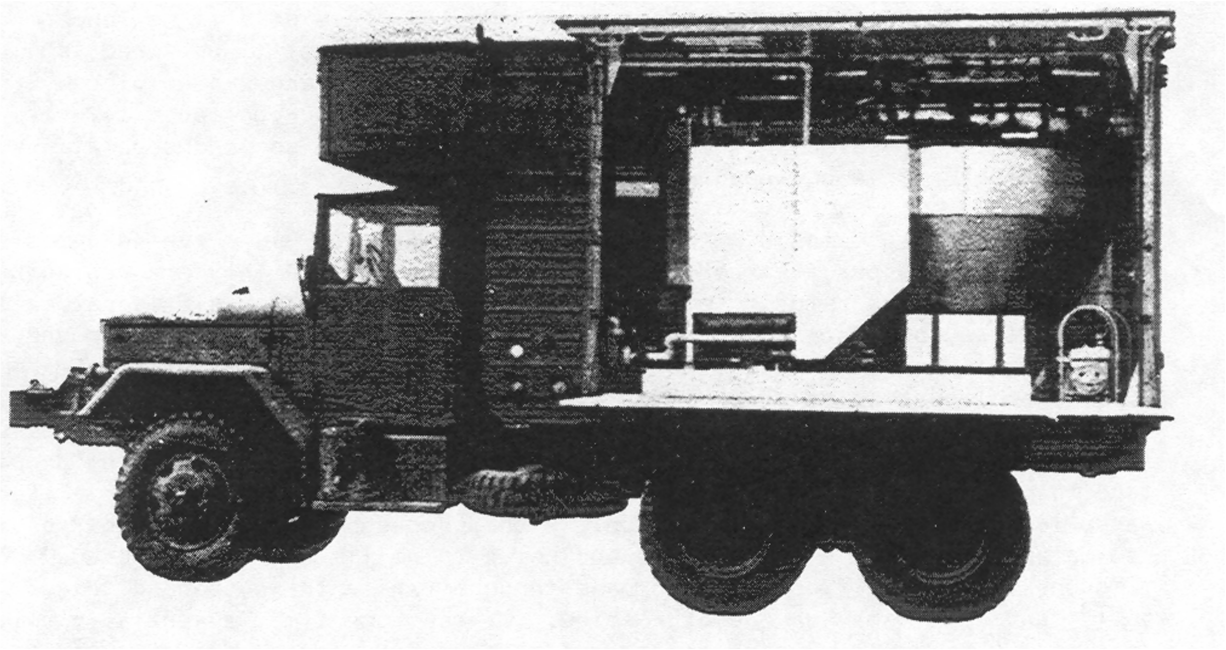


Figure 1-14. Water purification unit, van type body mounted, 1,500-gph.

(d) Water purification unit, van type body mounted, 3,000-gph. This unit is the largest mobile water purification unit in the Army inventory. It is mounted on a standard 2 1/2-ton long-wheelbase truck chassis (see figure 1-15).

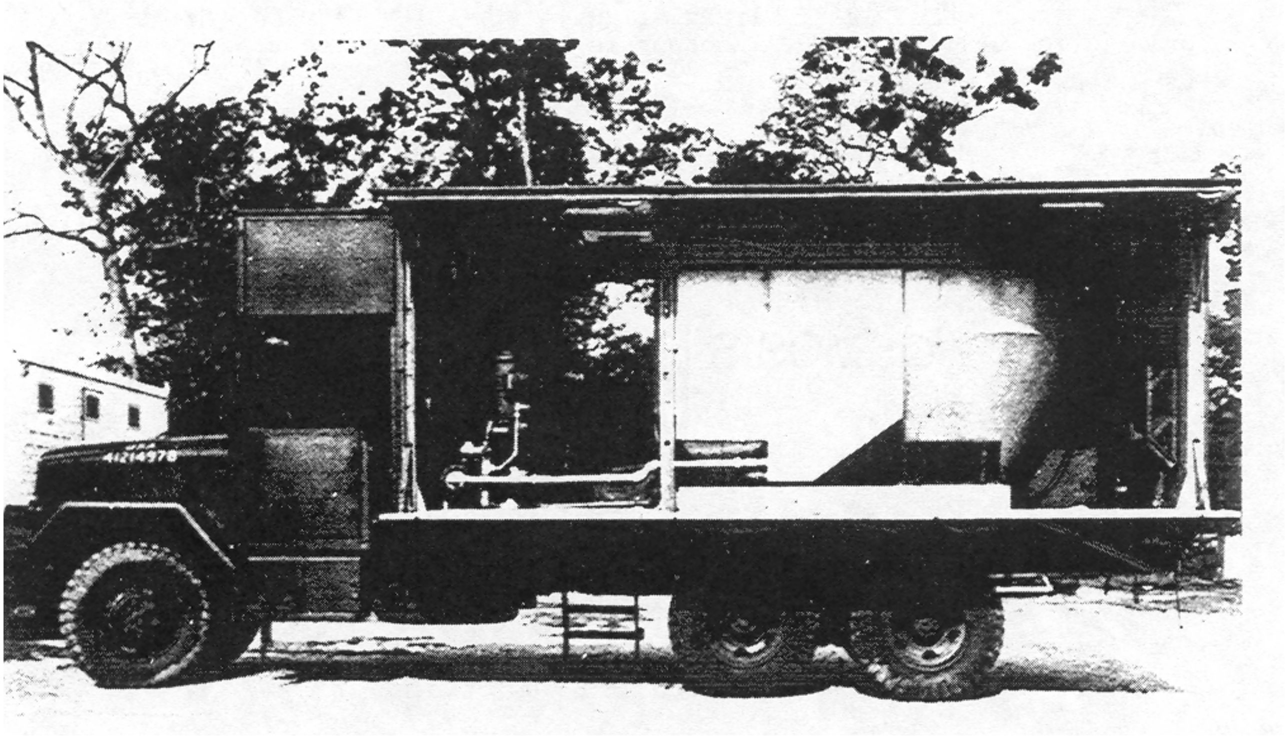


Figure 1-15. Water purification unit, van type body mounted, 3,000-gph.

(e) Water purification unit, base mounted, 3,000-gph. This item is essentially the same as the van type body mounted unit except that it is mounted as a permanent or semi permanent installation. It also has an oil fired water heater for use under arctic conditions.

(f) Water purification unit, 10,000-gph. The 10,000-gph unit is the largest standard water purification set utilizing the erdlator. It differs from the smaller sets in that it employs two rapid sand filters rather than diatomite filters. This unit, like the 3,000-gph base mounted set, is used in permanent or semi permanent installations (rear area support areas which is manned for an extended time).

b. **Engineer Water Purification Set No.4**. This unit is no longer service in some reserve component units and in allied forces receiving US Military assistance. The Engineer Set No.4 has a 3,OOO-gph capacity. It uses conventional batch pretreatment with alum and soda ash and separate batch disinfection. It is equipped with the diatomite filter.

c. **Reverse Osmosis Water Purification Unit**. Reverse osmosis water purification units (ROWPU) are used to purify fresh, brackish, or salt water. ***They are replacing erdlators***. Reverse osmosis is the opposite of osmosis. Osmosis is nature's biological way or process of passing more a dilute or clearer solution through semi-permeable or semi-porous membrane into a more concentrated solution (from a pure to an impure solution). Osmosis occurs in humans and is the means for nutrients to reach and nourish cell tissue. Plants absorb food and moisture from the soil in the same way (see figure 1-16). Reverse osmosis is the process used to purify water. Separating suspended and dissolved solids from filtered water (or high concentrated solution) is the process. This is done by forcing raw water under very high pressure against a thin fi1m called a membrane. The membrane allows purified water to pass through leaving the suspended, dissolved solids and salts stay on the other side. At the same time, essentially all particles, including microorganisms and suspended colloids, are removed (see figure 1-17). The Army has this equipment. The equipment is called the reverse osmosis water purification unit.

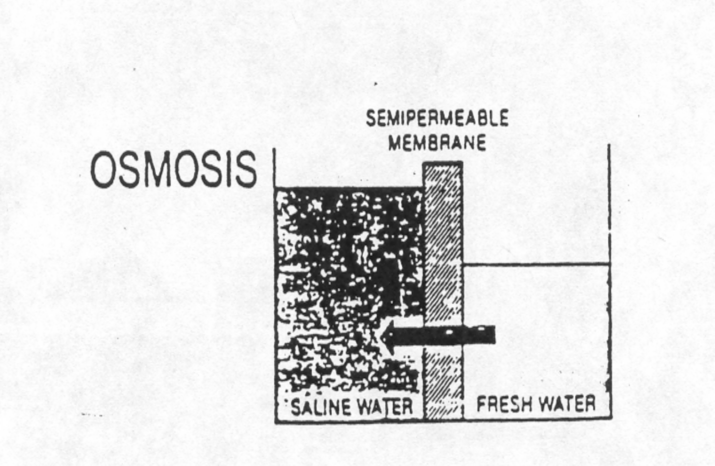


Figure 1-16. Osmosis.

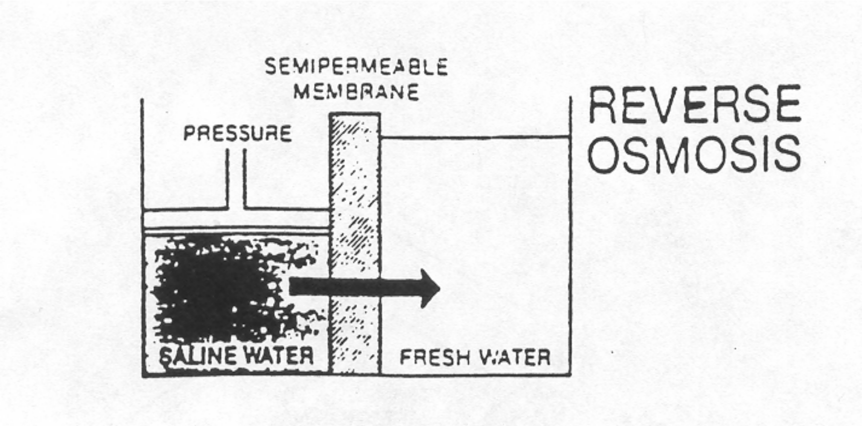


Figure 1-17. Reverse osmosis.

(1) <u>Principles of operation</u>. All of the reverse osmosis water purification units or ROWPU incorporate the following technical principles of operation: The ROWPU reduces the number of small particles, chemicals, and solids in solution (called dissolved solids), found in most fresh water systems, dirty streams, and seawater, to a level fit for drinking by humans (figure 1-18).

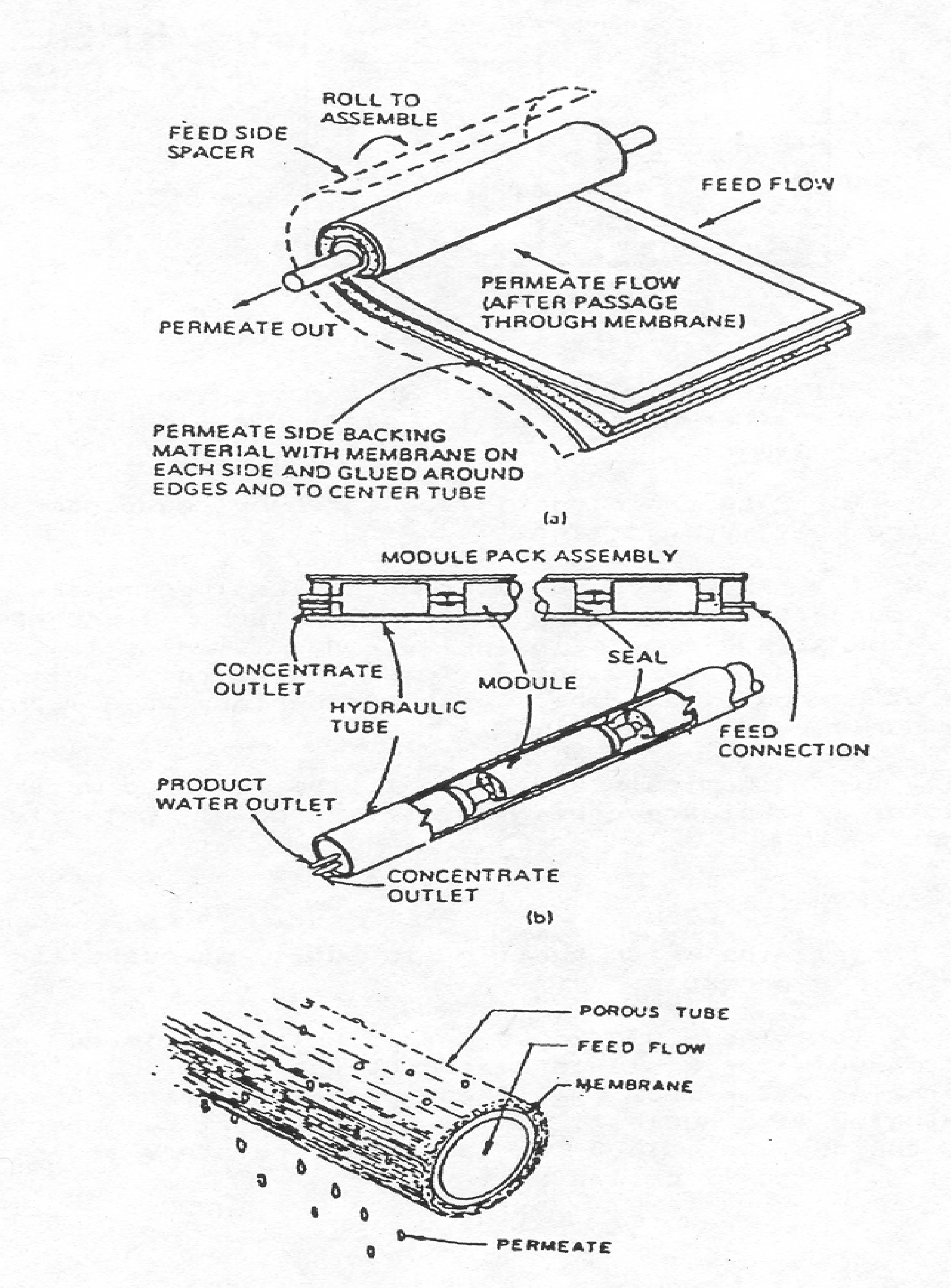


Figure 1-18. Reverse osmosis, spiral wound membrane system.

(b) The multimedia filter removes the large solids that pass through the input trainer as well as the smaller solids that were acted upon by the chemical (polymer).

(c) The cartridge filter takes out suspended particles that pass through the multimedia filter.

(d) Reverse osmosis removes dissolved minerals and other bacteria that succeeded in getting past the filters. There are eight of these spiral reverse osmosis elements in series, one element after the other. The spiral construction of the elements allows a relatively small space to contain a large area of permeate membrane. A larger surface area means that more water can be purified.

(e) Chemicals are added to the filtered water to kill any remaining bacterial that are present. At this point, water is stored for human consumption.

(2) Models.

(a) The water purification unit, standardized 600--gph ROWPU, (see figure 1-19), is portable.

(b) The 3,000/2,000 gph is being developed for field use and is being patterned after a standardized 60G--gph ROWPU. The unit is capable of producing drinking water from raw, fresh water, seawater, brackish water, and water contaminated with nuclear, biological, or chemical agents. This ROWPU replaces the 420, 600, 1500, 3000--gph erdlators, and several other miscellaneous water purification units.

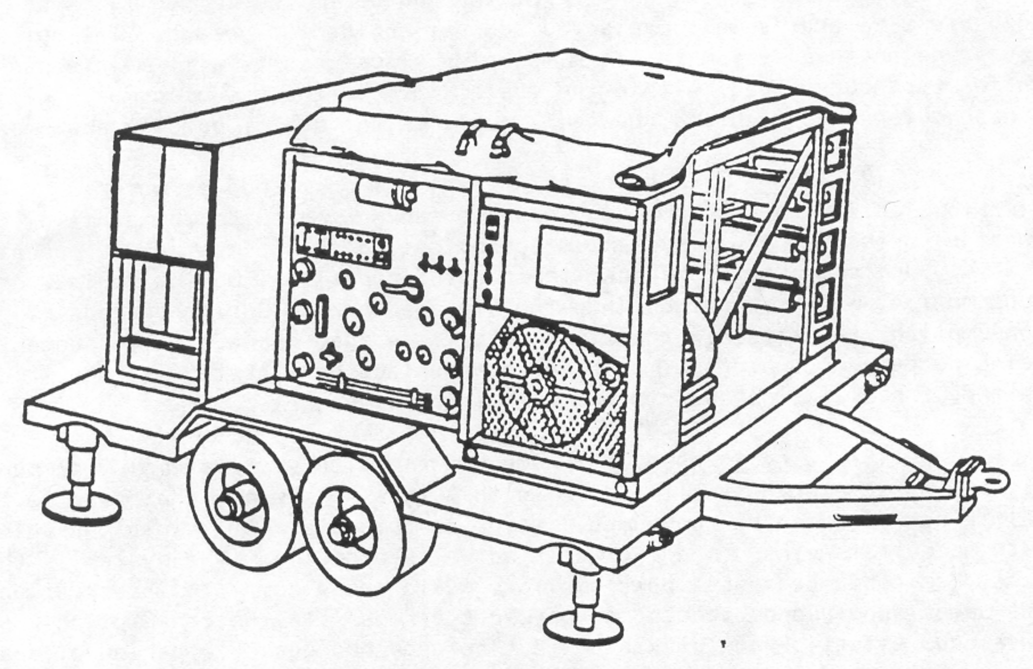


Figure 1-19 Water purification unit, reverse osmosis, 600 gph trailer mounted.

## Section IV. WATER DISTRIBUTION SYSTEMS

### 1-18. GENERAL

Water distribution is the process of getting water from the point of treatment to the place where it is to be used by the consumer. In a municipal or garrison system, this involves two important functions--carrying potable water for domestic use and concentrating high rates of flow for fire fighting purposes. In a field distribution system, the provision of water for fire fighting purposes is not included since such a mission would overtax our field water distribution capabilities. In both garrison and field water distribution systems, purity is a paramount consideration. No matter how completely and carefully the potable water supply is treated, all efforts are wasted, and the health of the command is endangered if drinking water is permitted to become contaminated.

### 1-19. GARRISON WATER DISTRI8UTION SYSTEMS

a. **Types of Systems**. In a garrison or municipal water distribution system, water is distributed to the consumer by anyone or a combination of the following methods:

(1) <u>Gravity</u>. Where the source of supply is a lake or impounding reservoir, which is located at an elevation higher than that of the community being served, water may be distributed by gravity. This is the most reliable system, if the conduit from the source to the community is of adequate size and is well protected against accidental breaks. The principal advantage of this system is its simplicity since gravity maintains a uniform pressure (head) within the system without the use of pumps. High pressure for fire fighting, however, requires the use of pumping equipment.

(2) <u>Pumps with storage</u>. A very common method of water distribution is that of combining storage tanks with pumps to maintain constant pressure. This system is economical in that pumps may be operated at a uniform rate at or near their rated capacity. During periods of low consumption, water is pumped into the storage tanks. During periods of high consumption, the water in the storage tanks is then drawn upon to augment that being pumped. The storage may be either surface or elevated storage. In the latter, the elevation assists in maintaining pressure.

(3) <u>Direct pressure</u>. Some distribution systems employ pumps without water storage facilities. In this type of system, the pressure is maintained directly by the pumps. Water is pumped directly into the mains with no outlets other than the water actually consumed. The system is the least desirable because a power failure would cause complete interruption of the water supply and because the pressure varies with the consumption. A very hazardous situation could exist if a fire occurred during a period of peak consumption. Additional booster pumps are required to cope with such a contingency.

b. **Components**. A typical garrison water distribution system consists of the following components:

(1) Mains and piping. The network of mains and pipes makes up the heart of the water distribution system. They provide the means by which the water is actually transported from the storage or pumping facilities to the user. They form a closed system that protects the water from outside contamination. It is important in the respect that the mains and pipes are free from cracks and loose joints. Maintenance of constant water pressure is also very important because positive pressure within an underground pipe will help to prevent contamination from entering the system if a leak should occur.

(2) Storage. If the water distribution system includes storage facilities, a number of variations in types of facilities may exist. Storage facilities may consist of tanks, standpipes, or reservoirs. They may be of metal or of concrete. Storage may be elevated or at ground level. The most commonly found arrangement is elevated, steel, covered tank located on the highest ground available.

(3) Valves and hydrants. Valves are used to regulate the flow and to enable maintenance personnel to temporarily stop the flow for repairs and cleaning. Hydrants are located at various intervals along the mains to provide for fire fighting. The spacing depends upon the area that each hydrant is to serve, but the average is about 7 1/2 hydrants per mile of water main

(4) Pumps. Occasionally, an installation or community may have a water supply that is located at an elevation sufficient to furnish water to consumers entirely by gravity. More commonly, however, pumps must be used both to convey water to the consumer and to ensure that adequate pressure is maintained. Pumps may be required to force water through the mains, to lift it from the treatment plant to elevated storage, and to boost the water pressure at various points throughout the system.

## 1-20. FIELD WATER DISTRIBUTION SYSTEMS

Field water distribution systems are much less sophisticated than municipal or garrison systems. They normally do not provide sufficient quantities for firefighting. They are also subject to recontamination of purified water by careless handling or unclean equipment, because they are not closed systems. Whereas garrison or municipal water distribution systems are intended to satisfy all of the needs of the community for water, a field water distribution system is intended to provide potable water for drinking, cooking, and personal hygiene. A field water distribution system may consist of any combination of the following components:

a. **Water Points**. A water point is a location at which potable water is produced and made available for pickup by using units. Figure 1-20 illustrates a typical combat water point. The selection of a water point is the responsibility of Corps of Engineers personnel.

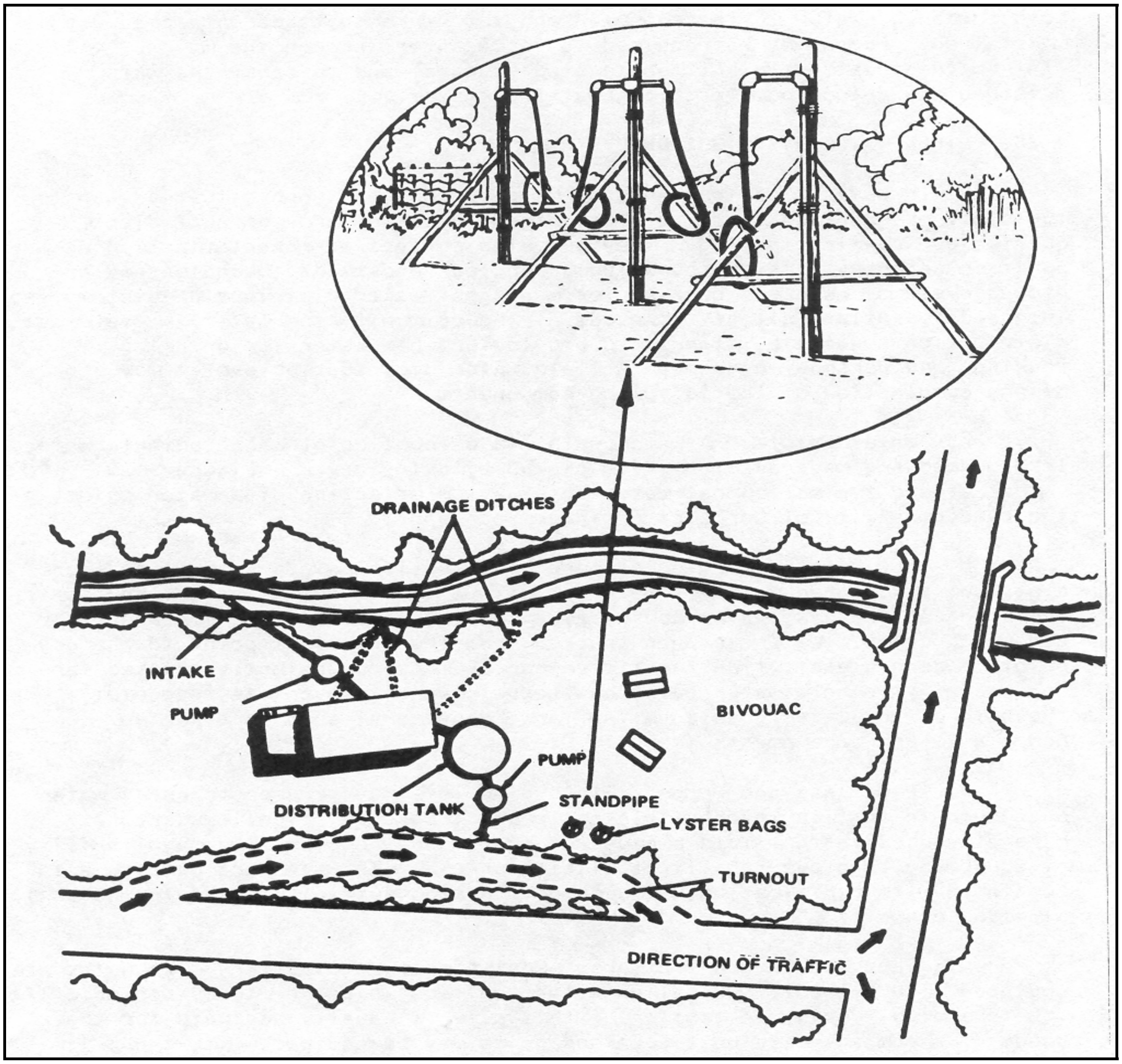


Figure 1-20. Typical combat water point.

b. **Dry Points**. Dry points are distribution points established for distributing treated water. Their use allows the installation of treatment equipment at the best water source even though it may be some distance from consuming units. Water is then trucked from the treatment point to the dry points, where distribution facilities can be more conveniently located for consumers. A single water point can serve several dry points, especially when the bulk of the water goes to a few large consumers, such as bakeries, hospitals, and encampments (see figure 1-21).

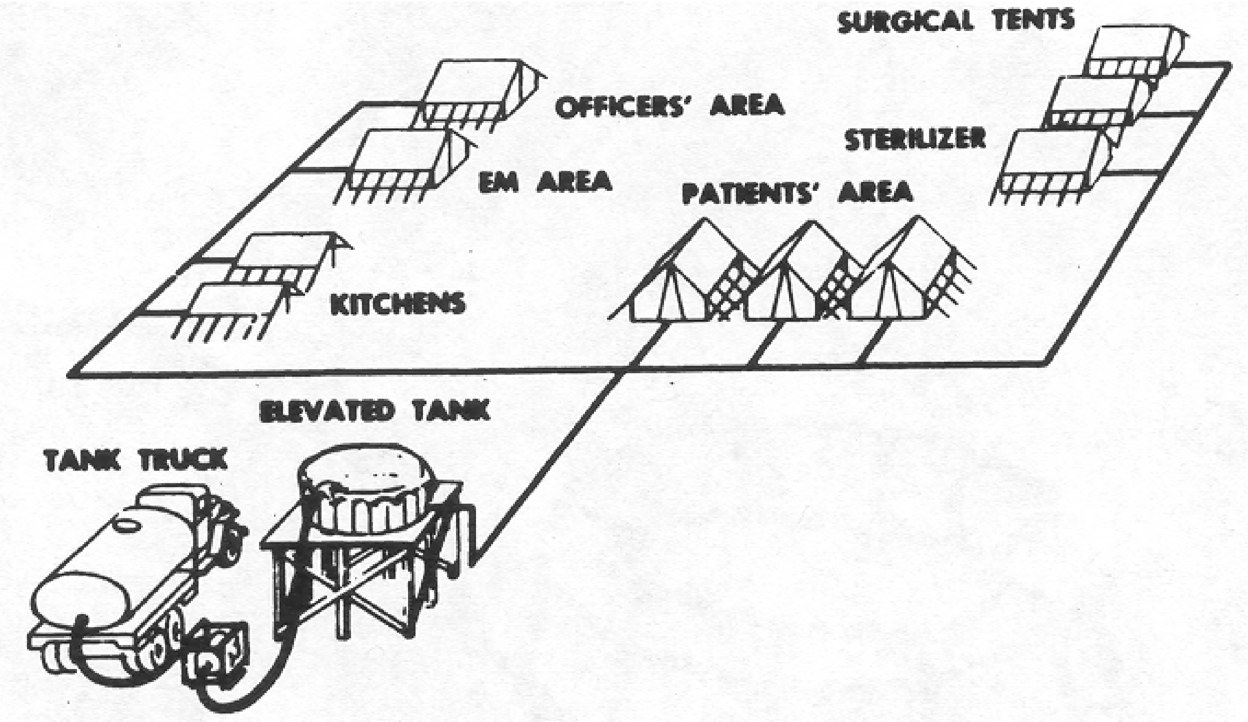


Figure 1-21. Dry point for a hospital in a corps area.

c. **Pipelines and Pumps**. Field pipelines may be used to carry water over terrain that is inaccessible to trucks. However, pipelines are not generally used in the field because of cost, construction time, availability of equipment, and adaptability to field terrain. The standard pumping sets furnished with purification units do not develop sufficient head for general pipeline use.

d. **Tank Trucks and Trailers**. Most company and battery-size units are equipped with 2-wheel, 400-gallon water trailers that are towed behind 2 1/2 1/2-ton cargo trucks. A trailer of this size is usually adequate for the needs of a company-size unit. Larger units may be equipped with the 2 1/2-ton, 1,000-gallon water tank truck for distributing water to its subordinate units.

e. **Storage Containers**. The following containers are authorized for the storage of water in the field:

(1) <u>Storage tanks</u>. Engineer water points are equipped with collapsible fabric water storage tanks with capacities of 500 gallons, 1,500 gallons, or 3,000 gallons, depending upon the size of the water purification unit. Figure 1-22 shows a 1,500-gallon collapsible fabric water tank mounted on a wooden ground platform.

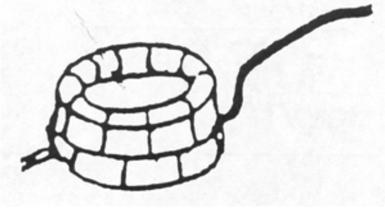


Figure 1-22. 1,500-gllon tank on ground platform.

(2) Lyster bags. Each unit is equipped with the 36-gallon water-sterilizing bag known as a Lyster bag. These bags are issued based on one per 100 men and are used for purifying and storing water in the unit area. These bags are used primarily for filling individual canteens in both the unit area and at the water point.

(3) Water cans. All Army units are issued 5-gallon water cans for use by individual sections (maintenance, food service, and so forth) to carry and store water in the accomplishment of their tactical missions

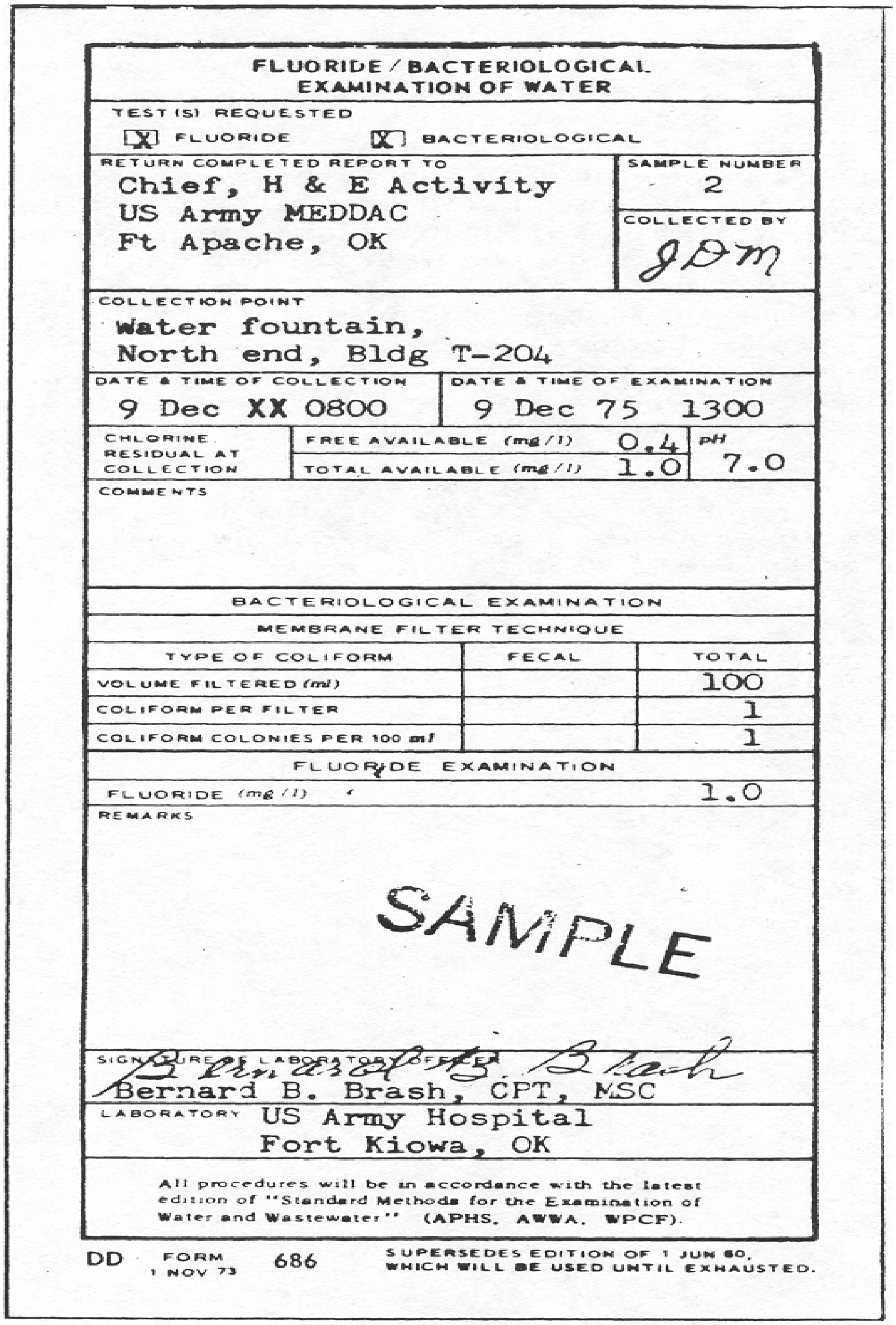
(4) Canteens. The 1-quart canteen is a basic item of issue to all soldiers.

## 1-21. INSPECTION OF WATER POINTS AND FACILITIES

Although the production of potable water is a QM responsibility, the AMEDD is responsible for inspecting water points and facilities and for making recommendations concerning the sanitary quality of the water.

a. **Garrison Water Treatment Facilities**. Inspection of garrison water treatment facilities is made by personnel of the Preventive Medicine Activity of the installation medical department activity (MEDDAC) or of the preventive medicine service of the Army medical center furnishing medical support. The essential criterion used for evaluating the water supply is the coliform bacteria count in water samples collected during the inspection. Samples are submitted with DO Form 686, Fluoride/Bacteriological Examination of water (see figure 1-23), to the supporting medical or clinical laboratory for bacteriological examination. The completed report is then returned to the activity conducting the inspection. Additional samples are collected and analyzed during the month. The actual number of samples depends upon the size of the installation (see Lesson 3). In addition to collecting bacteriological samples, inspecting personnel usually furnish the installation engineer with a report of the findings of the inspection using a locally devised inspection checklist.

b. **Field Water Points**. Inspection of field water points is made by personnel of a preventive medicine detachment or other medical unit having responsibility for medical support in the area where the water point is located. As in the case of garrison treatment facilities, the basic criterion in evaluating a water point in the field is the potability of the water. Because facilities for conducting a bacteriological test are not always available, potability is based upon determination of the residual chlorine in the treated water. In addition to testing the water for residual chlorine, the inspector should observe the operation of the water point equipment and overall cleanliness of the area. Particular attention should be given to possible sources of gross contamination, such as latrines located too close to the water supply source, dead animals, and washing of vehicles or laundry upstream from the source. The inspection should also include a check of safety hazards, including electrical grounds and connections, handling and storage of gasoline, and storage of chemicals. All chemicals should be stored separately. Calcium hypochlorite and activated carbon are particularly hazardous in that, when mixed in the proper proportions, they cause a violent explosion. The results of the inspection are submitted to the commander of the engineer unit operating the water point on DA Form 1715-R, Water Point Inspection Report (see figure 1-24). Many medical units devise checklists to supplement DA Form 1715-R and to assist inspectors in conducting complete and uniform inspections. In order to assist in developing rapport with the water point personnel, it is recommended that the inspector and the operator make the chlorine residual determination together. Specific items to look for in the operation of the water purification equipment are discussed in paragraph 5-11, Lesson 5, Field Water Treatment.



**FLUORIDE / BACTERIOLOGICAL EXAMINATION OF WATER**

TEST(S) REQUESTED

☒ FLUORIDE ☒ BACTERIOLOGICAL

RETURN COMPLETED REPORT TO

Chief, H & E Activity
US Army MEDDAC
Ft Apache, OK

SAMPLE NUMBER: 2

COLLECTED BY: JDM

COLLECTION POINT

Water fountain,
North end, Bldg T-204

DATE & TIME OF COLLECTION: 9 Dec XX 0800

DATE & TIME OF EXAMINATION: 9 Dec 75 1300

| | | | |
|---|---|---|---|
| CHLORINE RESIDUAL AT COLLECTION | FREE AVAILABLE (mg/l) | 0.4 | pH<br>7.0 |
| | TOTAL AVAILABLE (mg/l) | 1.0 | |

COMMENTS

BACTERIOLOGICAL EXAMINATION

MEMBRANE FILTER TECHNIQUE

| TYPE OF COLIFORM | FECAL | TOTAL |
|---|---|---|
| VOLUME FILTERED (ml) | | 100 |
| COLIFORM PER FILTER | | 1 |
| COLIFORM COLONIES PER 100 ml | | 1 |

FLUORIDE EXAMINATION

FLUORIDE (mg/l): 1.0

REMARKS

SAMPLE

SIGNATURE OF LABORATORY OFFICER

Bernard B. Brash

Bernard B. Brash, CPT, MSC

LABORATORY

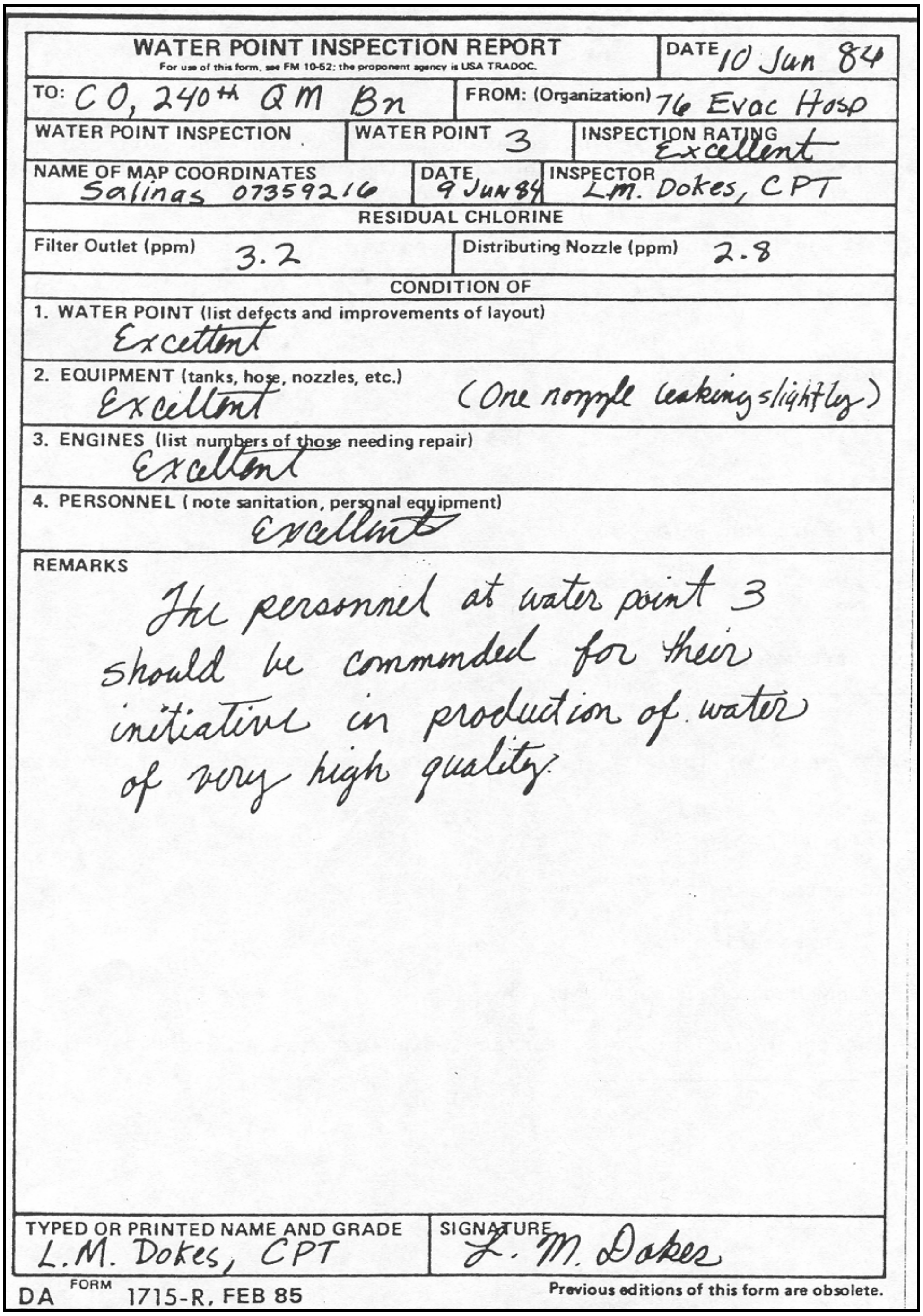
US Army Hospital
Fort Kiowa, OK

All procedures will be in accordance with the latest edition of "Standard Methods for the Examination of Water and Wastewater" (APHS, AWWA, WPCF).

DD FORM 1 NOV 73 686

SUPERSEDES EDITION OF 1 JUN 60, WHICH WILL BE USED UNTIL EXHAUSTED.

Figure 1-23. DD Form 686, Flouride/Bacteriological Examination.



**WATER POINT INSPECTION REPORT**
For use of this form, see FM 10-52; the proponent agency is USA TRADOC.

DATE 10 Jun 84

TO: CO, 240th QM Bn

FROM: (Organization) 76 Evac Hosp

WATER POINT INSPECTION

WATER POINT 3

INSPECTION RATING Excellent

NAME OF MAP COORDINATES Salinas 07359216

DATE 9 JUN 84

INSPECTOR LM. Dokes, CPT

RESIDUAL CHLORINE

Filter Outlet (ppm) 3.2

Distributing Nozzle (ppm) 2.8

CONDITION OF

1. WATER POINT (list defects and improvements of layout)
Excellent

2. EQUIPMENT (tanks, hose, nozzles, etc.)
Excellent (One nozzle leaking slightly)

3. ENGINES (list numbers of those needing repair)
Excellent

4. PERSONNEL (note sanitation, personal equipment)
Excellent

REMARKS
The personnel at water point 3 should be commended for their initiative in production of water of very high quality.

TYPED OR PRINTED NAME AND GRADE L.M. Dokes, CPT

SIGNATURE L. M. Dokes

DA FORM 1715-R, FEB 85

Previous editions of this form are obsolete.

Figure 1-24. DA Form 1715-R (Water Point Inspection Report).

*Continue with Exercises*

**EXERCISES: LESSON 1**

**INSTRUCTIONS:** Answer the following exercises by marking the lettered response that best answer(s) the exercise, by completing the incomplete statement, or by writing the answer in the space provided at the end of the exercise.

After you have completed all the exercises, turn to "Solutions to Exercises" at the end of the lesson and check your answers. For each exercise answered incorrectly, reread the material referenced with the solution.

1. Potable water must be:

   a. Cool.

   b. Palatable.

   c. Free of contamination.

   d. Free of dissolved solids.

2. Reverse osmosis is a process, which separates _______________ and __________ ___________ from filtered water.

3. Which branch of the Army is responsible for the production of potable water?

   a. Engineers.

   b. Quartermaster.

   c. Transporation.

   d. Army Medical Department.

4. During the hydrolic cycle, surface water becomes ground water through the process of. ______________________________.

5. In the space preceding each of the following characteristics, enter an "S" if it applies more to a surface water source or a "G" if it app lies more to a ground water source:

_____Low turbidity.

_____Usually contaminated.

_____Relatively accessible.

_____Quantity not readily apparent.

_____Frequently has a high mineral content.

6. The most important physical characteristics of water are:

   a. Color, odor. taste, basic value, and turbidity.

   b. Odor and taste, color, turbidity, and temperature.

   c. Turbidity, color, acid, odor and taste, and temperature.

   d. Temperature, radiological activity, odor and taste, turbidity, and heat.

7. Total dissolved solids consist of small amounts of organic and inorganic substances or _______________ and _________________________.

8. Water with a pH of 4.4 is:

   a. Acid in character.

   b. Alkaline in character.

9. The palatability of water is affected by its odor and taste, but not ____________.

10. A ____________________ usually best meets the needs of a unit because of its accessibility and quantity.

11. Partial clarification of water by coagulation and sedimentation done prior to filtration is known as ___________________.

12. If used, plain sedimentation always includes:

    a. Filtration.

    b. Disinfection.

    c. Chemically induced disinfection.

    d. Chemically assisted filtration.

13. What is floc?

    a. A fluffy white, sticky substance, which floats on the surface.

    b. A transparent, gelatinous and sticky mass, which makes the water very viscous.

    c. An insoluble, jelly-like substance that entraps turbid particles to form fast settling clumps.

    d. A chemical compound, which reduces surface tension, thereby assisting in the filtration process.

14. What are the three critical essentials to proper flocculation?

    a. Gentle agitation.

    b. Continuous aeration.

    c. Thorough and uniform mixing.

    d. Carefully controlled temperature.

    e. Carefully controlled chemical feeding.

    f. Carefully controlled depth of the water.

15. What are the four combined water treatment filtration processes that the military uses to clarify water?

________________________________.

________________________________.

________________________________.

________________________________.

16. Name four types of water filters.

________________________________.

________________________________.

________________________________.

________________________________.

17. Which type of filter accomplishes the highest degree of bacteria removal?

______________________.

18. Which type of filter is most commonly used in garrison and municipal water treatment facilities?

______________________.

19. Which filter uses diatomaceous earth, is the standard US Army field treatment process, and is not used in reverse osmosis?

______________________.

20. Why must the pressure difference be maintained at all times on the filter element?

_____________________________________________.

21. In diatomite filtration, the diatomaceous earth's irregularity in size and shape enables the particles to be:

    a. Highly porous and separate quickly.

    b. Highly porous and cling together.

    c. Separate quickly and become rigid.

    d. Separate slowly and become hard.

22. What are three of the common methods of disinfection?

    _______________________.
    _______________________.
    _______________________.

23. Which is the most field expedient method of disinfection?

    ____________________.

24. What type and form of coal are sometimes used to replace the sand in rapid sand filtration?

    ____________________.

25. The erdlator incorporates which of the following processes and/or equipment?

    a. Plain sedimentation.

    b. Sodium aluminate as a coagulant.

    c. Filtration by means of a slow sand filter.

    d. Chemical pretreatment combined with disinfection.

    e. Continuous flow treatment, using an up flow clarifier.

26. Which field water treatment equipment is being phased out?

_________________________.

27. Which field water purification unit is no longer standard equipment in the active Army?

_________________________________________.

28. Which water purification unit is being used in the active Army to convert salt water?

____________________________.

29. In reverse osmosis, which filter is used to take out smaller suspended particles?

___________________.

30. What is the most reliable means of providing head (pressure) for a water distribution system?

_______________________.

31. The least desirable type of water distribution system is ___________.

32. Who is responsible for selecting the water point location?

_______________________.

33. A point located some distance from the treatment site to which water is transported for further distribution is a ________________________.

34. Which of the following are normal components of a field water distribution system?

a. Lyster bags.

b. Fire hydrants.

c. 1,000-gal tank trucks.

d. 400-gal water trailers.

e. Water mains and piping.

f. 100,000-gal concrete storage tanks.

g. 500-to 3,000-gal fabric storage tanks.

35. What forms are used in conducting inspections of water treatment facilities?

_________________________________.

_________________________________.

**Check Your Answers on Next Page**

## SOLUTIONS TO EXERCISES, LESSON 1

1. c (para 1-2a)

2. suspended; dissolved solids. (para 1-2k)

3. b (para 1-3b)

4. infiltration-percolation. (para 1-5b)

5. G
S
S
G
G (para 1-8c)

6. b (para 1-7a)

7. particles; mineral salts. (para 1-7b)(1))

8. a (para 1-7b(2))

9. potability. (para 1-7a(3))

10. surface water source. (para 1-8c)

11. pretreatment. (para 1-10)

12. c para 1-10b)

13. c (paras 1-10c(2), 1-12c)

14. a, c, e (para 1-12).

15. Chemical mixing.
Flocculation.
Sedimentation.
Disinfection. (para 1-12e)

16. Slow sand.
Rapid sand.
Pressure.
Diatomite. (paras 1-13, 1-14)

17. Slow sand. (paras 1-13b(1)(c), (2)(c))

18. Rapid sand. (para 1-13b(2))

19. Diatomite. (para 1-13b(4))

20. To keep diatomite on the filter. (para 1-13b(4)(b))

21. b (para 1-13b(4))

22. Boiling.
    Iiodine.
    Chlorine. (para 1-15)

23. Boiling. (para 1-15a)

24. Anthracite (hard coal). (para 1-16b)

25. d, e (para 1-17a(1))

26. Erdlators. (para 1-17a(2))

27. Engineer Water Purification Set No.4. (para 1-17b)

28. Reverse osmosis. (para 1-17c)

29. Cartridge. (para 1-17c(1)(c))

30. Gravity. (para 1-19a(1))

31. direct pressure. (para 1-19a(3))

32. Corps of Engineers. (paras 1-3c, 1-20a)

33. Dry point. (para 1-20b)

34. a, c, d, g. (paras 1-20d, e)

35. DD Form 686
    DA Form 1715-R. (paras 1-20a, b).

**End of of Lesson 1**

## LESSON ASSIGNMENT

**LESSON 2** Disinfection of Water.

**TEXT ASSIGNMENT** Paragraphs 2-1 through 2-13.

**LESSON OBJECTIVES** After completing this lesson, you should be able to:

2-1. Select the statement that best defines the basic terms used in the disinfection of water.

2-2. Select the statement that properly describes the requirements for disinfection.

2-3. Select the statement that identifies the different ways to chlorinate water.

2-4. Identify factors that affect the effectiveness of a disinfectant.

2-5. Select the proper chlorine residual and calculate the amount of disinfectant required for different water supply situations.

2-6. Recognize and place in proper sequence the steps in determining pH, total available chlorine, free available chlorine, and combined available chlorine in a water sample using the color comparator.

2-7. Identify standard and improvised water disinfection procedures.

**SUGGESTION** After completing the assignment, complete the exercises at the end of this lesson. These exercises will help you to achieve the lesson objectives.

# LESSON 2

# DISINFECTION OF WATER

## Section I. PRINCIPLES OF DISINFECTION

### 2-1. GENERAL

Disinfection is the destruction of pathogenic (disease-producing) microorganisms. It is essential in the purification process of military water treatment. Disinfection is always included in military water purification because the other three steps--coagulation, sedimentation, and filtration--cannot be relied upon to remove all pathogenic microorganisms from water. Even when the water comes from a very safe source (such as a deep well) and requires no other treatment, disinfection is always practiced to protect against possible contamination or recontamination during handling.

### 2-2. DISINFECTION REQUIREMENTS

Every disinfectant or means of disinfection should satisfy certain criteria. The disinfectant:

a. Must contact all particles of the water treated.

b. Must be effective for a wide range of expected changes in the conditions of treatment or in the characteristics of the water being treated.

c. Must be nontoxic to humans at the concentration levels present in the finished water.

d. Must have a residual action sufficient to protect the distribution system from bacterial growths and be measurable. For example: with chlorine residual action must be at least 5.0 ppm after 30 minutes).

e. Must be of a practical method.

### 2-3 CHLORINE AS A DISINFECTANT

When calcium hypochlorite ($Ca(ClO)_2$) is dissolved in water, the chlorine goes into solution and the calcium settles out in the form of a sludge consisting of calcium carbonate ($CaCO_3$), calcium hydroxide ($Ca(OH)_2$), or both, depending upon the carbonate content of the water. The chlorine is present in solution as hypochlorous acid (HOCl) or free hypochlorite ion (ClO-), depending on the pH. Both HClO and ClO- are powerful oxidizing substances and the available chlorine in either of these two forms rapidly oxidizes both organic and inorganic substances in the water, including bacteria. The chlorine used in this reaction is converted to chloride and is no longer available as a disinfectant.

a. **Chlorine Dosage**. Chlorine dosage is the amount of chlorine added to water to satisfy the chlorine demand (b, below) and to provide a chlorine residual (c, below) after a specified period of time. The amount required to disinfect the water varies with the organic content of the water, the pH, the temperature, the contact time, and the residual required. High pH and low temperatures retard disinfection by chlorination, thus requiring a higher dosage. Dosage is usually expressed in terms of parts per million (ppm) or milligrams per liter (mg/1).

b. **Chlorine Demand**. Chlorine demand is the amount of chlorine dosage that is consumed by the substances, either organic or inorganic, in the water. Some of these chlorine-consuming agents in the water are nonpathogenic organisms, but they still contribute to the total chlorine demand of the water.

c. **Chlorine Residual**. The chlorine residual is the amount of measurable unreacted chlorine remaining at a specific time (contact time) after the chlorine compound has been added. Dosage minus demand equals residual. The total residual chlorine in water can be chemically divided into three types:

(1) Free available chlorine. The free available chlorine (FAC) is the chlorine present in the form of hypochlorous acid and hypochlorite ion. These forms are the most effective disinfectants. Free available chlorine is rapid in its action, destroying bacteria relatively quickly-20 to 30 times faster reacting than in the combined form.

(2) Combined available chlorine. Combined available chlorine (CAC) is the chlorine that has combined with ammonia or organic nitrogen in the water to form chloramines. Chloramines are weak disinfectants and are much less active than FAC. A free available chlorine residual of 0.05 ppm with a contact time of 10minutes at a pH of 7.0 will result in the same bacterial kill as a combined available chlorine residual of 0.6 ppm with a contact time of 60 minutes. It is the chloramines in water that cause the chlorine tastes which many people find objectionable. When the combined chlorine residual is replaced by free chlorine residual, there is a distinct improvement in the taste of most waters.

(3) Total available residual chlorine. Total available residual chlorine (TAC) is the sum of the free available chlorine ((l), above) and the combined available chlorine ((2), above).

d. **Contact Time**. Chlorine demand in most water is likely to be largely satisfied after a 10-minute contact time. After the first 10 minutes of chlorination, disinfection continues, but at a diminished rate. A standard contact time of 30 minutes is used in Army chlorination to assure that highly resistant or highly pathogenic organisms are destroyed.

## 2-4. CHLORINATION METHODS

a. **Marginal Chlorination**. This term refers to the application of chlorine to produce the desired total chlorine residual without reference to the relative amounts of free or combined chlorine present. In marginal chlorination, the initial chlorine demand has been satisfied but some oxidizable substances remain. This type of chlorination is the most common type of chlorination practiced at fixed facilities in CONUS and their overseas equivalent.

b. **Breakpoint Chlorination**. If chlorine is added to water that has no chlorine demand, the chlorine residual is the same as the chlorine dosage, as shown by line A in figure 2-1. However, in water that has a chlorine demand, the chlorine residual appears graphically as a curve, as shown by line B. The initial dosage (line B-1) is used up satisfying the chlorine demand, and no residual is obtained. As the dosage is increased, a combined residual (CAC) in the form of nitrogen compounds, mostly chloramines, is produced (line B-2). As the dosage is further increased, the increasing concentration of chlorine breaks down the chloramines (line B-3). When this reaction is complete, any additional chlorine added will be present as free available chlorine, a very active disinfecting agent (line B-4). The point at which the breakdown of chloramines is completed, and the addition of chlorine results in free available chlorine at a one-to-one ratio, is known as the "breakpoint." Breakpoint chlorination results in a residue that is in excess of 90 percent free available chlorine. Advantages of chlorinating to and beyond the breakpoint to obtain free available chlorine residuals are that most odors and tastes normal to water are destroyed and rigorous disinfection is assured. For field water supplies, Army procedures require the provision of breakpoint chlorination in obtaining the minimum residual requirement of free available chlorine.

c. **Super chlorination**. Super chlorination is the process of adding an amount of chlorine greater than that required to achieve a chlorine residual. It is used to remove contamination by various poisons, including some CBR agents (see Table 2-1), to disinfect distribution systems following repairs, or to remove undesirable tastes and/or odors. After super chlorination, excess chlorine must be removed by dechlorination (see d, below).

d. **Dechlorination**. Dechlorination is the process of removing excess chlorine from water in order to avoid chlorinous taste before distribution to the consumer. In addition to the activated carbon process, water may be dechlorinated by the addition of sodium thiosulfate ($Na_2S_2O_3$.), sodium metabisulfate ($Na_2S_2O_5$.), sodium sulfite ($Na_2SO_3$), sodium bisulphite ($NaHSO_3$), ammonia ($NH_4OH$), or sulfur dioxide ($SO_2$). Aeration is also a means of dechlorination.

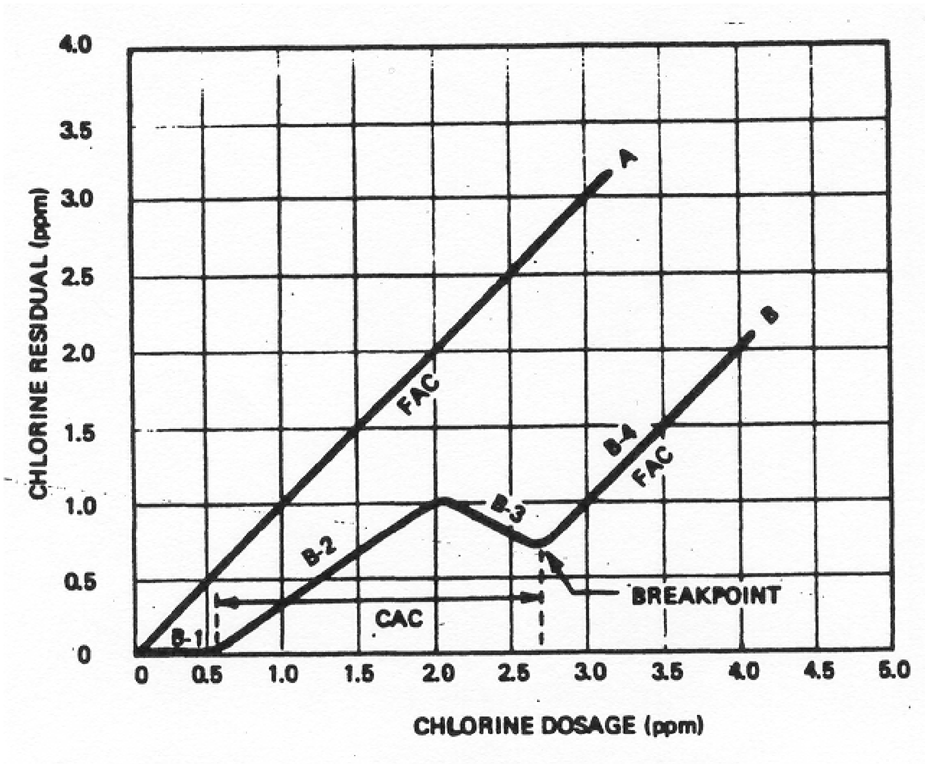


Figure 2-1. Breakpoint chlorination.

| | 30-Minute FAC Residual, mg/l (ppm) | | |
|---|---|---|---|
| pH | Bactericidal concentration | Cysticidal concentration | |
| | | Winter | Summer |
| 6 | 0.2* | 10 | 2 |
| 7 | 0.2* | 10 | 5 |
| 8 | 0.2* | ** | 10 |
| 9 | 0.2* | ** | ** |

* This residual should be maintained, even though true bactericidal concentrations may be considerably lower.

** pH control must be exercised to maintain FAC residual within reasonable range.

Table 2-1. Minimum required FAC residuals.

e. **Prechlorination**. Prechlorination is the practice of adding chlorine to water prior to other treatment processes. Prechlorination has several advantages:

(1) It may improve coagulation.

(2) It will reduce tastes and odors caused by sludge in this dimentation tank.

(3) It helps to keep filter sand cleaner and increases the length of filter runs by reducing algae and other organisms.

f. **Postchlorination**. Postchlorination is the practice of adding chlorine after filtration. When combined with prechlorination, the process is referred to as double chlorination. When prechlorination is practiced, postchlorination (double chlorination in that case) is still recommended as a safety precaution against recontamination.

## 2-5. VARIABLES AFFECTING EFFICACY OF CHLORINE

a. Under normal operating conditions the only acceptable procedure for the routine disinfection of water is chlorination. Six major variables have been shown to affect the efficacy of chlorine disinfection. These are:

(1) The types and concentrations of the chlorine forms present.

(2) The equilibrium relationships between coexistent chlorine forms. (This factor is governed largely by the pH of the water.)

(3) The type and density of organisms (virus, protozoa, heiminth, or others) and their resistivity to chlorine.

(4) The time of contact of the organisms with the chlorine.

(5) The temperature of the water. (This factor influences the rate of reaction of chlorine compounds and the rate of kill of organisms.)

(6) The concentration of substances exerting chlorine demand.

b. It is generally accepted that, of the waterborne diseases, those that are caused by bacteria are the most susceptible to chlorine disinfection. On the other extreme, certain pathogenic organisms such as the cysts of the protozoa E. <u>hiystolytica</u> are the most resistant. Therefore, two parallel recommendations for chlorine residuals are often made; the lower one sufficient for bactericidal purposes and the higher one for cysticidal purposes. Available information suggests that cysticidal residuals are also veridical. Bactericidal levels are routinely used for all water supplies at fixed installations in CONUS, since waterborne bacteria are likely to be the most prevalent organisms. Cysticidal levels should be instituted whenever epidemiological evidence indicates the probability that agents of nonbacterial waterborne diseases such as amebiasis, infectious hepatitis, or schistosomiasis are present.

## 2-6. ARMY CHLORINATION POLICY

a. **Fixed Installations**. The purpose of chlorinating potable water supplies at fixed installations is to disinfect the water before consumption and to provide residual in the distribution system. Demonstration of a proper residual indicates that the system is operating satisfactorily, while a reduction in the strength or absence of a residual may be associated with contamination of the system. The amount of residual and the contact time necessary to assure destruction of pathogenic microorganisms are dependent upon the pH and temperature of the water and whether the chlorine is acting in a free or combined state.

(1) Unless an installation is served by a public water system approved by the appropriate health authority, chlorination must be sufficient to provide a measurable residual of free available chlorine at all times in all parts of the potable water distribution system under constant circulation.

(2) Where disinfection must be assured because of sanitary deficiencies in production, purification, or distribution, the chlorine residual must not be less than the values shown in Table 2-1.

b. **Field Water Treatment**. Engineer field water treatment equipment, when properly operated, produces a water of high quality, free of turbidity, suspended solids, and parasitic, ova. The disinfection that is included inthe continuous flow purification process is for the purpose of providing a margin of safety against bacteria and viruses pathogenic to man. As previously mentioned, the effectiveness of chlorination is dependent upon the pH, the temperature, and the contact time. The chlorine dosage used in field water treatment must be sufficient to produce finished water which, after a30-minute contact time, will have a free available chlorine residual at least as high as shown in Table 2-1. If adequate provisions are not made for accurate and frequent measurement of pH, a residual of 5.0 ppm FAC must be maintained. In areas requiring veridical or cysticidal treatment, a minimum residual of 10.0 ppm FAC must be maintained. Procedures for measuring pH and chlorine residuals are discussed in Lesson 4.

c. **Individuals and Small Units**. When potable water provided by standard water purification equipment is a not available, individual and small units must treat their own water in Lyster bags, canteens, and other water containers (paras 2-10, 2-11). These purification methods do not include the removal of impurities by coagulation and filtration; therefore, the entire reliance for rendering the water safe for consumption is placed on the disinfection process. The chlorine dosage must be sufficient to provide a residual of at least 5.0 ppm (or 10.0 ppm where veridical/cysticidal treatment is indicated) after a 30-minute contact period.

## Section II. INDIVIDUAL AND SMALL UNIT WATER DISINFECTION

### 2-7. GENERAL

Whenever possible, troops in the field should consume only potable water prepared by Quartermaster Corps units. However, this is not always possible under tactical conditions. Isolated units may not be able to obtain water from engineer water points. In this case they must obtain and treat their own water. Since the primary reliance for protection against pathogens is placed upon disinfection, it is important that all possible measures betaken to obtain a raw water that is as free from gross impurities as possible. The more impurities present in the raw water, the more chlorine will be required to satisfy the chlorine demand. There are now two chlorination kits. Methods to more accurately determine chlorine residual are contained in paragraphs 2-10 and 2-11.

a. **Selection of a Water Source**. Possible sources of water are discussed in paragraph 1-8. The source that appears the cleanest should be selected.

b. **Pretreatment**. In order to reduce the chlorine demand as much as possible, water from a surface source should be clarified to the maximum extent possible before disinfecting. Sticks, leaves, and other debris may be removed by straining through a clean cloth. Water from a muddy stream can be improved in quality by digging a settling basin near the edge of the bank and below the water level. Water will then seep slowly through the bank and remain still. After the dirt has settled, the clean water may be removed and treated by one of the methods described in the following paragraphs. Other containers, such as buckets and tubs, may also be used for settling turbid water prior to disinfection.

### 2-8. ORIGINAL CHLORINATION KIT

The chlorination kit (see figure 2-2) is a standard expendable supply item available for issue to all units through normal supply channels. It is used for chlorinating unit water supplies and for testing water for the proper chlorine residual. This method is only approximate. The kit is to be used until the stock is depleted.

a. **Components**. The chlorination kit consists of the following components: (1) 100 glass ampules of calcium hypochlorite, each containing0.5 grams, for chlorination; (2) three plastic tubes for measuring chlorine residule. Each tube has a translucent yellow band around it. Each of the yellow bands is of a different shade; the lightest indicates a chlorine residual of I ppm; the medium shade indicates 5 ppm; and the darkest shade indicates 10 ppm. These figures are printed on the tubes.); and (3) three vials of orthotolidine tablets. The vials are packed inside the plastic tubes. Orthotolidine is a chemical that, upon contact with chlorine in solution, turns the solution a yellow color. The higher the concentration of chlorine, the darker will be the shade of yellow.

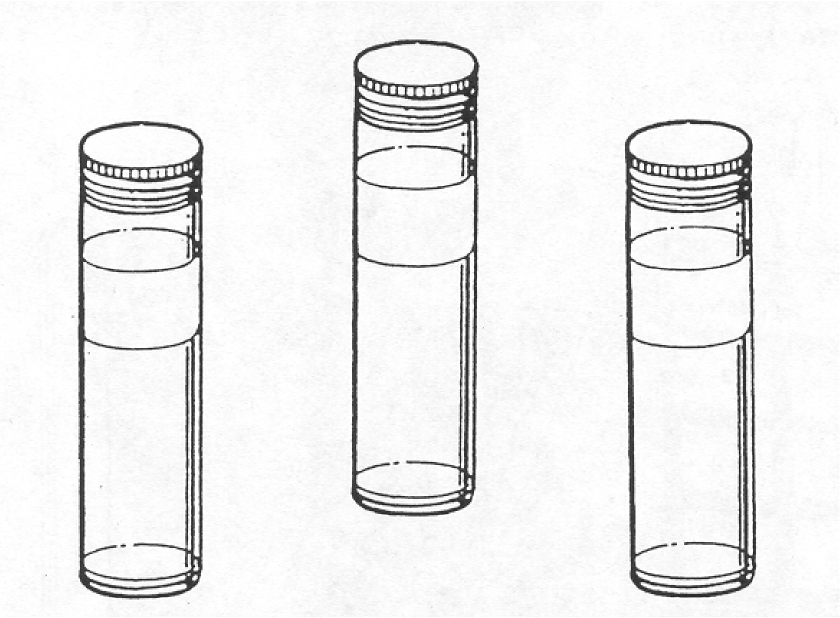


Figure 2-2. Original chlorination kit.

b. **Use of the Chlorination Kit.**

(1) Chlorinate the water. To chlorinate water, first remove the contents of calcium hypochlorite from a glass ampule by gently taping the powder to one end. (Hold the ampule between the thumb and forefinger of both hands, with the full end down, away from the face and in a safe direction.) Then exert pressure with both thumbs on the center of the ampule. The ampule will snap neatly into two pieces. This content is poured into the mixing container in which the water is to be disinfected. Normally, the chlorine demand (amount of disinfectant necessary to destroy organisms) is satisfied after 10 minutes, but not always. Although the chlorine residual is sufficient after 10 minutes, it is possible that microorganisms will continue to create a chlorine demand. That is why it is important to wait another 20 minutes (total of 30 minutes) and measure the chlorine residual. If the chlorine residual is less than 5 ppm (or as established by competent medical authority), additional chlorine must be added and the above procedures repeated.

(2) Measure for chlorine residual. The chlorine residual of water is determined by use of the plastic comparator tubes and the orthotolidine tablets. The procedure is as follows:

(a) Select the appropriate tube from the kit. The proper tube is the one on which is printed the number of ppm chlorine residual required within the command.

(b) Fill the plastic tube to a point just below the yellow band with a sample of the water to be tested.

(c) Add one crushed orthotalidine tablet (crush it with the top of the test tablet bottle), cover the end of the tube, and shake it until the orthotolidine is completely dissolved.

(d) Compare the shade of the water with the shade of the yellow band on the tube. If the color of the water is the same shade or darker than that of the band, the chlorine residual is equal to or greater than the number printed on the tube. If the water has a lighter color or no color, the chlorine residual is insufficient and more chlorine must be added.

c. **Care of the Chlorination Kit**. The orthotolidine tablets in the chlorination kit will deteriorate when exposed to sunlight and/or moisture. Therefore, when the kit is not in use, the vials of orthotolidine tablets should be tightly closed and stored in a dark place. The bands on the comparator tubes will also fade when exposed to sunlight, so they should be protected accordingly. It is not recommended that testing be conducted in the direct rays of the sun.

## 2-9. NEW CHLORINATION KIT

a. **General**. The new chlorination kit, FSN 6850-00-270-6225, (see figure 2-3), improves the determination of chlorine residual and uses the N, N-diethyl-p-Phenylenediamine (DPD) method.

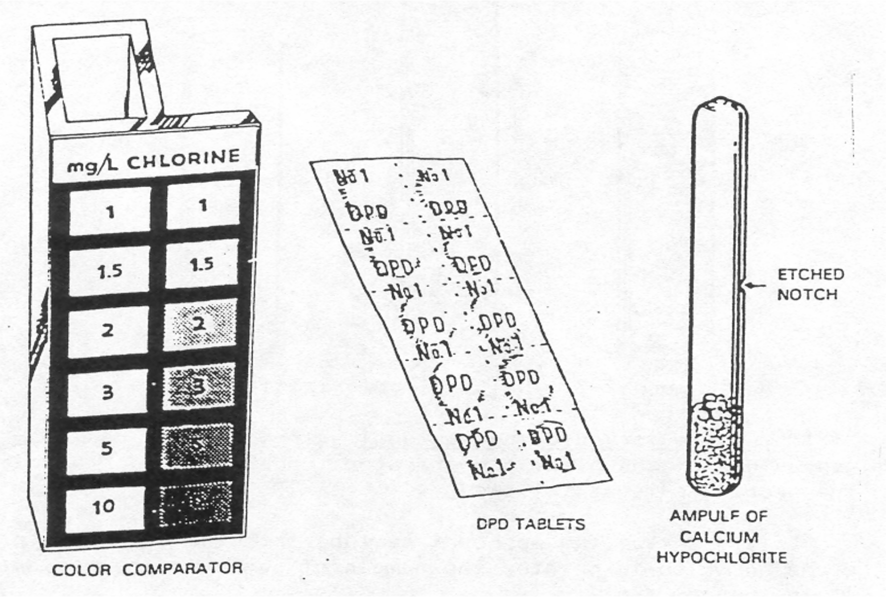


Figure 2-3. New chlorination kit.

b. **Components**. The new kit contains: (1) 100 calcium hypochlorite ampules, (2) 150 DPD tablets, and (3) 1 DPD comparator.

c. **Use of and Method for the Kit**. Procedures to test water for proper chlorination are listed below.

(1) As with the original chlorination kit procedures, prepare a stock solution by mixing and dissolving the contents of one or more calcium hypochlorite ampules, depending on the quantity of water to be chlorinated, in a small, separate container of water. The stock solution is then poured into the container that houses/holds the water (such as a 5 gallon water can) to be disinfected. The water is stirred with a clean stick. If faucets are present, they should be flushed with a small quantity of water.

(2) After waiting 10 minutes, draw water to fill the DPD color comparator above the tip of the uppermost black border. Flush tap and rinse the color comparator several times.

(3) Tear open one DPD tablet package and drop the tablet into the comparator.

(4) After waiting 2 minutes, place the thumb over the opening of the comparator and invert it 3 times to mix the water and tablet contents.

(5) It is now time to compare the color of the chlorinated water with that of the comparator color. If the color of the water in the left window marked one is the same or darker than the right window marked one, the chlorination is acceptable for the water. However, wait an additional 20 minutes before drinking or using the water and compare the colorations again. If the color of the water is lighter than the window marked one, repeat chlorination and testing. See (6) below.

(6) When comparing the chlorinated water that was obtained directly from untreated sources (streams, lakes, springs, wells, and so forth), compare the window marked five with that of the comparator marked five. If the color of the water in the left window marked five is darker than the right window, chlorination is acceptable. However, wait an additional 20 minutes before using the water. If the color of the water is lighter than the window marked five, repeat chlorination and testing. (The lighter water means there is not sufficient chlorine residual to maintain disinfected water [microorganisms live]).

**CAUTION**: When testing water with the DPD color comparator, carefully observe the color changes of the water. When the chlorine residual is above10 mg/l, the water color will change through the comparator level sand then turn clear. Failure to carefully observe the color changes may lead to an excessive amount of chlorination. Too much chlorine in the water may be just as harmful as too little.

## 2-10. DETERMINING CHLORINE RESIDUAL WITH THE COLOR COMPARATOR

a. **General**. The method for determining the chlorine residual of drinking water by means of the chlorination kit was discussed in paragraph 2-9. This procedure is only an approximate method, because (1) it does not distinguish between free available chlorine (FAC) and combined available chlorine (CAC); (2) there are only three color standards (1.0, 5.0, and 10.0ppm) between which the observer must interpolate; and (3) there is no way to compensate for the natural color of the water. The color comparator, using the modified orthotolidine-sodium arsenite (OTA) method or N, N-diet'hyl-P-Phenyi-enediamine (DPD), will provide an accurate measure of the free available chlorine from 0.1 to 10 ppm and compensate for the natural color of the water. All readings should be taken within 1 minute.

b. **Chemical Principles of the Modified Orthotolidine-Sodium Arsenite**. The chemical principles involved in determining the chlorine residual by means of the color comparator are based upon the reactions of orthotolidine and sodium arsenite with chlorine.

(1) When orthotolidine is added to water containing chlorine, the two react to produce a yellow color. The more chlorine, the deeper the yellow.

(a) Orthotolidine reacts rapidly with free available chlorine, producing color within five seconds.

(b) Orthotolidine reacts more slowly with combined available chlorine, developing additional color over 5 minutes.

(2) Sodium arsenite also reacts with chlorine, but its reaction is much more rapid than that of orthotolidine. Sodium arsenite, when added to chlorinated water, immediately combines with both FAC and CAC. However, the combination of sodium arsenite and chlorine produces no color.

(a) Sodium arsenite added to chlorinated water before the addition of orthotolidine will "tie up" (react with) the chlorine and prevent color formation.

(b) Sodium arsenite added to chlorinated water after the addition of orthotolidine will not change any color that has formed, but it will prevent the formation of additional color.

(3) Therefore, if orthotolidine is added to a sample of chlorinated water, and after about 5 seconds, the reaction is "stopped" with sodium arsenite, and the color that develops is due to FAC.

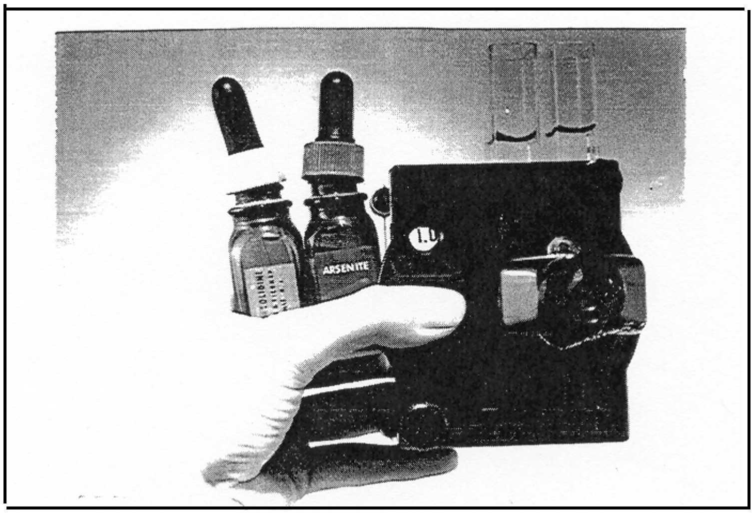
c. **Procedure for Determining Free Available Chlorine**.

(1) Modified modified orthotolidine-sodium arsenite method. The procedure for determining FAC residual in a water sample by means of the color comparator is referred to as the OTA method. The two comparator tubes are filled with the water to be tested. A control tube, called a "blank," is first prepared by adding sodium arsenite, then orthotolidine. Any color formed is due to the natural color of the water or interfering substances, such as iron or manganese. Orthotolidine is added to a second tube (called the "indicator"). Then, within 5 seconds, sodium arsenite is added to the indicator. Any difference in color between the blank and the indicator is due to the reaction of orthotolidine with FAC. The difference may be read by means of the chlorine disk in the comparator. Figures 2-4 A through H illustrate the step-by-step procedure. It is important in conducting the test that:

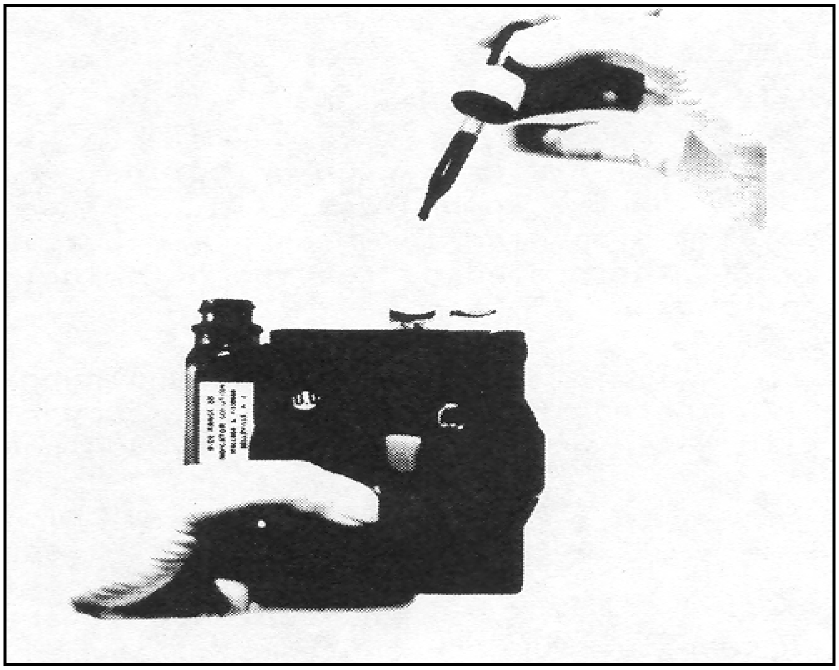
(a) The comparator tubes be chemically clean before filling them with the sample water.

(b) The reagent droppers and comparator tubes be filled exactly to the etched mark.

(c) The reading not be made in direct sunlight since this will cause fading of the color.

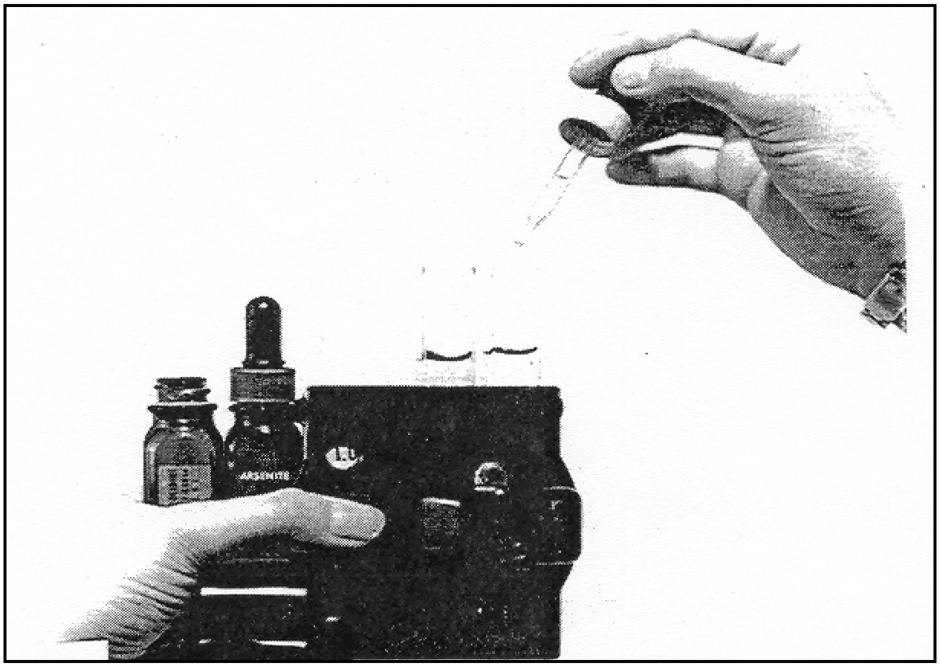


**A.** Place the two water-filled tubs into the openings at the top of the comparator. Fill droppers of sodium arsenite and orthotolidine bottles and let droppers set loosely in the bottles.

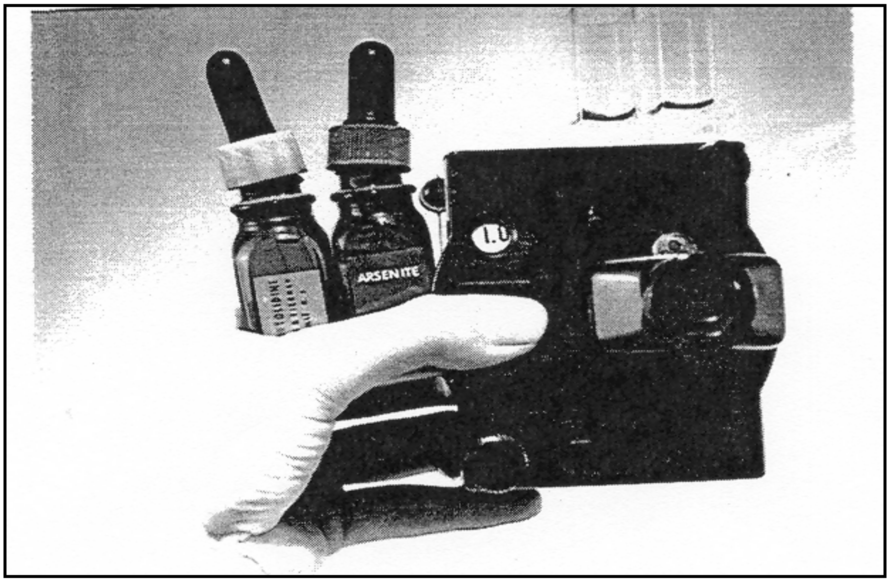


**B.** Squirt with force one dropper full of sodium arsenite into the tube in right opening of the comparator.

Figure 2-4. Modified OTA method, color comparator determination of free available chlorine (continued).

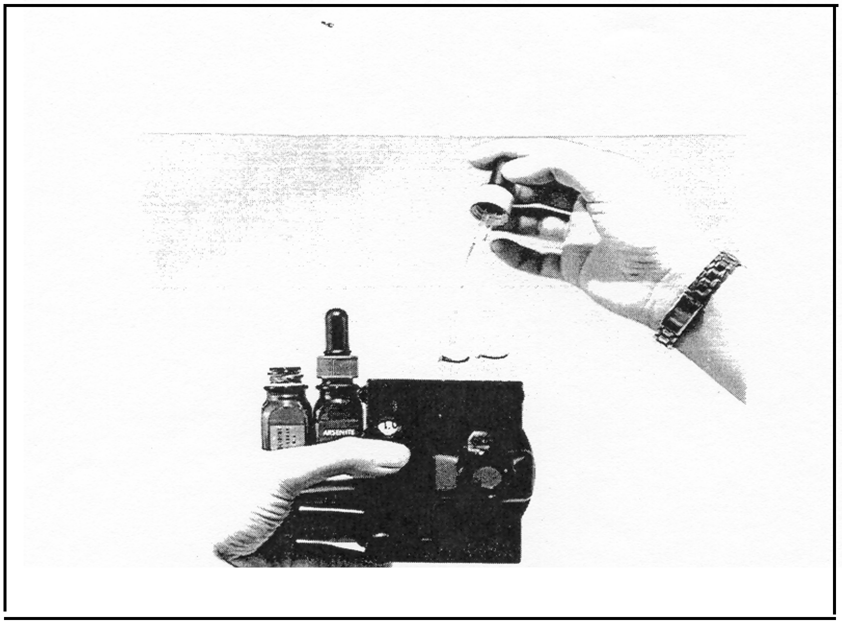


**C.** Squirt with force one dropper full of orthotolidine into the same tube. This is the blank.

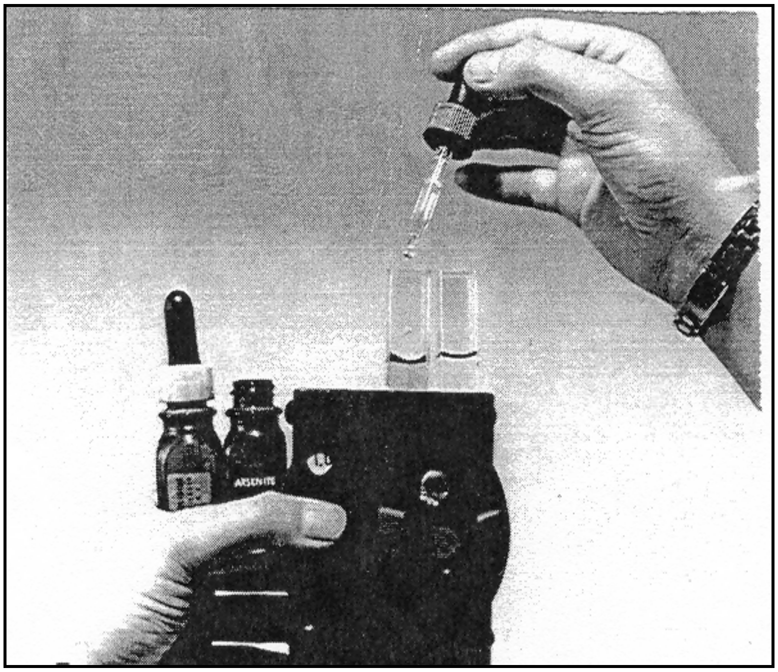


**D.** Refill the sodium arsenite and orthotolidine droppers and let the droppers set loosely in the bottles.

Figure 2-4. Modified OTA method, color comparator determination of free available chlorine (continued).

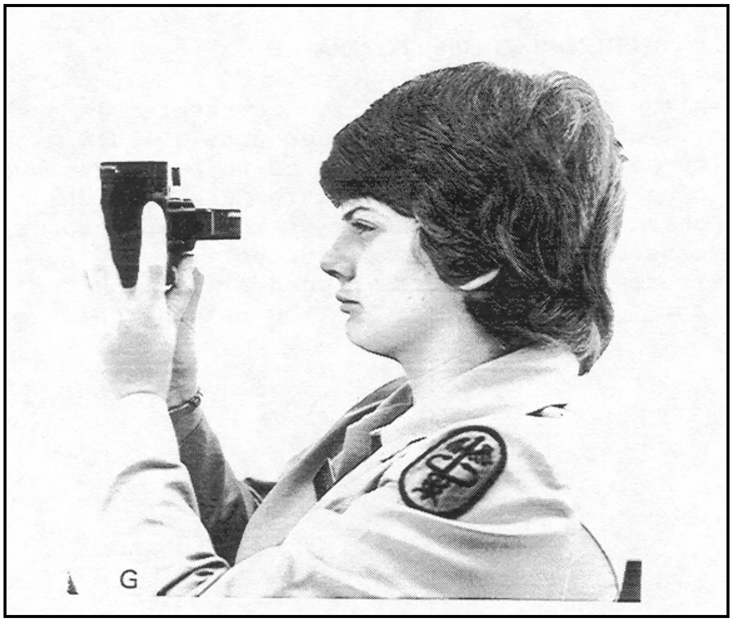


**E.** Squirt with force one dropper full of orthotolidine into the tube in left opening of the comparator.

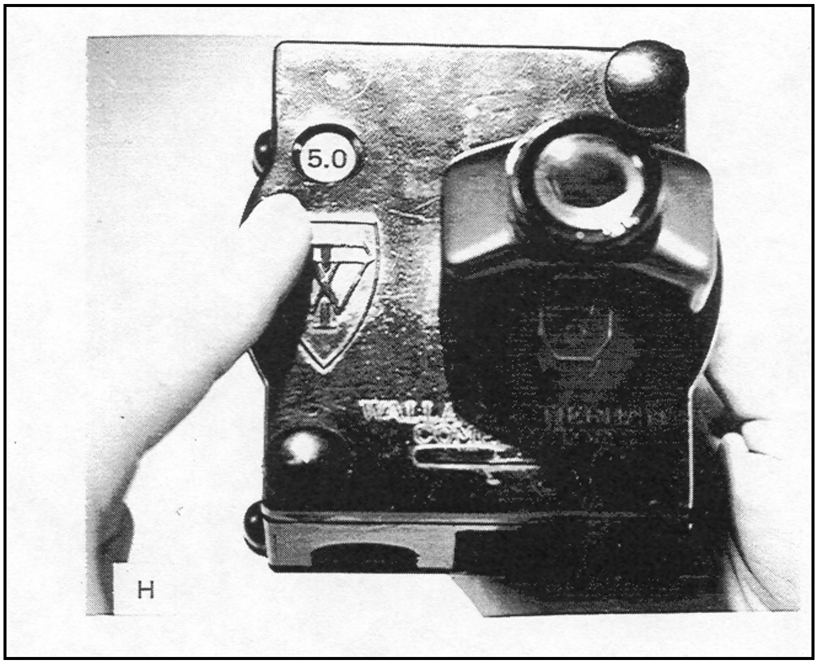


**F.** Immediately squirt with force one dropper full of sodium arsenite into the same tube.

Figure 2-4. Modified OTA method, color comparator determination of free available chlorine (continued).



**G.** Push both tubes down until tops are flush with top of comparator. Hold the comparator close to your eye and face a good light source. Rotate the color disk until the color on the disc matches the color of the solution in the indicator (left) tube.



**H**. Read free chlorine residual directly (5.0) ppm).

Figure 2-4. Modified OTA method, color comparator determination of free available chlorine (concluded).

(2) N, N-diethyl-p-Phenyl-enediamine Test. The modified OTA method has been replaced by the DPD test. The OTA test method is currently being phased out. When new equipment is required, the DPD test equipment should be obtained to replace the OTA test equipment. The DPD test procedure is similar to the OTA procedure with minor exceptions. The two comparator tubes are filled with water to be tested. Place the two water-filled tubes into the openings at the top of the comparator. Add one DPD-free available chlorine tablet (DPD tablet No. 1) to the tube in the right opening of the comparator. Cap this test tube and shake in order to disintegrate the tablet. For those kits with hard to dissolve tablets, a stirring rod is usually provided to "crush" the tablets. In "crushing" the tablets, be sure to take the tube from the comparator, and place the tube on a tabletop, and hold firmly with one hand while using the rods in the other to "crush" the tablet. Hold the comparator close to your eye and face a good light source (daylight, but not the direct rays of the sun; daylight illuminator; or artificial light reflected from a white surface). Rotate the chlorine color comparator disc until a color on the disc matches the color of the indicator (left) tube. The reading can be made directly from the window in front of the comparator. The value is expressed in milligrarns per liter (mg/ l).

d. **Procedure for Determining Total Available Chlorine**.

(1) The procedure for determining FAC residual in a water sample by means of the color comparator method (OTA). The procedures for determining TAC

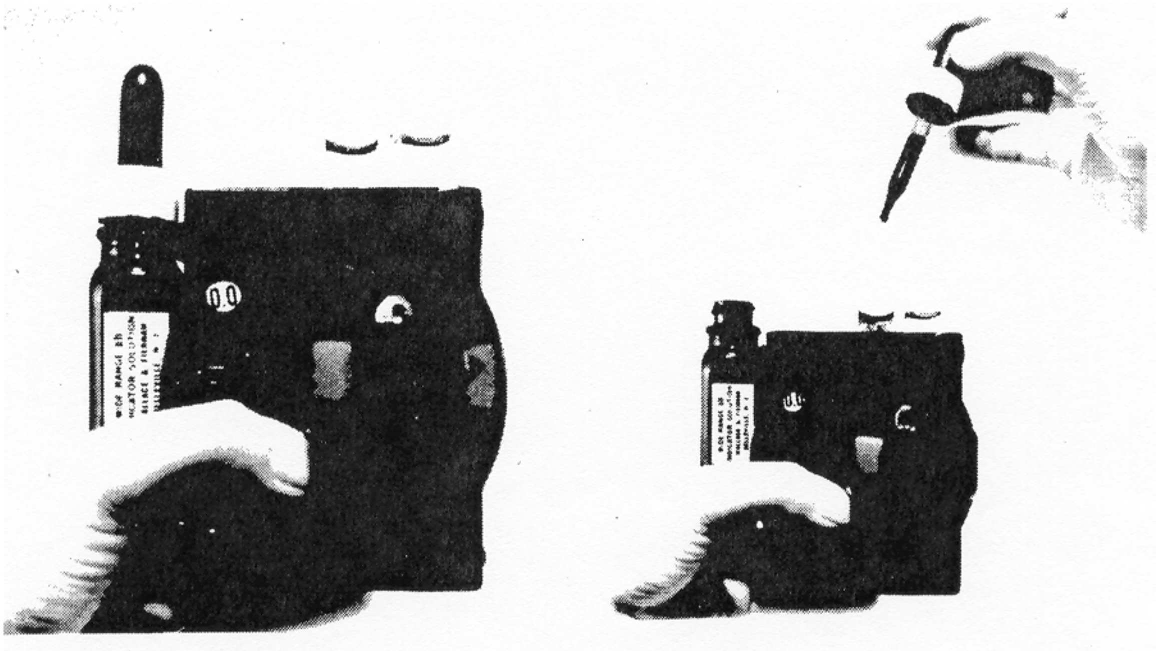
involves the use of only one reagent - orthotolidine. The blank consists only of the water sample. To the indicator tube is added a dropper full of orthotolidine. Five minutes after the orthotolidine is added, the TAC is read as described in figure 2-4. The difference between the TAC and the FAC is CAC.

**NOTE**: CAC can be determined by using DPD Tablet No. 3.

(2) N, N-diethyl-p-Phenyl-enediamine method. The procedure for TAC involves the same basic procedure. Substitute one total available chlorine tablet (DPD tablet No.4) for the free residual chlorine tablet.

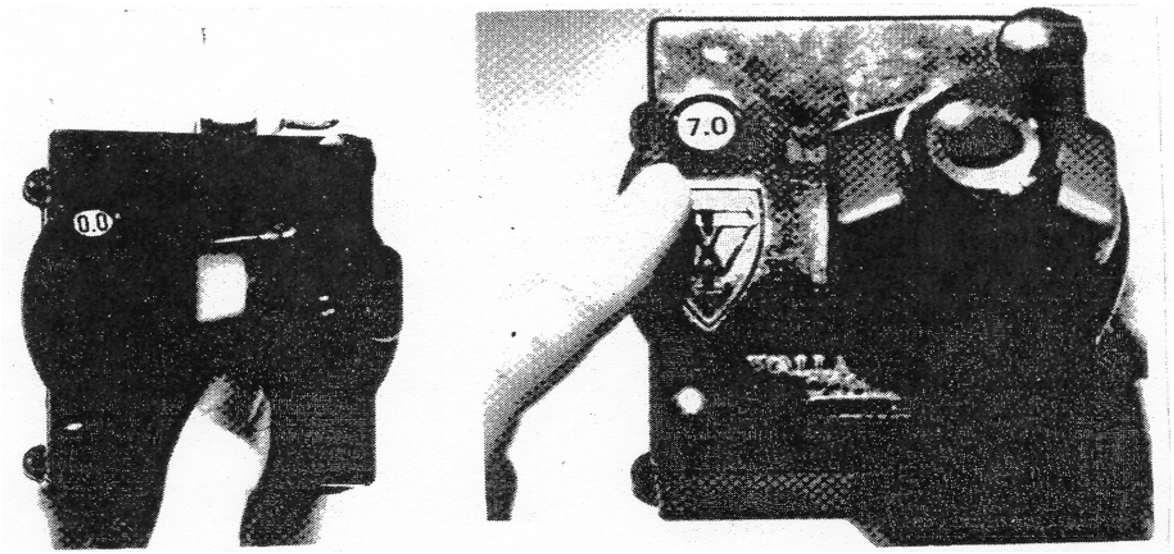
## 2-11. DETERMINING pH WITH THE COLOR COMPARATOR.

The determination of pH with the color comparator is essentially the same as the total available chlorine test (see para 2-10d), except that time is not critical. The same precautions--chemical cleanliness and exact measurements--should be observed as in tests for residual chlorine. In addition, it is important that the pH range of the comparator disk agrees with that of the indicator solution (printed on the bottle). Figure 2-5 (A through D) illustrates the procedure in conducting a pH test with the color comparator. The blank tube compensates for the natural color of the water.



**A.** Fill both tubes with water being tested and place in comparator.

**B**. Squirt with force one dropper full of pH indicator solution into tube on left.



**C**. Hold comparator close to your eye and face a good light source. Rotate color disc until a color on the disc matches the color of the sample in the tube.

**D.** The pH is read directly on the color disc. Value of this sample was 7.0.

Figure 2-5. Color comparator for determination of pH.

## 2-12. UNIT CHLORINATION

a. **Lyster Bag Chlorination**. Water is disinfected at the unit level by using the Lyster bag (see figure 2-6) or other suitable container and ampules of calcium hypochlorite that are provided in the chlorination kit (see figure2-2). The procedure for the chlorination of water in the Lyster bag is as follows:

(1) Clean the bag and hang it by the supporting ropes as illustrated in figure 2-6. The supports must be sturdy, as the bag filled with water weighs approximately 300 pounds.

(2) Fill the bag to within 4 inches from the top (the 36-gallonmark). If possible, use settled, clear water.

(3) Put the contents of one calcium hypochlorite ampule into a canteen cup (or the contents of as many ampules as necessary for the color to reach the required 5 ppm per mg/i chlorine residual), add a small amount of water from the Lyster bag, and stir with a small stick until a thick mixture results. Then fill the cup one-half full of water and stir again.

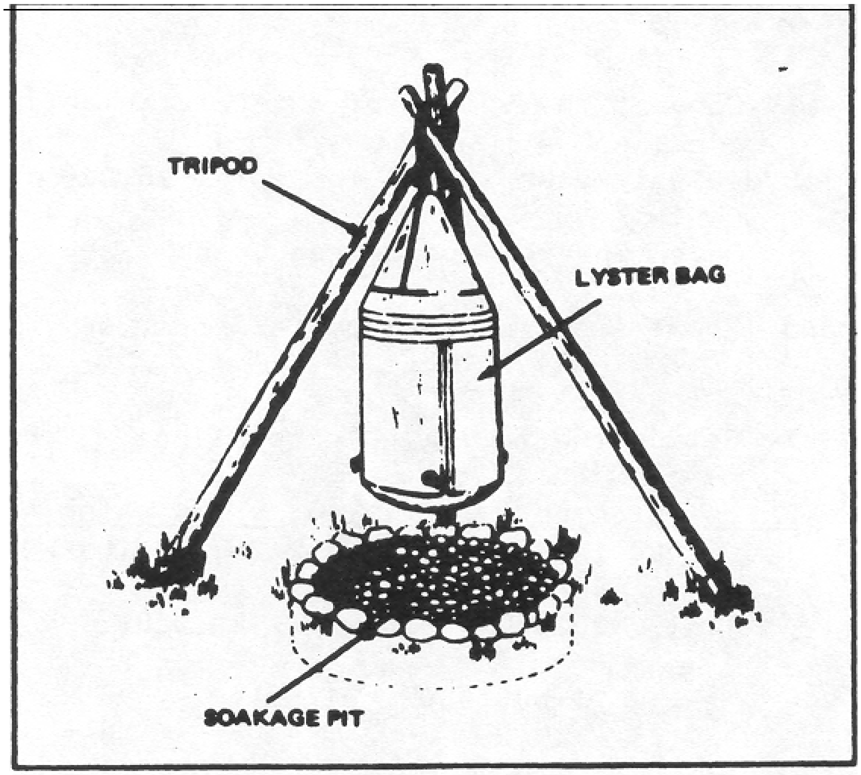


Figure 2-6. Lyster bad, 36-gallon, sterilizing water.

(4) Empty the prepared solution slowly into the Lyster bag and stir the water with a clean stick.

(5) Cover the bag and flush the faucets by running a small quantity of the water through each of them.

(6) After the disinfecting solution has been mixed with the water for 10 minutes, flush the faucets again. Then collect a sample of water from one of the faucets in the 5 ppm plastic tube for testing (para 2-9b(2)).

**CAUTION**: Collecting the water sample in the same cup or container used to dissolve the calcium hypochlorite will invalidate the results and the whole measurement or test will need to be done again.

(7) If the test shows a chlorine residual less than 5 ppm, add the contents of an additional calcium hypochlorite ampule and, after 10 minutes, repeat the test.

(8) If the test shows the chlorine residual to be at least 5 ppm, wait an additional 20 minutes since a total disinfection time of 30 minutes is required. Check the residual again. If the chlorine residual is 5 ppm or more, the water is ready for drinking.

b. **Chlorination in Other Bulk Containers**. The same general procedures described in subparagraph a above can be used to treat water in containers other than the bag, but a different amount of calcium hypochlorite must be used. For a 5-gallon can of water, one-half of the contents of one calcium hypochlorite ampule should be used initially as explained in a (3) above; then, additional small amounts should be added if necessary (a (7) and (8) above). For a 55-gallon drum of water, four or five ampules should be used initially. For a 400-gallon trailer of water, 30 ampules should be used initially. Water, in larger containers, is not easily chlorinated by use of ampules. The use of bulk calcium hypochlorite is described in subparagraph c, below.

c. **Batch Chlorination**. The term "batch chlorination" applies to the practice of using bulk calcium hypochlorite quantities of water for which the calcium hypochlorite ampules are not appropriate.

(1) Chlorine demand. In order to determine the required dosage, we determine chlorine since chlorine residual equals the dosage minus the demand. Determination of the chlorine demand requires a more accurate method of measuring the chlorine residual than afforded by the comparator tubes in the chlorination kit. This procedure is discussed in detail in paragraphs 2-10 and 5-10b. Briefly, it is determined by adding a known quantity of chlorine (in ppm) to a known amount of raw water and measuring the chlorine residual after the required contact time.

(2) Available chlorine. Calcium hypochlorite consists of 70 percent active chlorine. Therefore, when the amount of chlorine required to provide a given residual has been determined, that figure must be divided by 0.70 to determine the amount of calcium hypochlorite compound required.

(3) Calculation. To determine the amount of calcium hypochlorite necessary to provide a chlorine residual of 5 ppm-in a 3,000-gallon container of water having a chlorine demand of 2 ppm, the following procedure should be followed:

(a) Convert the volume of water to weight:

3,000 gal water x 8.34 lbs/gal = 25,020 lbs

(b) Determine the dosage required:

$$\text{Dosage} = \text{demand (2ppm)} + \text{residual (5ppm)} = 7 \text{ ppm, or } \frac{7 \text{ lbs chlorine}}{1{,}000{,}000 \text{ lbs water}}$$

(c) Set up the following proportion:

$$\frac{7 \text{ lbs chlorine x lbs chlorine}}{1{,}000{,}000 \text{ lbs water}} = \frac{\text{X lbs chorine}}{25{,}020 \text{ lbs water}}$$

$$(1{,}000{,}000)\,(x) = (7)\,(25{,}020)$$

$$1{,}000{,}000x = 175{,}140$$

$$X = \frac{175{,}140}{1{,}000{,}000} = 0.175 \text{ lbs. chlorine (2.8 ounces)}$$

(d) Since the $CA(ClO)_2$ is only 70 percent chlorine, then

$$\text{amount of } CA(ClO)_2 \text{ required} = \frac{2.8 \text{ oz}}{0.70} = \underline{4 \text{ oz}}$$

## 2-13. INDIVIDUAL WATER TREATMENT

When individuals and small detachments are operating away from their parent units, it is frequently impossible or impracticable for them to obtain treated water. In this case, it is necessary that they treat their own water. The unit may issue these individuals calcium hypochlorite ampules from the chlorination kit, or they may issue them the standard iodine water purification tablets packed in a small, airtight, wax-sealed bottle. There are 100 tablets in each bottle.

a. **Iodine Tablets**. The following procedures are needed to be followed when treating canteen water with iodine tablets:

(1) Check for physical change. The tablets may lose their disinfecting ability in time. Tablets, which are not steel gray in color stick together, or are crumbled, should not be used. If need be, obtain another bottle.

(2) Fill the canteen with the cleanest, clearest water available.

(3) Add two iodine tablets to a one-quart canteen to this water (each iodine tablet supplies a dosage of 8 ppm active iodine in one quart of water). The same two tablets are needed for turbid (muddy or unclear) or cold (below 400ºF). For a two-quart canteen, double the amounts.

**NOTE**: Using two iodine tablets instead of one is a change from the previous policy.

(4) Place the cap on the canteen and wait 5 minutes; then shake the canteen well, loosen the cap, and allow the treated water to cleanse the threads around the neck of the canteen to kill any microorganisms.

(5) Tighten the cap and wait an additional 20 minutes before using the water.

b. **Calcium Hypochicrite Ampules**. The following procedure is used to purify water in a one-quart canteen with calcium hypochlorite ampules:

(1) Fill the canteen with the cleanest, clearest water available leaving an air space of an inch or more below the neck of the canteen.

(2) Fill a canteen cap half full of water and add the calcium hypochlorite from one ampule. Stir with a clean stick until this powder is dissolved.

(3) Fill the cap of a plastic canteen half full of the solution in the cup and add it to the water in the canteen, then place the cap on the canteen and shake it thoroughly. This mixture provides a dosage of 10-15 ppm active chlorine.

**NOTE:** If an aluminum one-quart is being used, add at least three capfuls of the calcium hypochlorite solution to the canteen as this cap is much smaller than the one on the plastic canteen.

(4) Loosen the cap slightly and invert the canteen, letting the treated water leak onto the threads around the neck of the canteen.

(5) Tighten the cap on the canteen and wait at least 30 minutes before using the water.

c. **Field Expedient Methods**. When neither the issue calcium hypochlorite ampules nor iodine tablets are available, several improvised means of disinfection may

(1) Boiling. Boiling is used when disinfecting compounds are not available. It is a good but not the best method for killing disease-producing microorganisms. It has several disadvantages: (1) fuel is needed; (2) a rolling boil for 5 to 10 minutes is needed to kill most microorganisms and then it needs to cool (in an emergency, even water boiled for 15 seconds would help; (3) there is no residual protection against recontamination; (4) Clean, closed containers must be used to store the water.

(2) Tincture of iodine. Ordinary tincture of iodine may be used in the same manner as iodine tablets. Each drop of tincture of iodine will supply a dosage of I ppm of active iodine in a one-quart canteen; therefore, 8 or 16 drops should be used, depending, upon whether the water is clear or cloudy.

(3) Household bleach. Commercial brands of household bleach are normally 5 percent active chlorine (the percentage may be found on the label). One drop of 5 percent bleach will provide approximately 2 1/2 ppm available chlorine in a one-quart canteen of water; therefore, 2 drops will suffice for a 5 ppm dosage, or twice that amount for a 10 ppm dosage.

***Continue with Exercises***

## EXERCISES: LESSON 2

**INSTRUCTIONS**: Answer the following exercises by marking the lettered response that best answers the exercise, by completing the statement, or by writing the answer in the space provided at the end of the exercise.

After you have completed all the exercises turn to "Solutions to Exercises" at the end of the lesson and check your answers. For each exercise answered incorrectly, reread the material referenced with the solution.

1. Which purification process is always included in military water treatment?

   a. Filtration.

   b. Coagulation.

   c. Disinfection.

   d. Sedimentation.

2. What are disinfection requirements for treated water?

   a. There should be no residual action.

   b. It must destroy just about all microorganisms.

   c. It must be nontoxic to humans when ready to drink.

   d. All good particles should be free of the disinfectant.

3. Which two substances are powerful oxidizing substances that kill bacteria?

______________________________ and ________________________________.

4. Calcium hypochlorite's effectiveness as a disinfectant is enhanced by:

   a. Low temperature and low pH.

   b. Low temperature and high pH.

   c. High temperature and low pH.

   d. High temperature and high pH.

5. How many mg of available chlorine are present in 20 liters of water having a chlorine residual of 5 ppm? ________ mg.

6. Chlorine residual is:

   a. Dosage minus demand equal residual.

   b. The amount of chlorine dosage consumed by substances in water.

   c. The sum of the free and combined available chlorine found in water.

   d. The amount of chlorine left in water after flocculation and disinfection.

7. How many ounces of available chlorine are present in a 3,000-gal storage tank of water having a chlorine residual of 10 ppm? ______ oz.

8. How much calcium hypochlorite (70 percent available chlorine) was required to establish the residual in 7 above assuming that there was no chlorine demands? _____ oz.

9. How much $Ca(Cl0)_2$ was required to establish the residual in seven above if the chlorine demand was 4 ppm? ______oz.

10. How much $CA(ClO)_2$ is required to batch chlorinate two 3,000-gal storage tanks if the chlorine demand is 5 ppm and the required chlorine residual is 1 ppm? ___ oz.

11. If a sample of water that has just been chlorinated (using the chlorination kit) has a chlorine residual of 10 ppm, and 30 minutes later it has a chlorine residual of 5 ppm, what is the chlorine demand? _______ ppm.

12. Breakpoint chlorination is the point at which the breakdown of choraminesis completed and the addition of ______________________________________ ____________________________________________________.

13. What is the required chlorine residual in a fixed military installation water supply system?

    a. 0.4 ppm FAC after a 10-minute contact period.

    b. 1.0 ppm FAC after a 30-minute contact period

    c. 2.0 ppm FAC after a 60-minute contact period.

    d. 5.0 ppm FAC after a 30-minute contact period.

    e. 10.0 ppm FAC after a 60-minute contact period.

    f. A measurable residual of FAC at all times in potable water.

14. If provisions for pH measurement are on hand, water treated in the field having a pH of 6.0 should have a residual of _____ ppm FAC in the summer where the presence of amoebic cysts is likely.

15. Water treated in the field, with an unknown pH, must have a residual of ____ ppm.

16. How many calcium hypochlorite ampules are used to initially disinfect a Lyster bag of raw water? _________________.

17. When testing with the new chlorination kit, what must be observed?

    ______________________________________.

18. Five soldiers on extended patrol need to drink water but it is muddy. How many iodine purification tablets should be used per canteen?

    a. None.

    b. Boiling.

    c. One calcium hypochlorite tablet per canteen.

    d. One iodine tablet per canteen.

    e. Two iodine tablets per canteen.

19. Orthotolidine, when added to water containing chlorine, produces a __________________ color.

20. What color is produced if orthotolidine is added to water containing chlorine that has already reacted with sodium arsenite? _________________.

21. The modified OTA method has been replaced by the ________ method.

22. In the DPD method, a __________________ is used in place of a free available chlorine tablet.

23. In determining the pH with the color comparator, for what does the blank tube compensate? ________________________________________.

24. What is the required total disinfection time in checking for chlorine residual in a canteen or a Lyster bag? __________________________.

25. How many tincture of iodine drops should be used to disinfect a one-quart canteen? ____________________________________________________________

***Check Your Answers on Next Page***

## SOLUTIONS TO EXERCISE, LESSON 2

1. c (para 2-1)

2. b, c (para 2-2)

3. hypochorous acid, free hypochlorite ion. (para 2-3)

4. c para 2-3a)

5. 100 mg

5 ppm = 5 mg/l

$$\frac{5 \text{ mg}}{1} = \frac{X \text{ mg}}{20}$$

$$X = \frac{5 \times 20}{1} = 100 \text{ mg}$$ (para 2-10c)

6. a (para 2-3b, c)

7. 4 oz.

3,000 gal x 8.34 lb/gal = 25,020 lb

$$\frac{10}{1{,}000{,}000} = \frac{X \text{ lb}}{25{,}020 \text{ lb}}$$

$$X = \frac{10 \times 25{,}020}{1{,}000{,}000} = \frac{250{,}200}{1{,}000{,}000} = 0.25 \text{ lb } (4 \text{ oz})$$ (para 2-12c)

8. 5.7 oz.

70 percent = 0.7
0.7X = 4 oz

$$X = \frac{4}{0.7} = 5.7 \text{ oz}$$ (para 2-12c)

9. 8 oz. Cl residual = 10 ppm

$\underline{\text{Cl demand}} = \underline{4\text{ ppm}}$
Cl dosage = 14 ppm

$$\frac{14}{1{,}000{,}00.0} \qquad \frac{X\ \text{lb}}{25{,}020\ \text{lb}}$$

$$X = \frac{350{,}380}{1{,}000{,}000} = 0.350\ \text{lb};\ \frac{0.350\ \text{lb};}{0.7} = 0.5\ \text{lb}$$

$$X = \frac{350{,}280}{1{,}000{,}000} = 0.350\ \text{lb};\ \frac{0.350\ \text{lb};}{0.7} = 0.5\ \text{lb}$$

(8 oz) (para 2-12c)

10. 7 oz Cl demand = 5 ppm

$\underline{\text{Cl residual}} \ = \ \underline{1\text{ ppm}}$
Cl dosage 6 ppm

$$\frac{6}{1{,}000{,}000} = \frac{X\ \text{lb}}{6{,}000} \times 8.34\ \text{lb}$$

$$X = \frac{(6)\,(6{,}000)\,(8.34)}{1{,}000{,}000} = 0.300\ \text{lb} = \frac{0.300\ \text{lb}}{0.7} = 0.43\ \text{lb} = 6.88\ \text{oz}$$ (para 2-12c)0.7

11. 5 (para 2-8)

12. chlorine results in free available chlorine on a one-to-one ratio. (para2-4b)

13. f (para 2-6a)

14. 2 (paras 2-6b, Table 2-1)

15. 5.0 (para 2-6b,c)

16. 1 (para 2-12a(3))

17. change in color of water. (para 2-9c(6))

18. e para 2-13a(3))

19. yellow. (para 2-10b(l))

20. none. (para 2-10b(2)(b))

21. DPO. (para 2-10c(2))

22. DPD tablet. (para 2-10d(2))

23. natural color of water. (para 2-11)

24. 30 minutes. (paras 2-12a(8), 2-13b(5))

25. 8 or 16 drops, depending whether the water is clear or cloudy. (para2-13c(2))

**End of Lesson 2**

## LESSON ASSIGNMENT

**LESSON 3** Bacteriological Tests and Standards

**TEXT ASSIGNMENT** Paragraphs 3-1 through 3-15.

**LESSON OBJECTIVES** After completing this lesson, you should be able to:

3-1. Select the statement that best describes indicator organisms and the reasons for testing for their presence in water samples.

3-2. Select the correct sampling procedure for the bacteriological analysis of water.

3-3. Select the proper sequence of steps in conducting a total coliform test on a water sample.

3-4. Select the proper equipment and prepare it for conducting a bacteriological test on a water sample.

3-5. Interpret the bacteriological tests of a water sample against a set of Army standards and report the results on a DD Form 686.

**SUGGESTION** After completing the assignment, complete the exercises at the end of this lesson. These exercises wail help you to achieve the lesson objectives.

# LESSON 3

# BACTERIOLOGICAL TESTS AND STANDARDS

## Section I. BACTERIOLOGICAL TESTS

### 3-1. GENERAL

Bacteriological tests are a measure of the portability of a water supply. One of the criteria of potability (para 1-4a) is that water be free from pathogenic organisms. All surface and ground waters can be expected to contain pathogenic organisms and must, therefore, be disinfected prior to being used as drinking water supplies. Treated water supplies should be free from pathogens; however, we cannot be sure of the effectiveness of our treatment processes unless we conduct bacteriological tests for the presence of bacteria.

### 3-2. INDICATOR ORGANISMS

a. **Waterborne Diseases**. Pathogens that may exist in water supplies include the causative of the waterborne diseases listed below. All of these organisms are introduced into a water supply by contamination of the water with urine, feces, or both from infected persons or animals.

(1) Typhoid fever.

(2) Paratyphoid fever.

(3) Shigellosis (bacillary dysentery).

(4) Cholera.

(5) Viral Hepatitis.

(6) Leptospirosis.

(7) Amebiasis.

(8) Schistosomiasis (a parasitic infestation).

b. **Reasons for Using Indicator Organisms**. It is possible, in some cases, to conduct bacteriological examinations of water for the presence of specific pathogens. It is not practical to do so, however; first, because the concentration of pathogens is usually quite low; and second, because isolation and detection techniques for even the most common pathogens involve relatively complicated procedures that will exceed the capabilities of all but a few well-equipped water laboratories. Consequently, we test for a relatively easy-to-isolate indicator organism whose presence suggests probable contamination with pathogens, but whose absence offers reasonable assurance that no pathogens are present.

c. **Characteristics of Indicator Organisms**. In order for an indicator organism to give a true indication as to the presence of pathogens in a water supply, it must meet several criteria. The criteria are that the indicator:

(1) Must be present when the water is contaminated--preferably in greater numbers than the pathogens.

(2) Must respond to environment and water treatment processes in the same manner as pathogens, having a similar life span.

(3) Must be easily identified and counted by simple procedures.

(4) Should be nonpathogenic itself (safe to the laboratory technician).

d. **Coliform Bacteria as Indicators**. A group of nonpathogenic bacteria known as the coliform group has been selected as the indicator of fecal contamination of water and, thus, the presence of pathogens causing waterborne diseases. The coliform group is not a particular species of bacteria, but a group of several genera of bacteria that are normal inhabitants of the intestinal tracts of human, and other warm--blooded animals.

(1) There are two definitions of the coliform group, depending upon which test is being employed to detect them. They comprise all of the aerobic and facultative anaerobic, gram--negative, non-spore--forming, rod--shaped bacteria which:

(a) Ferment lactose broth with gas formation within 48 hours at 35ºC (multiple tube method); or

(b) Produce a dark colony with a gold-green metallic sheen on an Endo-type medium with lactose within 24 hours at 35ºC (membrane filter technique.) (See paragraph 3-7b for media.)

(2) The most important members of the coliform group are Escherichia coli (E. coli), a normal inhabitant of the intestinal tracts of warm-blooded animals, and Aerobacter aeroqenes, which is widely distributed in nature and is normally found on plants and grains, in the soil, and to a varying degree in the feces of humans and animals. The presence of either of these organisms in water is prima facie evidence of contamination of the water with feces or soil. (Prima facie evidence of contamination means that enough evidence is present to presume contamination.)

(3) The coliform group of bacteria was selected as the indicator for pathogenic organisms in water for the following reasons:

(a) Coliform organisms are present in fecal wastes on the order of $10^{11}$ to $10^{13}$ per capita per day. They are roughly 100,000 times more numerous than pathogenic organisms.

(b) Coliforms are found in both natural and treated waters where contamination has occurred. The optimum conditions for their survival are about the same as for pathogenic organisms.

(c) The coliform group may be identified and counted by relatively simple laboratory procedures.

(d) The coliform bacteria are not, in themselves, pathogenic to adults; therefore, they present little hazard to the laboratory technician who works with them.

## 3-3. COLLECTION OF SAMPLES FOR BACTERIOLOGICAL ANALYSIS

### a. **Sample Bottles and Collection Points**.

(1) Samples of water for bacteriological analyses must be collected in sterile bottles. Screw cap bottles of about 120--milliliter capacity are preferred, but glass-stoppered bottles are acceptable. These bottles must have been cleaned; capped with a protective hood of paper, foil, or cloth; and sterilized. The sample bottles are normally provided by the laboratory that performs the bacteriological analyses. This laboratory also places in each bottle 0.02 to 0.05 grams of <u>sodium thiosulfate</u>, a reducing agent to neutralize any chlorine residual which may be in the water at the time of collection. Such neutralization prevents the chlorine from killing any living organisms in the water samples after collection. If necessary, the laboratory provides standard cardboard and metal mailing tubes in which the bottled samples can be sent through the mail. If sample bottles are prepared by the agency collecting the samples, they should be sterilized in an autoclave at a temperature of 121ºC and a pressure of 15 pounds per square inch for a minimum of 15 minutes. If sodium thiosulfate is used (required only for samples of chlorinated water), it must be added prior to sterilization.

(2) Samples from the potable water system should be taken at points that are truly representative of the water flowing in the system. These locations on most posts would be kitchens, dining halls, barracks, administrative areas, hospitals, clubs, snack bars, family quarters, and other locations where water is consumed. Occasionally, special samples, for reasons determined to be important by the surgeon, may be collected from raw water sources and from water in various stages of the treatment process, at dead ends, or at infrequently used points of the distribution system.

(3) Normally, samples are taken from cold-water faucets, which are used frequently. Do not take samples from hot water faucets. Most of the residual chlorine will dissipate when heated. Samples should not be taken from leaking faucets, since the surface may be contaminated from flowing over the outside of the soiled surface of

the faucet. It is awkward to obtain water samples form fire hydrants and drinking fountains. Ordinarily, nothing is gained by sampling a tap on the dead and of a distribution system.

b. **Procedure for Collecting and Forwarding Water Samples**.

(1) Select a suitable cold-water faucet that has no leakage. Open the tap and let the water flow long enough to pull in water from the water main, serving that particular building. A flow for 3 to 5 minutes should be sufficient.

(2) Determine the chlorine residual and pH and record this information on DO Form 686 (Fluoride/Bacteriological Examination of Water) while waiting for the water to run before collecting the sample. The number of copies required of this form varies from one installation to another. The original and at least one copy must be submitted with the water sample. The original is returned to report the laboratory findings. The laboratory will advise as to the exact number of copies needed. Other copies may be routinely required by the surgeon, the post engineer, and other interested activities.

(3) Close the water tap and flame the outside and inside lip of the tap with a candle or alcohol lamp to destroy any live organisms that might be present.

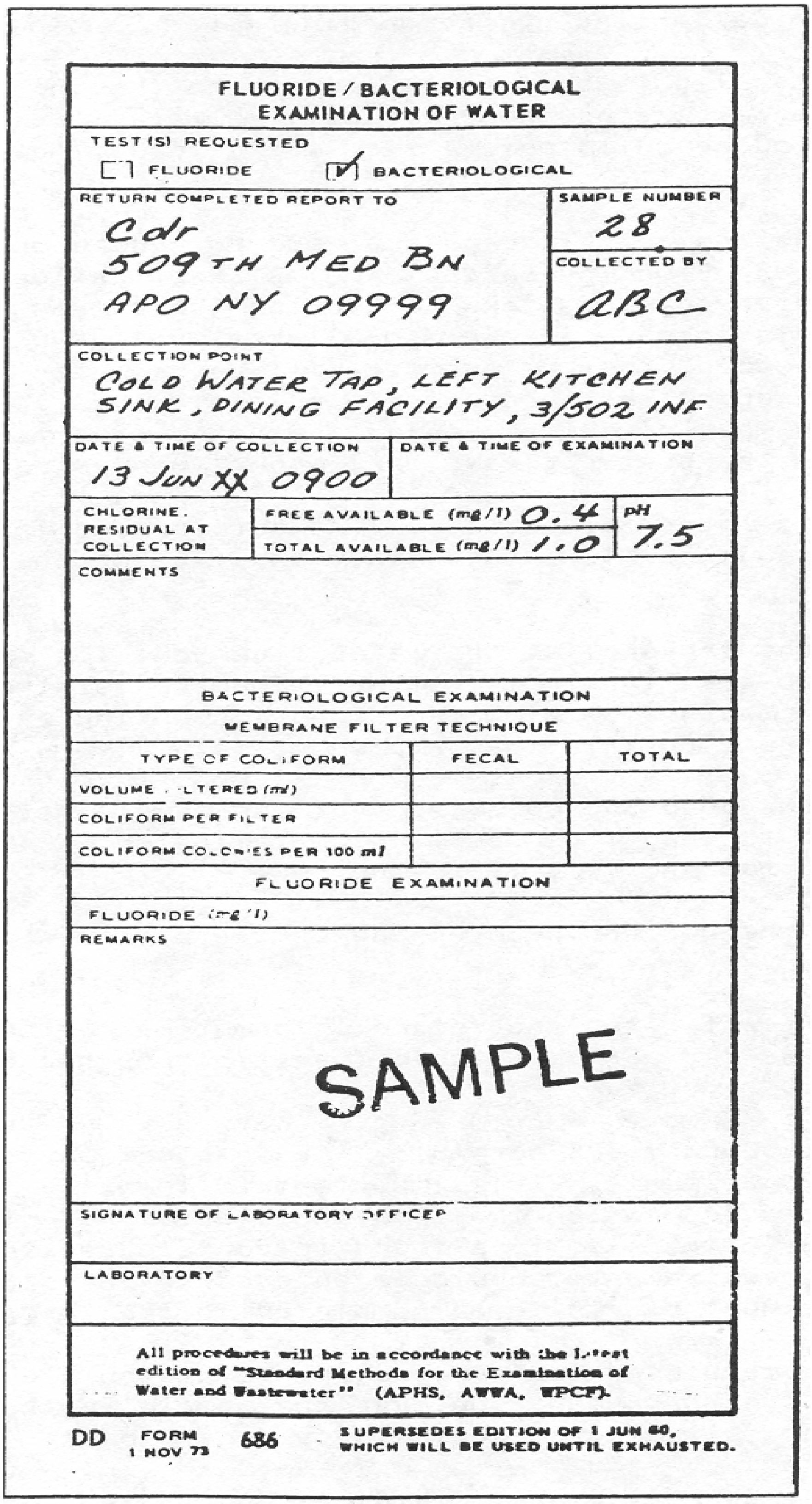
(4) Reopen the tap and let the water flush out the soot and other combustion products that resulted from flaming. Then adjust the tap to produce a gentle, easy, smooth flow of water, thus preventing splashes and contaminated water from getting into the sample bottle.

(5) Remove the hood and screw cap from the sample bottle and hold them together to prevent the cap from becoming contaminated. Place the sample bottle under the flowing tap and fill it to the neck.

(6) Replace the cap and hood on the sample bottle while they are still together.

(7) Close the water tap and record information pertaining to the sample on DO Form 686 (see figure 3-1). Record the sample number on the sample bottle at this time also.

(8) Complete DO Form 686 carefully. Each block on the form serves an essential purpose. For example, it is important to identify the collection point and the specific tap from which the sample was obtained. The water from this tap must be checked further if it is found to contain coliform group organisms. Any special requirements should be entered in the space labeled "Remarks." Leave blank those blocks to be completed in the laboratory.



**FLUORIDE / BACTERIOLOGICAL EXAMINATION OF WATER**

TEST (S) REQUESTED

☐ FLUORIDE ☑ BACTERIOLOGICAL

RETURN COMPLETED REPORT TO

Cdr
509TH MED BN
APO NY 09999

SAMPLE NUMBER: 28

COLLECTED BY: ABC

COLLECTION POINT: COLD WATER TAP, LEFT KITCHEN SINK, DINING FACILITY, 3/502 INF

DATE & TIME OF COLLECTION: 13 JUN XX 0900

DATE & TIME OF EXAMINATION:

| | | |
|---|---|---|
| CHLORINE RESIDUAL AT COLLECTION | FREE AVAILABLE (mg/l) 0.4 | pH 7.5 |
| | TOTAL AVAILABLE (mg/l) 1.0 | |

COMMENTS

BACTERIOLOGICAL EXAMINATION

MEMBRANE FILTER TECHNIQUE

| TYPE OF COLIFORM | FECAL | TOTAL |
|---|---|---|
| VOLUME FILTERED (ml) | | |
| COLIFORM PER FILTER | | |
| COLIFORM COLONIES PER 100 ml | | |

FLUORIDE EXAMINATION

FLUORIDE (mg/l)

REMARKS

SAMPLE

SIGNATURE OF LABORATORY OFFICER

LABORATORY

All procedures will be in accordance with the latest edition of "Standard Methods for the Examination of Water and Wastewater" (APHS, AWWA, WPCF).

DD FORM 1 NOV 73 686 SUPERSEDES EDITION OF 1 JUN 60, WHICH WILL BE USED UNTIL EXHAUSTED.

Figure 3-1. DD Form 686, Fluoride/Bacteriological Examination of Water.

(9) Wrap the completed form around the sample bottle and secure it in place with a string or rubber band. Deliver the sample to the laboratory as soon as possible. The following guidelines are recommended:

(a) Process the sample within one hour after collection, whenever possible. If this is not possible, refrigerate samples by means of ice coolers.

(b) Process refrigerated samples, normally, within 6 hours after collection. It should be noted that various state regulatory agencies might allow a modification to the above time guideline.

(c) Contact the appropriate state agency having regulatory power and/or installation medical authority (generally the Preventive Medicine Activity) for additional instructions when it is impossible to achieve the above-recommended time.

c. **Sampling Swimming Pools and Natural Waters**. The environmental health specialist will be required to collect water samples periodically from swimming pools, natural bathing areas, and natural raw water sources (lakes, ponds, and streams).

(1) Sample bottles, completion of DD Form 686, and forwarding of samples are as described in a and b, above.

(2) Samples from swimming pools should be from both the deep and shallow ends. In natural waters, samples usually should be collected about 25 feet from shore in water at least 2 1/2 feet deep and representative of the bathing water. Samples should be collected from wading pools and be representative of the wading water. Collect samples in accordance with (IAW) Chapter 7, TB MED 575.

(3) When samples are being collected, the bottle top should be removed and held so as to prevent contamination of the top or mouth of the bottle. The bottle is then plunged, mouth down, at least 6 inches below the surface of the water and filled by moving it forward through the water so that no water that has come in contact with the hand or outside of the bottle enters it. Do not rinse the bottle. In a stream, the bottle is moved against the current.

(4) Samples from raw water sources are collected in the same manner as those from natural bathing areas. The sampling point should be near the intake into the water supply system so that the sample is representative of the raw water entering the system.

## 3-4. BACTERIOLOGICAL ANALYSIS BY THE MULTIPLE-TUBE FERMENTATION TECHNIQUE

Prior to the development of the membrane-filter technique, the multiple-tube fermentation (MTF) technique was the standard method for determining the presence of coliform bacteria in water samples. Today it is used primarily as an alternate or back up method where the turbidity of a water sample precludes an accurate analysis by the membrane-filter technique. The multiple-tube method requires a complete laboratory setup, it requires a minimum of 48 hours (up to 4 days), and the results show only the presence of and an approximation of the "most probable number" (MPN) of coliform organisms.

a. **Procedure**. Appropriate quantities of the water to be tested (usually five 10-ml samples) are placed in sterile tubes containing a lactose broth medium. The tubes are incubated at 35°C for 24 hours and then examined for the presence of gas formation (para 3-2d(1)(a)). If no gas is present, they are incubated for an additional 24 hours and examined again.

(1) Presumptive test. If no gas is present at the end of 48 hours, the test is negative. If gas in any amount is present, it is a positive presumptive test.

(2) Confirmed test. Material from tubes showing fermentation (gas formation) is transferred to tubes containing brilliant green lactose bile broth and incubated for 48 hours at 35ºC. Absence of gas constitutes a negative test. Presence of gas constitutes a confirmed positive test.

(3) Completed test. This procedure is not always done. Its purpose is to demonstrate with certainty that the organisms giving positive results are really members of the coliform group. The procedure is to streak one or more Endo or eosin methylene blue (EMB) plates from each tube showing gas and incubate for 24 hours. A typical (or the most nearly typical) colony from each plate is then transferred to both a secondary lactose broth fermentation tube and an agar slant petri dish. After 48 hours of incubation at 35°C (24 hours if gas is present), gram--stain slides are prepared from the agar cultures of the colonies that formed gas in the secondary fermentation tubes. Microscopic demonstration of gram--negative, non--spore-forming, rod--shaped, bacteria, accompanied by gas formation, constitutes a completed test and demonstrates the presence of coliform organisms.

b. **Most Probable Number**. The most probable number (MPN) reported by the laboratory on a multiple-tube coliform determination is a statistical probability of the number of organisms per 100-ml of the water tested. It can be seen that the results are only approximate. The accuracy can be increased by using more tubes of varying amounts of sample, such as 5 of 50 ml, 5 of 10 ml, and 5 of 1 ml. Even with this increased size and number of portions, the accuracy can vary substantially.

**NOTE**: The EPA states that effective 31 December 1990, this technique is no longer to be used to determine coliform densities. It is to be replaced by the Presence/Absence coliform test.

c. **Presence-Absence Coliform Test**. Colilert is one of several products that may be used to rapidly determine the presence or absence of coliform in water. It is another method for MTF and membrane filtration (MF) testing. Other method testing takes from two to six days, in a sophisticated laboratory, to obtain a total coliform count. Their tests cannot determine specific indication of whether fecal contamination has occurred. Test invalidation may be caused by growth and interference from non-coliform heterotrophic bacteria. However, the Colilert method overcomes these problems and confirmed results take 24 hours or less. With Colilert, coliforms metabolize specific indicator nutrients, liberating a yellow color for the presence of total coliforms and a fluorescence color for the presence of E. coli. A negative test sample is indicated by no yellow color within 24 hours.

**NOTE**: A national study conducted by the American Water Works Association Research Foundation (AWWARF) and the United States Environmental Protection Agency (USEPA) in 1987 documented that no confirmation test is required when Colilert is used. The Washington office of EPA has approved Colilert as an alternate standard method for total coliform analysis.

(1) <u>Preparation procedures</u>.

(a) Wash hands thoroughly and work surface prior to performing the test.

"

(b) Remove one unit dosed tube from the box.

(c) Remove one sterile reaction vessel from its wrapper. Label the cap to reflect the date, time, and sample identification.

**CAUTION**: The inside of the water collecting vessel/bag, Colilert cap or tube, and the water sample must remain sterile. Keep objects and fingers from these areas.

(d) Mix the water sample vigorously and thoroughly.

(e) Uncap one sterile vessel. Leave the cap inverted on the clean table.

**CAUTION**: Never open a Colilert tube until it is ready to be used to prevent possible contamination or reduction of the potency of the contents.

(f) Pour 100 ml of the water sample into the reaction vessel.

(g) Add the contents of one unit dosed tube of Colilert reagent to the reaction vessel. Replace the cap of the vessel, without touching its interior surface. Then tighten the cap and mix vigorously to dissolve the reagent.

**NOTE**: It is normal if some reagent particles remain undissolved.

(h) Set the incubator at 35-37ºC and place the reaction vessel inside of it. Incubate for 24-28 hours (28 hours is the maximum time limit).

**NOTE**: Incubate within 30 minutes of combining the water sample with the reagent and mixing the solution.

**NOTE**: Follow the operating instructions when setting up and calibrating the incubator.

. (2) Interpretation procedures.

(a) Read the sample vessels after 24 hours (up to 28 hours, if needed, while incubation is at 35-37°C). The sample vessels will show one of two colors:

1 No color. This means that coliform and E. coli are absent, making the water potable or safe to drink.

2 Yellow color. This means that coliforms are present and the color will increase. Additional procedures should be performed.

(b) Place the carrier two inches from the ultra violet light in a dark area if the color of the sample is yellow. Depending on the yellow color, one of the following should be accomplished:

1 For a faint yellow or fluorescent color that you are unsure of, compare it to the comparator (W103).

2 For a yellow color equal to or greater that the comparator, interpret the sample to be positive.

3 For a yellow color that is slightly less than the comparator, incubate the sample up to an additional 4 hours. The yellow color will increase if coliforms are present.

4 Confirm and record the coliform results.

**NOTE**: The comparator should be dispensed into a vessel identical to the ones used in the presence--absence coliform test, before comparing it to the reacted test samples.

(3) Disposal procedure.

(a) Open each vessel and disinfect the vessel and contents. Add a household bleach to the top of each vessel.

(b) Cap each vessel tightly and shake or mix.

(c) Let each stand for 20 minutes and then flush the contents.

d) Dispose of each vessel as per local procedure or standard operating procedure (SOP).

**NOTE**: There is an alternate method of disinfecting the vessels and contents before disposing of the vessels. Alternately, autoclave the vessels, with contents, at 121º C for 20 minutes in a "biobag" or similar container as noted in the SOP. Then dispose of the vessels.

:

## 3-5. BACTERIOLOGICAL ANALYSIS BY THE MEMBRANE-FILTER TECHNIQUE

a. **General**. The membrane--filter technique is now considered the preferred method for the bacteriological analysis of water, unless the turbidity of the sample is sufficient to clog the pores of the filter. It permits: the examination of a larger volume of sample than does the multiple--tube technique; a direct count of the bacteria in the water, rather than a statistical approximation; and completion of the test in 24 hours, whereas the multiple--tube method usually requires 48--72 hours for a confirmed test (longer for a completed test).

b. **Principles**. The basic principles involved in the membrane--filter method of determining the presence and number of coliform organisms in a given quantity of water are as follows:

(1) A given quantity of water is filtered through a porous disk of polyester cellulose acetate. The porosity of the filter is 79 percent, and the size of the pores is 0.45 microns (u). Since coliform bacteria are from 1 to 4 microns in length, they are retained on the filter when the water passes through.

(2) Because the pores of the filter are so small, the water will not pass through the filter by gravity. Therefore, a vacuum source must be available to enable the water to penetrate the filter. In the laboratory, a hydrosol with a power vacuum source is used. In the field, a hand-operated vacuum pump is used.

(3) After the water sample has been filtered, the filter is incubated at 35ºC for 22-24 hours in contact with M--Endo medium in a petri dish. This culture medium is favorable to the growth of coliform bacteria, but it inhibits the growth of other types of bacteria. This gives it a selective characteristic. Although a few other types of bacterial colonies may develop on the culture medium, the coliform bacteria will reproduce better, forming readily identifiable colonies. Colonies may be counted using a low-power microscope or a simple hand magnifier.

c. **Procedures**. The specific procedures for conducting the analysis are outlined in succeeding paragraphs.

**NOTE**: The Federal Register, Part III, dated Thursday, 29 June 1989, 40 CFR Parts 141 and 142 states that heterotrophic bacteria may interfere with total coliform analysis. Therefore, if the total coliform sample produces a turbid culture in the absence of gas production, using the Multiple Tube Fermentation (MTF) Technique, or an acid reaction, using the Presence-absence (P-A) Coliform Test; or confluent growth or a colony number that is "too numerous to count" using the Membranes Filter (MF) Technique, the sample is invalid (unless total coliforms are detected, in which, case, the sample is valid). The system must, within 24 hours of being notified to the result, collect another sample from the same location as the original sample and have it analyzed for total coliforms. In these cases, EPA recommends using media that is less prone to interference from heterotrophic bacteria for analyzing the replacement sample." The 24-hour time limit may be waived on a case-by-case basis.

## 3-6. PREPARATION OF EQUIPMENT

a. **Water Testing Kit, Bacteriological (see figure 3-2)**. The bacteriological water testing kit is a standard item of table of organization and equipment (TOE) issued to preventive medicine units and the preventive medicine section of the division medical battalion. It has a portable incubator heated by direct current from a 6-, 12-, or 24-volt battery; or it may be powered by 115-volt, 60-cycle or 230-volt, 50-cycle alternating current. Adapters are provided for standard US or European wall outlets, battery terminals, or vehicle cigarette lighter receptacles. A manual of instructions is issued with the kit. It contains the following equipment:

(1). Funnel and filter-support assembly.

(2). Hand suction pump.

(3). Measuring cup.

(4) Forceps.

(5) Petri culture dishes.

(6) Absorbent pads.

(7) Membrane filter disks.

(8) Culture media or endo broth.

(9) Methanol.

(10) Distilled water.

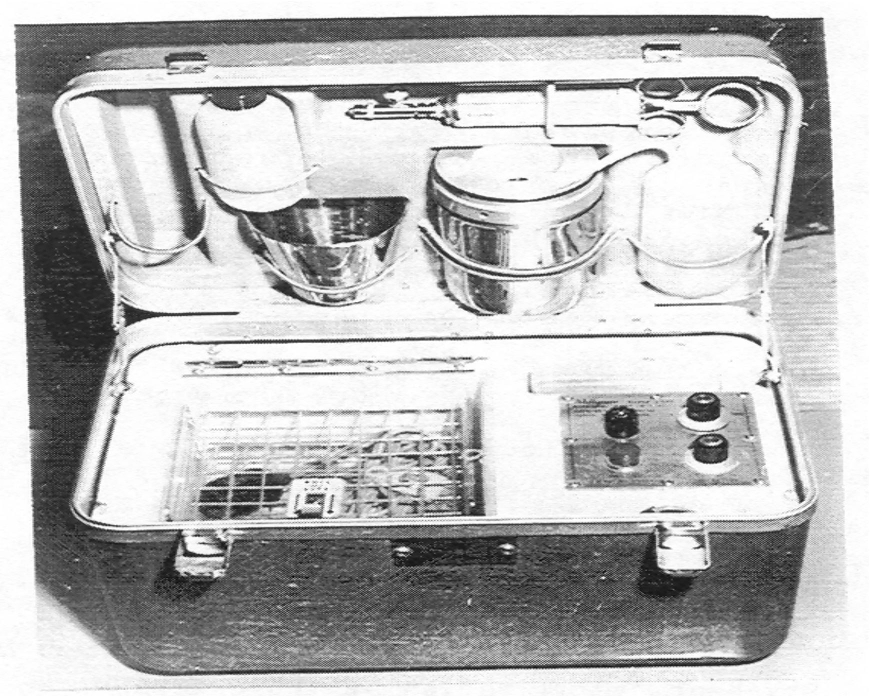


Figure 3-2. Water testing kit, bacteriological.

b. **Sterilization of Equipment**.

(1) Funnel and filter-support assembly.

(a) The funnel and filter-support assembly should be sterile at the beginning of each filtration series. It is not necessary to sterilize this assembly between successive filtrations or between successive filtrations of a series of samples unless an interruption of 30 or more minutes occurs between them. The probability of contaminating each succeeding sample with bacteria present in the previous one is reduced by properly flushing the funnel walls with sterile buffered water.

(b) The preferred method for sterilizing the funnel and filter-support assembly is in an autoclave. The funnel and filter holder should be wrapped separately in kraft paper and sterilized in the autoclave at 121ºC (249.8ºF) for 15 minutes. At the end of the 15-minute holding period, the steam pressure should be released rapidly to promote drying.

(c) The funnel and filter holder may be sterilized in a flowing steam sterilizer for a 30-minute holding period.

(d) In an emergency, or in the field when an autoclave or sterilizer is not available, the funnel and filter holder may be sterilized by keeping it immersed in boiling water for 10 minutes.

(e) The funnel and filter-support assembly may also be sterilized with formaldehyde gas. This method consists of putting methyl alcohol on a wick in the base of the assembly, igniting the methyl alcohol, and closing the unit after 30 seconds. Since the methyl alcohol is incompletely oxidized in the closed unit, formaldehyde gas, which is a bactericidal, is generated. The unit is kept closed for at least 15 minutes; then it is rinsed with sterile water before it is used. The formaldehyde gas method is recommended for emergency or field use only.

(f) When the funnel and filter-support assembly is heavily contaminated, it should be washed thoroughly prior to sterilization.

(2) Membrane filters and absorbent pads.

(a) The membrane filters and absorbent pads are supplied in separate envelopes with 10 to a package. These filters and pads must be sterilized in the envelopes in an autoclave for 10 minutes at 121ºC. After the sterilization period, the steam pressure should be released as rapidly as possible. The packages should then be removed from the autoclave.

(b) Membrane filters and absorbent pads for use in the field should be sterilized in advance.

(3) Plastic petri dishes. Since plastic petri dishes are manufactured by use of high temperature, then packaged, and sealed, they are considered sterile. These disposable-type petri dishes should be used once and discarded. Should reuse of plastic dishes become necessary in an emergency, they should be sterilized as described below as they will not withstand heat sterilization.

(a) Wash them thoroughly; then completely immerse them in a solution of 70 percent ethanol for a minimum period of 30 minutes.

(b) Remove the dish halves aseptically; then invert them on a dry sterile towel and let them drain and air-dry thoroughly.

(c) Using sterile techniques close the dishes and store them in a dustproof container.

(4) Glass petri dishes. If glass petri dishes are used, 10 dishes may be rolled in paper or metal foil and sterilized in an autoclave at 121ºC (249.8ºF) for 15 minutes.

(5) Pipette and graduated cylinders.

(a) Dry heat sterilization at 170ºC (338ºF) for at least 1 hour is preferred for most glassware. Pipettes can be placed in cans or wrapped individually in paper for sterilization. The openings of graduated cylinders should be covered with metal foil or kraft paper before sterilization.

(b) Sterilization in the autoclave at 121ºC (249.8ºF) for 15 minutes is satisfactory for glassware.

(c) Pipettes and graduated cylinders to be used in the field should be sterilized in the laboratory.

## 3-7. PREPARATION OF MATERIALS

### a. Sterile Buffered Dilution Water.

(1) Stock phosphate buffer solution is prepared by dissolving 34.0 grams of potassium dehydrogen phosphate ($KH_2PO_4$) in 500 milliliters (ml) of distilled water. The pH is then adjusted to 7.2 with a solution of 40 grams per liter (1 N) sodium hydroxide (NaOH). Distilled water is then added to increase the volume of the solution to 1 liter (1).

(2) Sterile buffered dilution water is made by adding 1.25 ml of the stock phosphate buffer solution to 1liter of distilled water and autoclaving it at 121ºC (249.8ºF) for 15 minutes.

### b. Culture Media.

(1) Ampuled M-Endo medium. An ampule of M-Endo medium is sufficient for one analysis. Ampuled medium, which has a limited shelf life, should be discarded after the expiration date indicated on the ampule box. Furthermore, it should not be used unless it is pink. Keeping ampuled medium refrigerated helps to reduce deterioration.

(2) Laboratory-prepared M-Endo medium. This medium should be used whenever possible. It may be prepared from dehydrated medium such as Difco M--Endo MF or BBL M-Coliform MF. This medium must be prepared on the same day that it is to be used in making the water analysis. The directions for preparation are on the container of the dehydrated medium. In the field, based upon the number of water samples to be analyzed, it is desirable to put proportional quantities of the dehydrated medium in sterile screw cap vials. Then, on the day that the medium is to be used, the proper amount of distilled water and ethanol can be added. The vials must then be placed in a boiling water bath and heated until the medium reaches the boiling point. The screw caps on the vials must be loosened during heating and tightened when the vials are removed from the water bath. This medium must be allowed to cool to room temperature before it is used

(3) Vials of dehydrated endo broth. Each vial contains 1.2 g of the dehydrated endo broth that is reconstituted by mixing it thoroughly with 24.5 ml of water

and 0.5 ml of ethanol. This mixture must then be heated with frequent agitation and boiled until the solution is complete. Two ml of this solution are used on each filter pad.

## 3-8. DETERMINING FILTRATION VOLUME

The quantity of water sample to be filtered is governed by the expected bacterial density. Sample volumes should be chosen to obtain at least one membrane filter with 20 to 80 coliform colonies. The total number of colonies of all types should not exceed 200.

a. **Data Available**. If bacteriological data are available from previous tests, water sample filtration volumes can be computed as follows:

(1) First, determine the arithmetic mean of the coliform counts; then determine the volume of sample, which, on the average, may be expected to produce 20 coliform colonies. This is known as the Basic Filtering Volume (BFV).

**Example:** Previous data show that a given source has an average coliform density of 160 coliform colonies per 100 milliliters.

$$\frac{20}{\text{Average coliforms per 100 ml}} \times 100 = \text{BFV}$$

$$\frac{20}{160} \times 100 = 12.5 \text{ ml BFV}$$

(2) If three sample volumes are to be filtered, as is preferred, then filter one-third of the BFV, the BFV, and three times the BFV. (The computed amounts for filtration in the example above would be 4.2, 12.5, and 37.5 ml. For convenience in measurement, the samples should be filtered in the amounts of 4, 10, and 40 ml).

(3) If two sample volumes are to be filtered, filter one-half of the BFV and one and one-half times the BFV. (The computed amounts for filtration in the example above would be 6.25 and 18.75 ml. For convenience in measurement, the sample should be filtered in amounts of 6 and 20 ml).

(4) If only one filtration is to be made (generally not recommended), filter the BFV. (In the example above, the amount for filtration would be 12.5 ml or 10 ml for convenience in measurement).

b. **Data Not Available**. In the absence of previous bacteriological data, the following water sample volumes should be filtered:

(1) Potable waters.

(a) Municipal (treated) supplies: 100, 200, or 300 ml. Preference should be given to these volumes in the order in which they are listed.

(b) Untreated supplies: 50 or 100 ml.

(c) Water from mains before resumption of service repairs or from new mains: 100 ml.

.

(2) Raw water sources.

(a) Unpolluted surface water: 5 to 50 ml.

(b) Polluted surface water: 0.01 to 10 ml.

## 3-9. FILTRATION AND INCUBATION

The following practices and procedures are desirable for effective application of the membrane filter technique:

a. Clean the work area with water; then allow the surface to dry.

b. Prepare fresh medium for the day's testing. If ampules are used, one ampule is required for each sample filtration.

c. Arrange and prepare certain equipment and supplies from the bacteriological water testing kit (see figure 3-2) for use as follows:

(1) Open the bottle of methanol and place forceps in it so that the tips are immersed approximately 1 inch.

(2) Position the Bunsen or alcohol burner. It will be used to " burn the alcohol off the tips of the forceps before they are used.

(3) Label the petri dishes with the sample number shown on DO Form 686, the date and time, analysist's initials, and the volume filtered. Position them on the work area.

(4) Place one sterile absorbent pad in each petri dish. Use sterile forceps to manipulate it. Before using the forceps, be sure to burn the alcohol off their tips. Do not hold the forceps in the flame any longer than necessary to ignite the alcohol since excessive heat will damage the forceps.

(5) Use a sterile pipette to deliver enough laboratory prepared culture medium to saturate each absorbent pad or empty the contents of one ampule of medium on each absorbent pad (see figure 3-3). The amount of culture medium required for each absorbent pad is approximately 2 milliliters. The amount should be sufficient to allow a large drop to drain from the pad freely when the petri dish is tipped.

Adequate medium is necessary for the organisms filtered out of the water to grow properly and provide valid results. On the other hand, the use of excess medium must be avoided since excessive medium causes the colonies to run together.

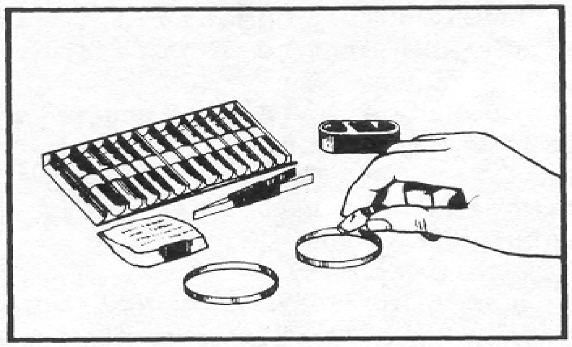


Figure 3-3. Saturate absorbent pad with culture medium.

(6) Rinse the funnel-assembly with 50 ml of buffered water.

(7) Place a sterile membrane filter disk with the grid side up on the filter base and center it over the porous part of the membrane support plate (see figure 3-4). A membrane filter is easily damaged. Using sterile forceps, <u>always</u> grasp the <u>outer</u> part of the membrane filter to prevent damage to the part through which the sample is to be filtered.

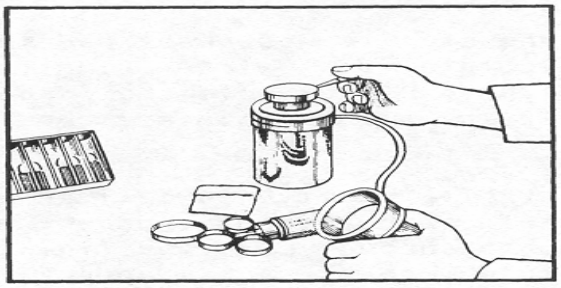


Figure 3-4. Place sterile membrane filter on filter holder.

(8) Attach the funnel element to the filter holder. To avoid damage to the membrane filter, never turn or twist the funnel element as you seat and lock it to the filter holder. In securing the funnel element to a filter holder which has a bayonet joint and locking ring, take special care to turn the locking ring sufficiently to give a snug fit, but do not tighten it excessively.

d. Filter the first water sample. Pour the measured water sample into the funnel (see figure 3-5); then enter in the appropriate space on DD Form 686 the volume of sample being filtered. Since the primary objectives in this step are accurate measurement of sample and optimum distribution of colonies on the filter, the methods

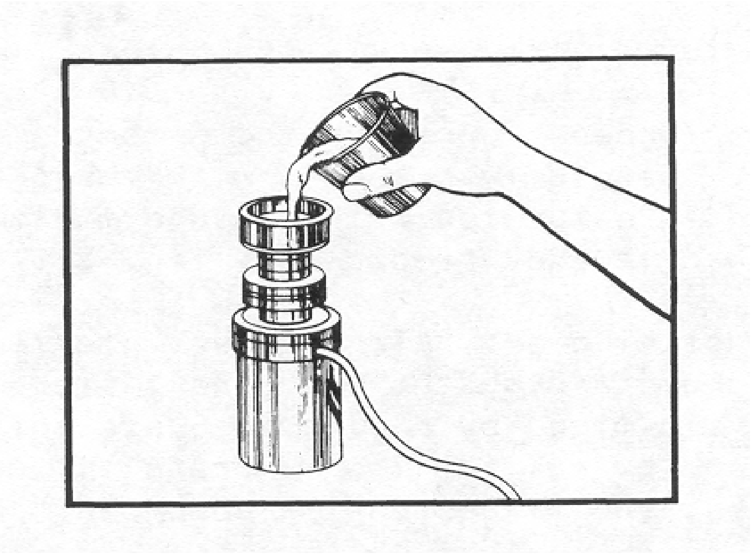


Figure 3-5. Pour measured water sample into funnel.

(1) <u>Sample greater than 20 ml</u>: Use a sterile graduated cylinder to measure the sample and pour it into the funnel.

(2) <u>Sample of 2 to 20 ml</u>: Pour about 30 ml of sterile buffered dilution water into the funnel; then using a sterile 10- or 20-ml pipette, measure the sample and put it into the funnel.

(3) <u>Sample of 0.5 to 2 ml</u>: Pour about 30 ml of sterile buffered dilution water into the funnel; then using a sterile 1- or 2-ml pipette, 1-5 measure the sample and put it into the funnel.

e. Connect the hand suction pump to the filter base and withdraw air by means of a pumping action, thus aiding the sample to pass through the filter (see figure 3-6).

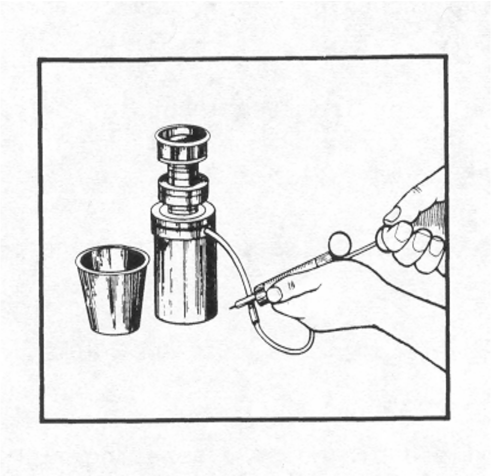


Figure 3-6. Apply suction to filter holder.

f. Rinse down funnel walls with at least 35 ml of sterile buffered dilution water for each rinse (see figure 3-7) after all the sample has passed through the membrane filter. Repeat the rinse twice after all the first rinse to has passed through the filter. Since the funnel is not routinely sterilized between successive filtration of a series of samples, minute droplets must be removed from the funnel walls to prevent contamination of subsequent samples.

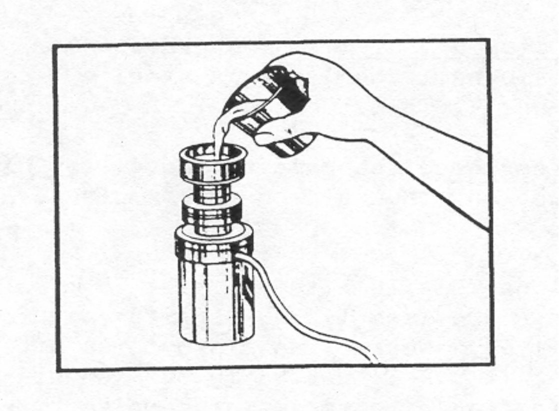


Figure 3-7. Rinse down funnel walls.

Cut off suction on the filter assembly as soon as all the water has been filtered for any sample. Continued suction with no sample may introduce unnecessary airborne contamination.

g. Remove the funnel from the filter holder.

h. Use sterile forceps to remove the membrane filter from the filter holder (see figure 3-8). Carefully place it with the grid side up on the appropriate pad, which is saturated with culture medium, but take care not to trap air bubbles between it and the pad (see figure 3-9).

**NOTE**: Then close the petri dish. Air bubbles interfere with the diffusion of the culture medium through the membrane filter. Entrapment of air bubbles can be minimized by having adequate culture medium on the absorbent pad and by rolling the membrane filter into position. If necessary, reseat the filter on the absorbent pad to eliminate bubbles.

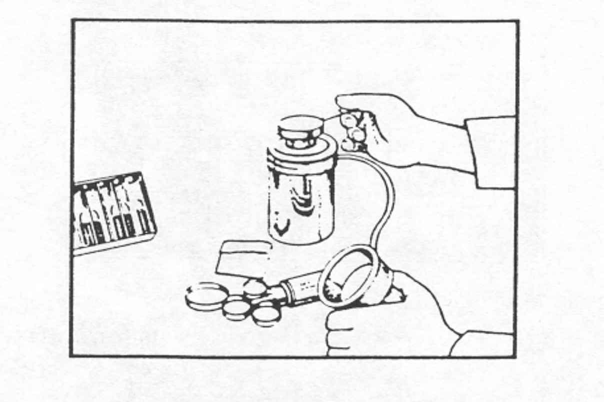


Figure 3-8. Remove membrane filter from filter holder.

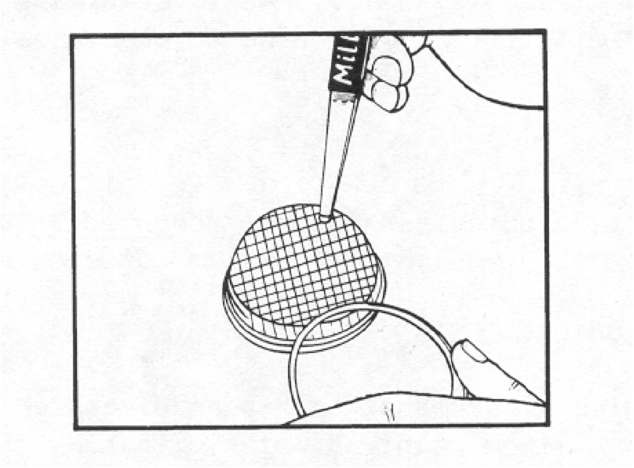


Figure 3-9. Place membrane filter on absorbent pad saturated with culture medium.

i. Place all membrane filters in the petri dishes and all petri dishes in the incubator, <u>grid-side down</u>. Incubate at 35ºC + or--0.5º for 22 to 24 hours. A high level of humidity (approximately 90 percent relative humidity) must be maintained in the incubator. This can be accomplished by placing a wet sponge in the incubator.

j. Remove the cultures from the incubator after incubation.

## 3-10. COUNTING COLONIES

Coliform colonies are dark, usually with a gold-green metallic sheen (see figure 3-10).

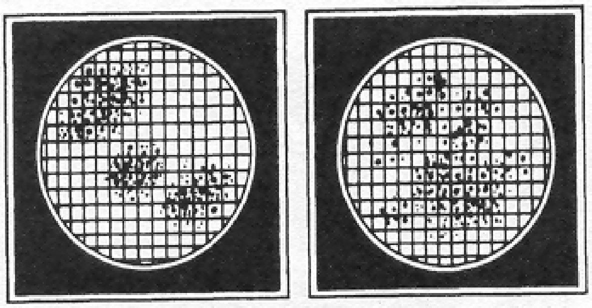


Figure 3-10. Typical coliform colonies.

a. The following equipment is most desirable in counting the coliform colonies:

(1) A wide field binocular dissecting microscope or a simple lens with magnification of 5 to 10 times.

(2) A light source directly above the membrane filter. (A small fluorescent lamp is ideal for this purpose).

b. The colonies are counted by using one of the two following procedures.

(1) Method 1. Remove membrane filter from the petri dish and dry it for about 1 hour on absorbent filter paper. Using the magnifying apparatus and light source (a above), count the colonies that have the characteristic metallic sheen (generally gold-green). The dried membrane filter may be held flat by placing it between two 2- by 2-inch glass slides. This counting procedure is preferred to the one described in (2) below.

(2) Method 2. Place the dish containing the absorbent pad and filter membrane, minus the top of the petri dish, under the magnifying apparatus and light source. Count the colonies that show the characteristic metallic sheen.

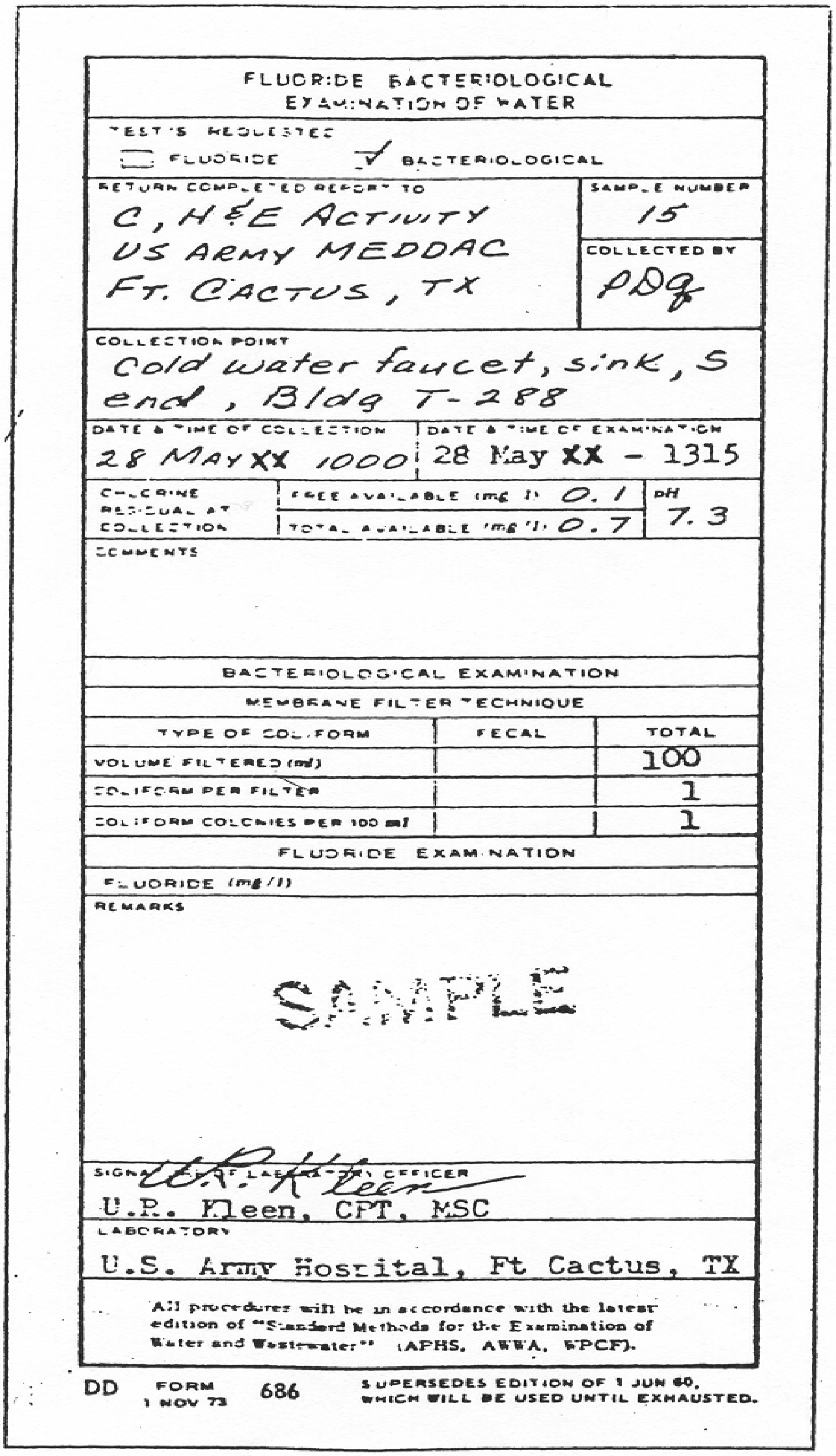
c Enter the colony count for each membrane filter in the space provided on DD Form 686 (see figure 3-11). Next, determine and enter the coliform count per 100 milliliters of the water sample using the following computation:

$$\text{No. colonies per 100 ml} = \frac{\text{No. of coliform colonies counted X 100.}}{\text{ml of sample filtered}}$$

## 3-11. OTHER BACTERIOLOGICAL TESTS

The bacteriological tests that have been discussed thus far are for determining the total coliform count in water. This is the only determination that is done on a routine basis. In special cases, however, it is sometimes desirable to conduct additional investigations to determine a particular source of contamination. Two tests that may also be conducted by the membrane filter technique, using modified procedures, are the following:

a. **Fecal Coliform**. The total coliform determination does not differentiate between fecal coliform organisms (those found in the colon of warm-blooded animals) and nonfecal forms (those found primarily in the soil and on plants). Although the presence of any coliforms indicates contamination, a determination of whether the contamination is fecal or nonfecal may be of value in detecting and correcting the cause. The test for fecal coliform is essentially the same as for total coliform, with the following exceptions:



**FLUORIDE BACTERIOLOGICAL EXAMINATION OF WATER**

TESTS REQUESTED
☐ FLUORIDE ☑ BACTERIOLOGICAL

RETURN COMPLETED REPORT TO
C, H&E ACTIVITY
US ARMY MEDDAC
FT. CACTUS, TX

SAMPLE NUMBER: 15

COLLECTED BY: PDQ

COLLECTION POINT
Cold water faucet, sink, S end, Bldg T-288

DATE & TIME OF COLLECTION: 28 MAY XX 1000

DATE & TIME OF EXAMINATION: 28 May XX - 1315

CHLORINE RESIDUAL AT COLLECTION
FREE AVAILABLE (mg/l): 0.1
TOTAL AVAILABLE (mg/l): 0.7

pH: 7.3

COMMENTS

BACTERIOLOGICAL EXAMINATION

MEMBRANE FILTER TECHNIQUE

| TYPE OF COLIFORM | FECAL | TOTAL |
|---|---|---|
| VOLUME FILTERED (ml) | | 100 |
| COLIFORM PER FILTER | | 1 |
| COLIFORM COLONIES PER 100 ml | | 1 |

FLUORIDE EXAMINATION

FLUORIDE (mg/l)

REMARKS

SAMPLE

SIGNATURE OF LABORATORY OFFICER
U.R. Kleen
U.R. Kleen, CPT, MSC

LABORATORY
U.S. Army Hospital, Ft Cactus, TX

All procedures will be in accordance with the latest edition of "Standard Methods for the Examination of Water and Wastewater" (APHS, AWWA, WPCF).

DD FORM 1 NOV 73 686 SUPERSEDES EDITION OF 1 JUN 60, WHICH WILL BE USED UNTIL EXHAUSTED.

Figure 3-11. DD Form 686 (Completed).

(1) The culture medium used is M-FC enriched, lactose medium containing aniline blue.

(2) The incubation temperature is 44.5°C, which requires incubating the petri dishes by submerging them, enclosed in a plastic bag, in a water bath.

(3) Fecal coliform colonies are blue in color, whereas nonfecal colonies are gray to cream-colored.

b. **Fecal Streptococci**. Fecal streptococci (enterococci), though not members of the coliform group, are normal inhabitants of the intestines of humans and other warm-blooded animals. Since the flora of the human digestive tract is predominantly fecal coliforms while that of animals is predominantly fecal streptococci, a comparison of the two groups present in a water sample may assist in determining whether contamination is of human or animal origin. To test for fecal streptococci, the following modifications are made to the standard procedure:

(1) The culture medium used is M--Enterococcus Agar.

(2) The incubation period is 48 hours.

(3) Fecal streptococcus colonies appear as pink or dark red colonies.

## Section II. BACTERIOLOGICAL STANDARDS

### 3-12. GENERAL

a. **Standards**. Conducting bacteriological tests on water supply samples is only a part of the control measures for ensuring a potable water supply. For these tests to have meaning, they must be interpreted against a set of standards. The standards for military water supplies are established by the following documents:

(1) <u>The National Primary Drinking Water Regulations</u>. These regulations promulgated by the EPA in accordance with the provisions of the Safe Drinking Water Act (Public law 93-523), are mandatory minimum standards for potable water. The regulations replaced the Public Health Service Drinking Water Standards of 1962. The National Primary Drinking Water Regulations (NPDWR) established primary maximum contaminant levels (MCL) for various contaminants that are directly related to safety of drinking water. Other parameters are listed in the Secondary Drinking Water Regulations relate to aesthetic quality.

(2) <u>T8 MED 576. Sanitary Control and Surveillance of Water Supplies at Fixed and Field Installations</u>. This document provides guidance to all personnel concerned with the production and surveillance of potable waters at either fixed or filed activities. It includes procedures for inspections, correction of sanitary defects,

collection of water samples, interpretation of the results of analyses of water samples, and the conduct of routine chlorine residual tests.

(3) TB MED 575. Sanitary Control of Army Swimming Pools and Swimming Areas. This document provides a guide for the sanitary control of all swimming pools and bathing areas constructed and/or operated with either appropriated or nonappropriated funds. (These standards also apply overseas, where appropriate).

(4) FM 21-10 Water Supply in Theaters of Operations. This document provides guidance for the appropriate surgeon in approving field water supplies.

(5) Planning, Organizing, and 0perating an Army Water Supply System in a Theater of Operations. The North Atlantic Treaty Organization (NATO) Armed Forces use this document to set minimum standards for potability of drinking water issued to troops in combat zones or in any other strict emergency.

(6) Standardization of Certain Aspects of Operations and Logistics Agreement 125. The Standardization of Certain Aspects of Operations and Logistics Agreement 125 (SOLOG) is used among the Armies of the US, United Kingdom, Canada, and Australia to set minimum potability standards for a safe emergency water supply for human consumption under field conditions. These standards are included in FM 10-52.

(7) FM 8-250. Preventive Medicine Specialist. This manual serves as a reverence handbook for preventive medicine specialists. It contains material on preventive medicine surveillance and control activities in combat zones, occupied areas, installations, and training situations.

b. **Interpretation of Test Results**. The interpretation of test results against established standards is the responsibility of the medical officer, sanitary engineer, or sanitarian that requests the bacteriological analysis. It will not be made by the laboratory or technician who conducts the analysis. Necessary corrective action where bacteriological tests do not meet established criteria is discussed in Lesson 6, Protection of Water Supplies.

## 3-13. STANDARDS FOR FIXED INSTALLATIONS

a. **Samples**.

(1) The number of water samples to be collected and analyzed monthly from each water supply is governed by the population being served by the system. In accordance with TB MED 576, a minimum of eight samples per month must be obtained from every fixed installation water system. If the population served exceeds 1,000 persons, one additional sample must be collected and analyzed per month for each 1,000 people.

(2) Samples collected will be prorated on a weekly basis at the selected sampling points. As an example, at a small installation, eight sampling points will be selected and a sample taken at each two points per week. Thus, in the course of four weeks, the eight sampling points will be progressively covered. Only samples of water distributed for drinking and culinary purposes should be used in the evaluation of potability. Daily samples collected following an unsatisfactory sample should be considered special samples and should not be included in totaling the number of samples examined monthly.

b. **New Coliform Rule (For Garrison and Field Testing)**.

(1) Based upon 40 CFR Parts 141 and 142 dated 99 June 1989, the--- and effective 31 December 1990, the maximum contamination level goal for coliform colonies is zero. Compliance for the maximum contamination level (MCL) of potable water is based on the presence/absence of total coliforms in the sample, rather than on an estimation of the coliform density.

**NOTE**: The division surgeon in the field and the preventive medicine officer in garrison may want you to also perform colony testing of water.

(2) When a sample test is positive for total coliforms, then within 24 hours, collect at least one repeat sample from the same tap where the original sample was taken; and, automatically test for fecal coliform or E. coli. If fecal coliform is present, the installation's official public relations representative must notify the public of this problem. Repeat testing is to continue until negative result sampling is maintained.

c. **Old Coliform Rule**.

(1) Prior to 31 December 1990, the multiple-filter technique (MFT) standard for the monthly average density of all samples examined was not to exceed one per 100 ml. The number of coliform colonies in an individual sample may exceed this average but must not exceed:

(a) One coliform colony per 100 ml average of all monthly samples, or

(b) Four coliform colonies per 100 ml in more than one sample if less than 20 samples are collected per month, or

(c) Four coliform colonies per 100 ml for than 5 percent of the samples if more than 20 samples are collected per month.

(2) When a single standard sample shows more than four coliform colonies per 100 ml, daily samples from the same sampling point must be collected and examined until the results obtained from at least two consecutive samples show less than one coliform per 100 ml. As an example of the application of these standards, an

installation having a population of 2,000 would require 10 samples per month. Assume the following test results from the test samples (membrane-filter technique):

| Sample No. | Filtration Volume ml | No. Colonies | Colonies per 100 ml | Acceptable |
|---|---|---|---|---|
| 1 | 100 | 0 | 0 | Yes |
| 2 | 100 | 0 | 0 | Yes |
| 3 | 100 | 5 | 5 | No |
| 4 | 100 | 0 | 0 | Yes |
| 5 | 100 | 2 | 0 | Yes |
| 6 | 100 | 0 | 0 | Yes |
| 7 | 100 | 2 | 2 | No |
| 8 | 100 | 0 | 0 | Yes |
| 9 | 100 | 0 | 0 | Yes |
| 10 | 100 | 0 | 0 | Yes |
|  |  |  | Total 7 |  |

$$\text{Monthly average} = \frac{7}{10} = 0.7 \text{ colonies/100 ml}$$

(3) The test results show the water supply meets the criterion of an average monthly coliform density of less than 1 per ml and not more than one sample exceeding 4 colonies per 100 ml (where the total number of samples per month is less than 20). However, since sample number three, above, shows more than four colonies per 100 ml, daily samples must be taken from collection point number three until the results of at least two consecutive samples show less than one coliform per 100 ml.

## 3-14. STANDARDS FOR GARRISON WATER SUPPLIES

a **Samples**. The number and frequency of samples for bacteriological analysis of garrison potable water supplies will be determined by the appropriate federal regulation, local facility engineer, and responsible preventive medicine personnel. The number of troops served, the situation, and local determining factors would be taken into account.

b. **Multiple--tube Technique**. In water testing, the multiple-tube technique has standard samples. Each sample must comprise of five standard portions of 10 ml each). Therefore,:

(a) Coliforms shall not be present in more than 10 percent of the portions per month, or;

(b) Nor more than 1 sample may have 3 or more portions positive when less than 20 samples are collected per month, or;

(c) Nor more than 5 percent of the samples may have 3 or more portions positive when 20 or more samples are collected per month.

## 3-15. STANDARDS FOR SWIMMING POOLS AND NATURAL BATHING AREAS

a. **Samples**. Samples should be collected at least twice weekly at both the deep and shallow end and should include periods of heaviest swimming.

b. **Coliform Densities**.

(1) Swimming pools. In order for swimming pool water to be acceptable, not more than 15 percent of the membrane filters may show more than 1.0 coliform colony per 50 ml. If the multiple-tube technique is used, not more than 15 percent of the samples may show positive (confirmed) tests for coliform organisms in any of the five 10-ml portions of a sample.

(2) Natural bathing areas. Since the sanitary quality of natural bathing waters cannot be controlled, it is not feasible to set an acceptable standard according to coliform density. Instead, natural bathing waters are classified according to their acceptability as shown in Tables 3-1 and 3-2. The decision whether or not to use a natural bathing area is made by the commanding officer based upon the recommendations of the appropriate surgeon.

| Classification | Average MPN/100 ml, or No. of Coliform/l00 ml of sample filtered [1] | Remarks |
|---|---|---|
| A | 0-50 | Preferred, but not generally attainable |
| B | 51-500 | Average degree of contamination for inland streams free to fresh sewage pollution. |
| C | 501-1,000 | Undesirable unless complete sanitary survey proves contamination harmless.<br>May be dangerous if caused by fresh sewage. |
| D | Over 1,000 | No swimming unless complete survey proved contamination harmless. |

[1] When the membrane-filter technique is used.

Table 3-1. Classification of inland (fresh) waters.

| Classification | Average MPN/100 ml, or No. of Coliform/l00 ml of sample filtered [1] | Remarks |
|---|---|---|
| A | 0-23 | Preferred |
| B | 24-240 | Satisfactory |
| C | Over-240 | Unsatisfactory |

[1] When the membrane--filter technique is used.

Table 3-2. Classification of tidal (salt) waters.

***Continue with Exercises***

## EXERCISES: LESSON 3

**INSTRUCTIONS:** Answer the following exercises by marking the lettered response that best answers the exercise, by completing the statement, or by writing the answer in the space provided at the end of the exercise.

After you have completed all the exercises, turn to "Solutions to Exercises" at the end of the lesson and check your answers. For each exercise answered incorrectly, reread the material referenced with the solution.

1. Which of the following are waterborne diseases?

   a. Shigellosis.

   b. Syphilis.

   c. Elephantiasis.

   d. Viral hepatitis.

   e. Typhoid fever.

   f. Amebiasis.

2. Which of the following are coliform organisms?

   a. *Shigella dvsenteriae*.

   b. *Escherichia coli*.

   c. *Salmonella tvphi*.

   d. *Schistosoma japonicum*.

   e. *Aerobacter aerogenes*.

3. Why was the coliform group of bacteria selected as an indicator for pathogenic organisms?

   a. Coliforms are easier to identify than specific pathogens.

   b. Coliforms are pathogenic to man.

   c. Water containing pathogens will almost certainly contain coliforms.

   d. Water containing coliforms will almost certainly contain pathogens.

4. During bacteriological analysis, which reducing agent is added to the sample bottle to neutralize any remaining chlorine residual?. __________________________.

5. Bacteriological samples should not be taken from hot water faucets or faucets that are: ___________.

6. Why are the hood and screw cap removed from the sample bottle and held together? _____________________________________.

7. Water samples for bacteriological analysis should be refrigerated if they wail not be examined within _______ hr.

8. In natural bathing waters, water samples should be collected _______ feet from shore and at least _________ feet deep?.

9. Which of the following are disadvantages of the multiple--tube fermentation technique in conducting bacteriological analysis on water?

   a. Time required.

   b. Accuracy of results.

   c. Reliability of results.

10. In which technique are the coliform bacteria retained on the filter when the water passes through? __________________________________.

11. The preferred method for sterilizing the funnel and filter--support assembly is in an ________________ when using the bacteriological water testing kit.

12. Membrane filters and absorbent pads must be autoclaved for ____ minutes at ______°C.

13. What is the recommended basic filtering volume (BFV) of an average coliform density if the previous tests on a given water source of same shows an average coliform density of 67 colonies per 100 ml? ____________ ml.

14. If three sample volumes (as noted in 13 above) are to be filtered, what should they be? _____, _____, and _____ ml.

15. After filtering, the filter and absorbent pad are incubated for __________ hours at ______°C.

16. If a petri dish contains 36 typical coliform colonies, and the volume of sample filtered was 60 ml, what is the coliform count? ______ per 100 ml.

17. Which of the following test(s) is (are) used to specifically identify the source of water contamination (human or animal origin)?

    a. Multiple-tube fermentation.

    b. Fecal coliform.

    c. Total coliform.

    d. Fecal streptococci.

18. How many water samples are required per month from a water supply system serving a military installation with a population of 6,000 persons? __________

19. What procedure is followed when a sample test is positive for total coliforms?.

    a. No action is required if this is the only sample which exceeds 4 colonies per 100 ml.

    b. No action is required if the average monthly coliform density does not exceed one colony per 100 ml.

    c. Within 24 hours, at least one repeat sample, from the same tap where the original sample was taken, is tested until a negative result sampling is maintained.

    d. No action is required if less than five percent of the samples exceed four colonies per 100 ml.

20. What method is used for total coliform testing instead of estimation of the coliform density?

    a. Presence/Absence method.

    b. Membrane-filter technique.

    c. Multiple-filter technique.

    d. Basic filtering volume technique.

***Check Your Answers on Next Page***

## SOLUTIONS TO EXERCISES, LESSON 3

1. a, d, e (para 3-2a)

2. b, e (para 3-2d)

3. a, c (para 3-2d)

4. sodium thiosulfate (para 3-3a).

5. leaking (para 3-3a(3))

6. to prevent contamination (para 3-3b(5)

7. 1 hour (para 3-3b(9)(b))

8. 25, 2 1/2 (para 3-3c(2))

9. a, b. The multiple-tube method is reliable for detecting coliforms, but the quantitative results are only a statistical approximation. (para 3-4)

10. membrane-filter technique (para 3-5b(1))

11. autoclave (para 3-6b(1) (b))

12. 10, 121 (para 3-6b(2) (a))

13. BFV = $\frac{20}{67.}$ x 100 = 30 ml (para 3-8a(1))

14. 10,30, and 90 ml (para 3-8a(2))

15. 18-22, 35 (para 3-9i)

16. 60 $\frac{36 \text{ colonies} \times 100.}{60 \text{ ml sample}}$= 60 colonies per 100 ml (para 3-10c)

17. b, d (paras 3-11a, b)

18. 14 (8 minimum + 1 per 1,000) (para 3-13a)

19. c (para 3-13b (2))

20. a (para 3-13c) Avg density must not exceed 1 per 100 ml, and not more than 1 sample may exceed 4 per 100 ml

**End of Lesson 3**

## LESSON ASSIGNMENT

**LESSON 4** Physical and Chemical Tests and Standards.

**TEXT ASSIGNMENT** Paragraphs 4-1 through 4-9.

**LESSON OBJECTIVES** After completing this lesson, you should be able to:

4-1. Select the statements that best identify the common chemical and physical constituents in water supplies, their maximum concentrations. and their significance.

4-2. Select the statement that best differentiates between the maximum constituents for field and fixed installation water concentrations.

4-3. Select which best identifies the correct procedures in collecting water samples for chemical analysis.

4-4. Select the appropriate equipment for chemical and physical water tests conducted in the field and the capabilities of each.

**SUGGESTION** After studying the assignment, complete the exercises at the end of this lesson. These exercises will help you to achieve the lesson objectives.

# LESSON 4

# PHYSICAL AND CHEMICAL TESTS AND STANDARDS

## Section I. PHYSICAL AND CHEMICAL STANDARDS

### 4-1. GENERAL

Although the sanitary quality of water (as measured by bacteriological analyses) is usually the governing criterion as to the potability of a water supply, the physical and chemical characteristics must also be considered. A brief discussion of the physical and chemical characteristics of water was included in paragraph 1-7. Some of these characteristics merely alter the aesthetic qualities of the water by imparting an unpleasant odor, taste, or appearance. Other impurities are actually harmful to the consumer when present in excessive quantities. The STANAG 2136 and SOLOG Agreement 125 establish physical and chemical, as well as bacteriological standards for drinking water. In addition, the Environmental Protection Agency (EPA) has established 1975 interim standards that govern when in conflict with other standards.

### 4-2. PHYSICAL CHARACTERISTICS

Turbidity, color, odor, and taste standards are easily attained by properly designed and operated treatment plants and equipment. Supplies used without treatment should also meet these requirements. Although these standards do not directly relate to the safety of the water, they are closely related to consumer acceptance. Experience has shown that many people turn to alternate supplies, which may be less safe, when these characteristics exceed the following levels:

a. Turbidity--1 unit (EPA int std)

b. Color--15 units

c. Threshold odor number--3

d. Taste--Unobjectionable

### 4-3. CHEMICAL SUBSTANCES

a. **Inorganic Chemicals--Primary Standards**. Any substances in excess of those concentrations listed in Table 4-1 constitute grounds for rejection of the water supply

Maximum  Contaminant Levels (MCL) in ppm (mg/l

| **Substance** | |
|---|---|
| Arsenic (As) | 0.05 |
| Barium (Ba) | 1 .0 |
| Cadmium (Cd) | 0.01 |
| Chromium (hexavalent) ($Cr^{16}$) | 0.05 |
| Fluoride (F) | (See Table 4-2) |
| Lead (Pb) | 0.05 |
| Mercury (Hg) | 0.002 |
| Nitrate (as N) | 10.0 |
| Selenium (Se) | 0.01 |
| Silver (Ag) | 0.05 |

Table 4-1. Maximum contaminant levels of inorganic chemicals (Primary Standards) in drinking water.

(1) Arsenic. The widespread use of inorganic insecticides and its presence in animal foods, tobacco, and other sources make it necessary to set a limit on the concentration of arsenic in drinking water. The toxicity of arsenic is well known. The ingestion of as little as 100 mg usually results in severe poisoning. A concentration of 0.01 ppm should not be exceeded if other more suitable water supplies are or can be made available.

(2) Barium. Barium is recognized as a general muscle stimulant, especially the heart muscle. The fatal dose for man is considered to be from 550-600 mg. Concentrations in excess of 1 mg/l are grounds for rejection of a 0water supply because of the seriousness of the toxic effects of barium on the heart, blood vessels, and nerves.

(3) Cadmium. Cadmium is recognized as an element of high toxic potential, but which is (as far as is known) biologically nonessential and nonbeneficial. Until fairly recently, little attention was paid to cadmium. Tests have shown accumulations in soft tissues from drinking water with cadmium concentrations down to and including 0.1 mg/i. Suspicion has been cast on the presence of minute amounts of cadmium in the kidney as responsible for adverse renal arterial changes in humans.

(4) Chromium. The level of chromate ion that can be tolerated over a lifetime without adverse effects on health is unknown. However, hexavalent chromium is known to have carcinogenic (cancer-causing) potential. Chromium is a known carcinogen agent when inhaled. A chromate concentration of 0.05 mg/l has been found toxic to Daphnia magna (a fresh-water crustacean).

(5) Fluoride. Fluoride, in drinking water, will help prevent dental caries in growing children. When the concentration is optimum, no ill effects will result and caries rate will be 60-65 percent below the rates in communities using water supplies with little or no fluoride. On the other hand, excessive amounts of fluoride in water consumed during the period of calcification of the teeth (from several months up to about 16 years of age) produces objectionable fluorosis (mottled teeth). The optimum fluoride concentration for a given community depends on climatic conditions since the amount of water consumed depends on the air temperature. Table 4-2 gives the recommended control limits. Concentrations greater than two times the optimum values in the table are grounds for rejection of the supply. The addition of fluoride (fluoridation) to the water supply is recommended where the concentration is less than the lower control limit. Other effects from excessively high fluoride intake include:

(a) Bone changes when water containing 8-20 mg/l is consumed daily for 20 or more years

(b) Crippling fluorosis when 20 mg or more from all sources is consumed daily for 20 or more years.

(c) Death from a single dose of 2.250-4.500 mg (5-10 g sodium fluoride).

| Annual average maximum daily air temperature[1] (° F) | Recommended control limits-- Fluoride concentration in ppm (mg/l) Lower | Optimum[2] | MCL |
|---|---|---|---|
| 53.7 and below | 1.1 | 1.2 | 2.4 |
| 53.8--58.3 | 1.0 | 1.1 | 2.2 |
| 58.4--63.8 | 0.9 | 1.0 | 2.0 |
| 63.9--70.6 | 0.8 | 0.9 | 1.8 |
| 70.7--79.2 | 0.7 | 0.8 | 1.6 |
| 79.3--90.5 | 0.6 | 0.7 | 1.4 |

[1] Based on temperature data obtained for a minimum of 5 years.
[2] Concentrations greater than 2 times the optimum values shall be grounds for rejection of the supply.

Table 4-2. Recommended fluoride concentration in drinking water.

(6) Lead. Lead taken into the body can be seriously injurious to health, even lethal, if taken in by either brief or prolonged exposure. Prolonged exposure to relatively small quantities may result in serious illness or death. Lead taken into the body in quantities in excess of certain relatively low "normal" limits is a cumulative poison. Poisoning may result from an accumulation of lead absorbed by the body from anyone or all four common sources: food, air (especially air contaminated by

automobile.exhaust), water and tobacco smoke. Since all of the above sources except water are, for the most part, unregulated concentrations of lead greater than 0.05 mg/l in drinking water constitute grounds for rejection of the supply.

(7) Mercury. Mercury is highly toxic to humans. Continued ingestion or large amounts can cause damage to the brain and central nervous system.

(8) Nitrate. Serious and occasionally fatal poisonings in infants have occurred following ingestion of well waters shown to contain nitrate ($NO_3$). Nitrate poisoning appears to be confined to infants during their first few months of life. Adults drinking the same water are not affected, but breast-fed infants of mothers drinking such water maybe poisoned. Cows drinking water containing nitrate may produce milk sufficiently high in nitrate to result in infant poisoning. Waste from chemical fertilizer plants and field fertilization may be sources of pollution.

(9) Selenium. Selenium is known to produce "alkali disease" in cattle. Its effects, like those of arsenic, may be permanent. Recent reports indicate that selenium may increase the incidence of dental caries. Of greater importance in limiting the concentration of selenium is its potential carcinogenicity (tendency to produce cancer).

(10) Silver. The chief effect of silver in the body is cosmetic, which consists of a permanent blue-gray discoloration of the skin, eyes, and mucous membranes. Evidence also indicates that silver, once absorbed, is held indefinitely in the tissues, particularly the skin, without evident loss through normal channels of elimination. It is also believed that certain vegetables, when cooked in water containing.silver, combine chemically with the silver. Thus, a person could possibly ingest the silver from several liters of water by eating such vegetables.

b. **Secondary Standards**. The following chemicals are among those in Table 4-3. These chemicals should not be present in a water supply in excess of the listed concentrations where other, more suitable supplies are available or can be made available.

(1) Chloride. sulfate and dissolved solids. The importance of chloride, sulfate, and dissolved solids as they affect water quality hinges upon their taste, laxative effect, and hardness.

(a) Taste. There is quite a variation between individuals as far as the taste threshold (concentration at which the taste can be detected) and the concentration at which taste becomes objectionable. More than 100 public water supplies in the United States provide water with more than 2,000 ppm total dissolved solids. Although newcomers and casual visitors would find these waters almost intolerable, and although some of the residents use other supplies for drinking, many are able to tolerate, if not enjoy, these highly mineralized waters. The maximum recommended limits in Table 4-3 are just below the median taste threshold obtained from tests.

| Substance | Recommended Secondary MCL |
|---|---|
| Chlorides | 250 mg/ l |
| Color | 15 color units |
| Copper | 1 mg/l |
| Corosivity | Noncorrosive |
| Foaming Agents | 0.5 mg/ l Iron |
| Iron | 0.3 mg/l |
| Manganese | 0.05 mg/l |
| Odor | 3 Threshold Odor Number |
| PH | 6.5 - 8.5 |
| Su l fate | 250 mg/l |
| TDs | 500 mg/l |
| Zinc | 5 mg/l |

Table 4-3. Recommended secondary MCL in drinking water.

(b) Laxative effect. Both sodium sulfate and magnesium sulfate are well known laxatives. Calcium sulfate is much less active in this respect. As with taste, the threshold for laxative effect varies considerably with the individual. Newcomers are commonly affected, but one evidently becomes acclimated in a relatively short time. When water is high in magnesium, a laxative effect occurs at lower sulfate concentrations than when the cation is calcium, potassium, or sodium.

(c) Hardness. Calcium and magnesium salt, both chlorides and sulfates, cause noncarbonate hardness in water. Hardness is undesirable in that it consumes soap, makes water less satisfactory for cooking, and produces scale in boilers and distillation units.

(2) Copper. Copper is an essential and beneficial element in human metabolism. In infants, a deficiency in copper results in nutritional anemia. Small amounts are regarded as nontoxic, but large doses may cause vomiting. Prolonged oral administration may result in liver damage. The recommended limit is based upon the lower taste threshold.

(3) Foaming agents. These synthetic organic chemicals belong to a group of chemicals known as anionic surfactants. These chemicals, whose action is the reduction of surface tension, are the principal ingredients in 75 percent of the common household detergents. Contamination of drinking water supplies with surfactants results from their disposal, as household and industrial wastes, into sources of raw water. They are appearing in supplies from both surface and ground waters. Concentrations as low as 1 mg/l cause frothing and objectionable taste. Concentrations above 0.5 mg/l are considered indicative of questionably, undesirable levels of waste water pollution.

(4) Iron. Iron is a highly objectionable constituent in water for either domestic or industrial use. It imparts a brownish color to laundered goods and appreciably affects the taste of beverages. It also forms crusts in plumbing and piping. The limit established to prevent laundry staining and objectionable taste is only a small fraction of the daily nutritional requirement and, therefore, is unlikely to have any toxicological significance.

(5) Manganese. Manganese, like iron, is an essential nutrient. However, it imparts a brownish color to laundered goods, even in small quantities, and impairs the taste of beverages, including coffee and tea. The primary reason for limiting the concentration of manganese in water is to provide water quality and reduce aesthetic and economic problems.

(6) Zinc. Zinc is an essential and beneficial element in human metabolism. A zinc deficiency in animals results in growth retardation that is overcome by supplying the necessary amount of zinc in the diet. Zinc salts act as gastrointestinal irritants; however, water supplies containing up to 50 mg/l have been used for a protracted period without noticeable harm. Soluble zinc salts impart a milky appearance to water at concentrations of 30 mg/l and a metallic taste at 40 mg/l. In as much as zinc in water does not cause serious effects on health, but produces undesirable aesthetic effects, it is recommended that concentrations of zinc be kept below 5 mg/l.

c. **Other Chemical Substances**. The US Public Health Service recommended the following chemical substances in 1962 as a possible water quality parameter (see Table 4-4).

(1) Carbon chloroform extract. Carbon chloroform extract (CCE) is not, in itself, an identifiable chemical substance. It is an extract obtained by filtering a measured sample of water through a carbon filter, then extracting the organic impurities from the filter with chloroform solvent. This procedure does not detect all organic substances in the water since some compounds are not absorbed by carbon or extractable by chloroform. However, the method is effective for detecting and measuring quantities of simple hydrocarbons, chlorinated pesticides, and many industrial pollutants. The CCE procedure does not ensure against the presence of organic pollutants, but CCE levels above 0.2 ppm indicate that the consumer is receiving an exceptional and unwarranted dosage of ill-defined chemicals. Public water supplies in which CCE concentrations have exceeded the maximum recommended concentrations have invariably received customer complaints because of tastes and/or odors.

(2) Cyanide. A single dose of 50-60 mg of cyanide is considered fatal for humans. A dosage of 19 mg is a threshold dose, which is approximately 100 times the limit established for rejection of the water supply. Since proper treatment will reduce cyanide levels to 0.01 mQ/1 or less, it is recommended that concentrations in water be kept below this level.

|  | FIELD SUPPLIES |  |  |  | FIXED INSTALLATION |  |
|---|---|---|---|---|---|---|
|  | Short term Consumption Standards (up to 7 days) |  | Long Term Consumption Standards (up to 1 year) |  | 1962 OHS Drinking Water Standards | EPA 1975 Interim Primary Drinking Water Standards |
| Constituent | 5 Liters/Day | 15 Liters/Day | 5 Liters/Day | 15 Liters/Day |  |  |
| PHYSICAL: |  |  |  |  |  |  |
| Color | 50 C.U.* | 50 C.U.* | 50 C.U*. | 50 C.U.* | 15 Units | ----- |
| Taste |  |  |  |  | Objectionable | ----- |
| Odor | 3 Threshold Odor No. Ion | 3 Ton | 3 Threshold Odor No. | 3 Ton | 3 | ----- |
| pH | 5-9 | 5-9 | 5-9 | 5-9 |  |  |
| Temperature | 4-35ºC<br>39-95ºF | 4-35ºC<br>39-95ºF | 15-22ºC<br>59-72ºF | 15-22ºC<br>59-72ºF |  |  |
| TDS | 1000 mg/l | 1000 mg/l | 1000 mg/l | 1000 mg/l |  |  |
| Turbidity | 1 NTU | 1 NTU | 1 NTU | 1 NTU | 5 units | 1 unit |
| CHEMICAL: |  |  |  |  |  |  |
| Alkyl benzeme Sulfonate |  |  |  |  | 0.5 mg/l | ------- |
| Arsenic | 0.3 mg/l | 0.1 mg/l | 0.06 mg/l | 0.02 mg/l | 0.05 mg/l | 0.05 mg/l |
| Barium |  | 1.0 mg/l | 1.0 mg/l |  | 1.0 mg/l | 1.0 mg/l |
| Cadmium |  |  |  |  | 0.01 mg/l | 0.01 mg/l |
| Chloride | 600 mg/l | 600 mg/l | 600 mg/l | 600 mg/l | 250 mg/l | ------ |
| Chromium hexavalent |  |  |  |  | 0.05 mg/l | 0.05 mg/l |
| Coliform | 1 per 100 ml | 1 per 100 ml | 1 per 100 ml | 1 per 100 ml | 1.0 mg/l | ------- |
| Copper |  |  |  |  | 1.0 mg/l | -------- |
| Carbon chloroform extract |  |  |  |  | 0.2 mg/l | 0.7 mg/l |
| Cyanide | 6.0 g/l | 2.0 mg/l | 6.0 mg/l | 2.0 mg/l | 0.2 mg/l | -------- |
| Fluoride |  |  |  |  | 0.6 to 1.7 mg/ | **(see table below |
| Iron |  |  |  |  | 0.3 mg/l | --- |
| Lead |  |  |  |  | 0.05 mg/l | 0.05 mg/l |
| Manganese |  |  |  |  | 0.05 mg/l | --- |
| Magnesium | 100 mg/l | 30 mg/l | 100 mg/l | 30 mg/l | 125 mg/l | --- |
| Mercury |  |  |  |  | --------- | 0.002 mg/l |
| Nitrate |  |  |  |  | 45 mg/l (NO3) | 10 mg/l (N) |
| Phenoile |  |  |  |  | 0.001 mg/l |  |
| Selenium |  |  |  |  | 0.01 mg/l | 0.01 mg/ |
| Silver |  |  |  |  | 0.05 mg/l | 0.05 mg/l |
| Sulfate ($SO_4$) | 300 mg/l | 100 mg/l | 300 mg/l | 100 mg/l | 250 mg/l | --- |
| Total dissolved solids | 1000 mg/l | 1000 mg/l | 1000 mg/l | 1000 mg/l | 500 mg/l | --- |
| Zinc |  |  |  |  | 5 mg/l | --- |
| PESTICIDES |  |  |  |  |  |  |
| Endrin |  |  |  |  | -------- | 0.0002 mg/l |
| Lindane |  |  |  |  | -------- | 0.004 mg/l |
| Methoxychlor |  |  |  |  | -------- | 0.1 mg/l |
| Toxephene |  |  |  |  | -------- | 0.005 mg/l |
| 2.4-D |  |  |  |  | -------- | 0.1 mg/l |
| 2.4-TP(Silverx) |  |  |  |  |  | 0.01 mg/l |

| Constituent | Short Term 5 liters/day | Short Term 15 liters/day | Long Term 5 liters/day | Long Term 5 liters/day | 1962 Standards | 1975 Standards |
|---|---|---|---|---|---|---|
| **CW AGENTS** | | | | | | |
| Hydrogen cyanide | 6.0 mg/l | 2.0 mg/l | 6.0 mg/l | 2.0 mg/l | -------- | -------- |
| Lewisite | 0.3 mg/l | 0.1 mg/l | N/A | N/A | -------- | -------- |
| Mustard | | | | | -------- | -------- |
| Nerve agents | 0.02 mg/l | 0.004 mg/l | N/A | N/A | -------- | -------- |
| | | | | 0.05 ICI/1 | -------- | -------- |
| **RADIOLOGY** (Assumes no other source of exposure) | 8.0 microcuries/1 | 3.0 UCI/2 | 8.0 microcuries/1 | | | |
| Gross alpha activity | | | | | -------- | 15 pCi/1 |
| Gross beta activity | | | | | 1000 uuc/1 | -------- |
| Strontium-90 | | | | | 10 uuc/1 | -------- |
| Radium-226 | | | | | 3 uuc/1 | -------- |
| Combined radium-226 and -228 | | | | | -------- | 5 pCi/1 |

* C.U. is the abbreviation for Color Units.

**

EPA 1975 Interim Primary Drinking Water Standards for Fluoride

| Temp (°F) | Level1 (mg//l) |
|---|---|
| 53.7 & below | 2.4 |
| 53.8–58.3 | 2.2 |
| 58.4–63.8 | 2.0 |
| 63.9–70.6 | 1.8 |
| 70.7–79.2 | 1.6 |
| 79.3–90.5 | 1.4 |

**NOTE:** For short-term continuation, 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 I suitable for continuation during occupancy not exceeding the one-week period. Material updated by Unclassified message, HQ DA, SGP S-PSP/DALO-TSE, 281300z 90, subject: Field water Quality Standards - Updated Standards (U)

Table 4-4. Maximum possible concentrations of impurities in treated water.

(3) Phenols. The term "phenols" is understood to include cresols and xylenols. The recommended limit of 0.001 ppm is based on the undesirable taste often resulting from the chlorination of waters containing extremely low concentrations of phenol. Phenol concentrations of 5 ppm or more are injurious to fish, whereas 1 ppm

will not seriously affect most fish. Concentrations up to 5,000 ppm have been consumed in drinking water by rats without ill effects. Thus, concentrations injurious to health are far in excess of those that impart an unpleasant taste.

## 4-4. PESTICIDES AND CHEMICAL WARFARE AGENTS

a. **Pesticides**. Because of the increased use of synthetic organic pesticides over the past 30 years, the EPA has established interim standards for maximum concentrations of pesticides in treated water. Since the available data concerning the effects of pesticides on humans are not complete these standards are constantly under revision. The maximum permissible concentrations are shown in Table 4-4.

b. **Chemical Warfare Agents**. STANAG 2136 and SOLOG Agreement 125 establish maximum permissible concentrations of chemical warfare agents (CW) agents in drinking water consumed under field (combat) conditions. These concentrations are shown in Table 4-4.

## 4-5. RADIOACTIVITY

The effects of radiation on human beings are viewed as harmful, and any unnecessary exposure should be avoided. Major sources of radioactivity in drinking water supplies are Radium-226, found only in certain ground waters or in industrial wastes containing radium; and Strontium-90, a constituent of delayed fallout from nuclear weapons.

a. **Physiological Effects of Radioisotopes**. Radioactive substances (radioisotopes) emit gamma rays, alpha particles, beta particles, or combinations thereof. Radium-226 is an alpha emitter, whereas Strontium-90 is a beta emitter. Both alpha and beta emitting material may be deposited as residual radiation in drinking water. Alpha emitters are particularly hazardous when taken internally, because of their deposition of energy in very small volumes of tissue and in specific organs. Beta particles are also very hazardous when taken internally; they, too, are absorbed by the body tissues. Generally speaking, however, the body is able to tolerate a slightly greater quantity of beta emitters than of alpha emitters, because the beta emitter deposits its energy over a greater tissue volume. An exception is the beta radiation from Strontium-90. This radioisotope is much more hazardous than other beta emitters, in that Strontium-90 is readily deposited in newly forming bone.

b. **Radiation Limits**.

(1) Water supplies are approved without further consideration of Radium-226 and Strontium-90 radioactivity intake from other sources when the water contains not more than:

(a) Radium-226: three uuc/l (micromicrocuries per liter).

(b) Strontium-90: ten uuc/i.

(2) When the above concentrations are exceeded. the water supply may be approved by the appropriate surgeon when a radiological survey shows that the intake from all sources (primarily food and water) does not exceed:

(a) Radium--226: 20 uuc/day.

(b) Strontium--90: 200 uuc/day.

(3) In the known absence of Strontium-90 and alpha emitters, the water supply is acceptable when the gross beta concentrations do not exceed 1,000 uuc/i. Gross beta concentrations in excess of 1,000 uuc/l are grounds for rejection of the supply except where a complete analysis indicates that the exposures in (2), above, will not be exceeded.

## 4-6. FIELD WATER SUPPLY STANDARDS

Physical and chemical standards for field water supplies fall into three categories:

a. **Emergency, Short-Term Consumption**. These standards, agreed to in both STANAG 2136 and SOLOG Agreement 125, are mandatory for all NATO forces under combat or similar conditions for a period not to exceed 7 days (see Table 4-4).

b. **Emergency, Long-Term Consumption**. These standards, agreed upon in SOLOG 125, are preferable in water for consumption by troops under combat or similar conditions for periods in excess of 7 days (see Table 4-4).

c. **Routine Consumption**. For rear areas, fixed installations, and other situations, which may be clearly distinguished from combat conditions or similar emergency, the concentrations of chemical substances in military water supplies should not exceed the values shown for fixed installations in Table 4-4. If local conditions or short term requirements necessitate the use of water containing higher chemical concentrations, the commander concerned should authorize such use only upon the recommendation of his surgeon.

## Section II. PHYSICAL AND CHEMICAL TESTS

## 4-7. GENERAL

The preventive medicine specialist must be able to properly collect water samples for chemical analysis, properly complete DD Form 710 (Physical and Chemical Analysis of Water), and properly measure the pH and chlorine residual of a water sample. In addition, depending upon the type of unit to which he is assigned and the type of equipment available, he may be required to conduct tests for poisons and other impurities in water. Most detailed analyses of drinking water are conducted by the

United States (US) Army Environmental Hygiene Agency for water quality control within the continental United States (CONUS), whereas Army laboratories (TOE) and preventive medicine organizations perform this service overseas. Responsibility for the interpretation of analyses is neither that of the preventive medicine specialist nor of the laboratory. The interpretation is made by the surgeon, preventive medicine officer, sanitary engineer, or environmental science officer who requests the chemical analysis.

## 4-8. COLLECTION OF SAMPLES.

a. **General**. Samples should be collected in chemically clean, glass-stoppered bottles of at least two-liter capacity. Protective cloth hoods should be provided over the tops of the bottles. Bacteriological water sample bottles will not be used for this purpose.

b. **Procedure**.

(1) Choose a sampling point that will provide the information desired. For example, if the chemical nature of a ground water is desired, the sample should be collected at the source or as near to it as possible.

(2) Flush the system by opening the sampling faucet and allowing the water to run until it is reasonably certain that the sample is representative.

(3) Remove the protective cover and stopper from the bottle. Rinse the bottle with the water being sampled and then fill the bottle to within one-half inch of the bottom of the neck.

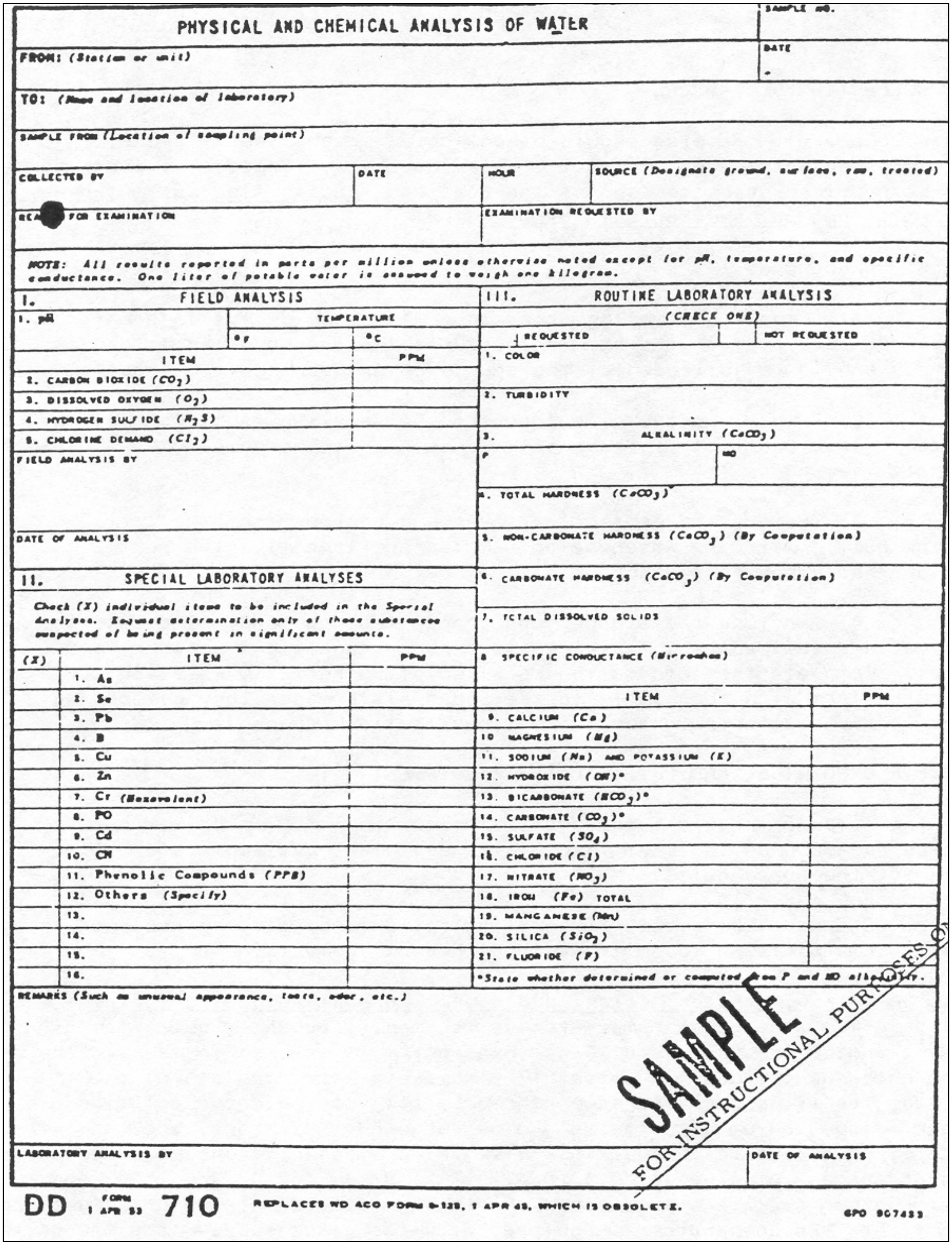
(4) Replace the stopper and the protective hood. Indicate the determinations desired, such as hardness, iron, manganese fluorides, and sulfates. Complete the information required of DD Form 710 (see figure 4-1) and forwards the form with the sample to the appropriate laboratory immediately. DD Form 710 is available through normal publications channels.

## 4-9. FIELD CHEMICAL AND PHYSICAL TEST EQUIPMENT

The scope of physical and chemical tests on water that may be conducted by AMEDD units is limited by the equipment available and the training of the personnel.

a. **Standard Equipment**. The following items of testing equipment are standard items of issue found in various preventive medicine units:

(1) Comparator. color. hydrogen ion and residual chlorine, (see figure 4-2). The color comparator is the most frequently used item of equipment in the preventive medicine inventory. It is used to measure the pH and the chlorine residual in water. The complete item consists of the comparator itself, a carrying case, three bottles of indicator solution (orthotolidine, sodium arsenite, and wide range pH indicator), and two



PHYSICAL AND CHEMICAL ANALYSIS OF WATER

SAMPLE NO.

DATE

FROM: (Station or unit)

TO: (Name and location of laboratory)

SAMPLE FROM (Location of sampling point)

| | | | |
|---|---|---|---|
| COLLECTED BY | DATE | HOUR | SOURCE (Designate ground, surface, raw, treated) |

REA[illegible] FOR EXAMINATION

EXAMINATION REQUESTED BY

NOTE: All results reported in parts per million unless otherwise noted except for pH, temperature, and specific conductance. One liter of potable water is assumed to weigh one kilogram.

I. FIELD ANALYSIS

| | | |
|---|---|---|
| 1. pH | TEMPERATURE | |
| | °F | °C |

| ITEM | PPM |
|---|---|
| 2. CARBON DIOXIDE ($CO_2$) | |
| 3. DISSOLVED OXYGEN ($O_2$) | |
| 4. HYDROGEN SULFIDE ($H_2S$) | |
| 5. CHLORINE DEMAND ($Cl_2$) | |

FIELD ANALYSIS BY

DATE OF ANALYSIS

II. SPECIAL LABORATORY ANALYSES

Check (X) individual items to be included in the Special Analyses. Request determination only of those substances suspected of being present in significant amounts.

| (X) | ITEM | PPM |
|---|---|---|
| | 1. As | |
| | 2. Se | |
| | 3. Pb | |
| | 4. B | |
| | 5. Cu | |
| | 6. Zn | |
| | 7. Cr (Hexavalent) | |
| | 8. PO | |
| | 9. Cd | |
| | 10. CN | |
| | 11. Phenolic Compounds (PPB) | |
| | 12. Others (Specify) | |
| | 13. | |
| | 14. | |
| | 15. | |
| | 16. | |

III. ROUTINE LABORATORY ANALYSIS

(CHECK ONE)

| | |
|---|---|
| ☐ REQUESTED | ☐ NOT REQUESTED |

1. COLOR

2. TURBIDITY

3. ALKALINITY ($CaCO_3$)

| | |
|---|---|
| P | MO |

4. TOTAL HARDNESS ($CaCO_3$)

5. NON-CARBONATE HARDNESS ($CaCO_3$) (By Computation)

6. CARBONATE HARDNESS ($CaCO_3$) (By Computation)

7. TOTAL DISSOLVED SOLIDS

8 SPECIFIC CONDUCTANCE (Micromhos)

| ITEM | PPM |
|---|---|
| 9. CALCIUM (Ca) | |
| 10 MAGNESIUM (Mg) | |
| 11. SODIUM (Na) AND POTASSIUM (K) | |
| 12. HYDROXIDE (OH)* | |
| 13. BICARBONATE ($HCO_3$)* | |
| 14. CARBONATE ($CO_3$)* | |
| 15. SULFATE ($SO_4$) | |
| 16. CHLORIDE (Cl) | |
| 17. NITRATE ($NO_3$) | |
| 18. IRON (Fe) TOTAL | |
| 19. MANGANESE (Mn) | |
| 20. SILICA ($SiO_2$) | |
| 21. FLUORIDE (F) | |

*State whether determined or computed from P and MO alkalinity.

REMARKS (Such as unusual appearance, taste, odor, etc.)

SAMPLE

FOR INSTRUCTIONAL PURPOSES O

| | |
|---|---|
| LABORATORY ANALYSIS BY | DATE OF ANALYSIS |

DD FORM 1 APR 53 710 REPLACES WD AGO FORM 8-133, 1 APR 45, WHICH IS OBSOLETE.

GPO 907433

Figure 4-1. DD Form 710, Physical and Chemical Analysis of Water.

removable, plastic color disks. One disk is for measuring chlorine residual and is graduated in values of 0.1, 0.4, 0.7, 1.0, 1.5, 2.0, 3.0, 5.0, and 10.0 ppm. The other disk is a wide range pH disk, graduated in even pH values from 3.0 to 11.0. The comparator is equipped with two glass tubes: the one right (outside) is referred to as the blank, which reflects the natural color of the water; the one on the left (inside) is referred to as the indicator. The difference in color between the blank and the indicator is compared, by means of a prism inside the comparator, to a like color on the appropriate color disk. When the colors match, the reading is made directly from the disk.

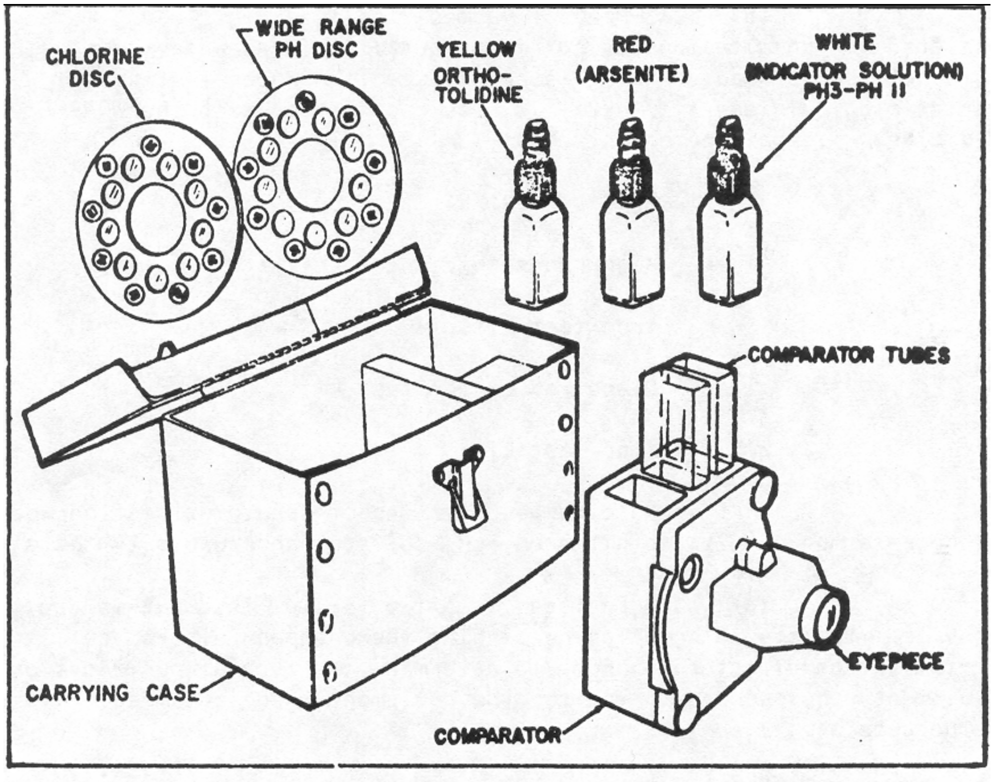


Figure 4-2. Color comparator with case.

(2) Water Quality Analysis or Control Sets. These are referred to in this subcourse as Water Quality Analysis or Control Sets Water Quality Analysis or Control Sets (WQAS or WQCS).

(a) General. The WQAS are authorized under current TOE for the division medical battalion, medical companies medical support battalion, medical teams LB (environmental sanitation) and LC (environmental engineering service), and all engineer units equipped with water purification equipment. The sets are designed for use as field sampling and testing equipment by personnel with a minimum of chemical training. The WQAS are entirely contained in a fiberglass case 16 inches high, 22 inches wide and 22 inches deep. The interior of the cases is lined with foamed plastic inserts to protect the equipment and supplies and to keep them in an upright position. The WQAS are proportioned in order to weigh less than 65 pounds each and to be carried by one man. The instruction manual issued with the sets provides detailed instructions, which enables the operator, with very little practice, to conduct the tests.

Figure 4-3. Water quality analysis set-preventive medicine.

(b) Water Quality Analysis or Control Sets--Preventive Medicine (see figure 4-3). This set is designed for on-site monitoring of the quality of-raw water sources, waste water effluents, and drinking water produced. A water testing kit, bacteriological (see figure 4-2), is required for use with the WQAS-Preventive Medicine. Its main components are:

<u>1</u> Acidity test kit.

<u>2</u> High-range chloride test kit.

<u>3</u> Iron test kit.

<u>4</u> Dissolved oxygen test kit.

<u>5</u> Zinc test kit.

<u>6</u> Multipurpose test spectrophotometic (fluoride, iron, nitrogen ammonia, nitrate nitrogen, pH, sulfate, and turbidity tests).

(c) Water Quality Analysis or Control Sets--Engineer (see figure 4-4). This set is designed to provide immediate information concerning the presence of chemical contamination of water in order to determine the type of purification equipment required and to monitor the equipment when installed. Its main components are:

1 Turbidity test kit.

2 Low-range chloride test kit.

3 Sulfate test kit.

4 Hardness test kit.

5 Alkalinity test kit.

6 Color test kit.

7 pH and residual chlorine test kit.

8 Conductivity meter.

9 Chemical agents kit--AN-M2.

10 Refill kit, chemical detector, VG, ABC--M30.

11 Coagulation test assembly.

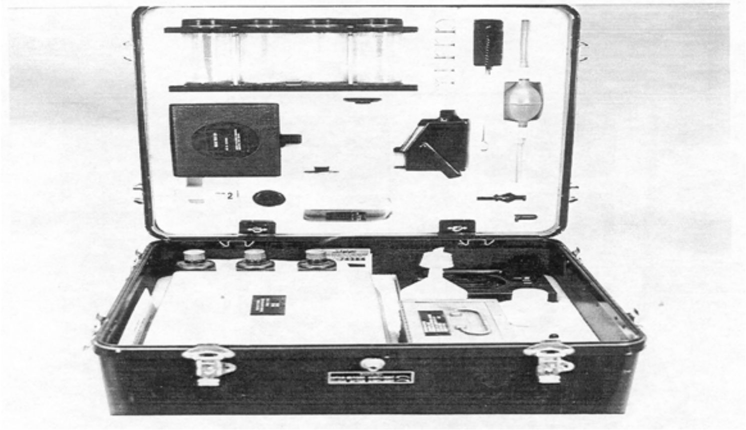


Figure 4-4. Water quality analysis set-engineer.

(3) Water Testing Kit. Chemical Agents, AN-M272 (see figures 4-5 A, B, and C). This kit is a "cookbook" type item, specifically designed for the detection and identification of harmful amounts of CW agents in raw or treated water. Instructions for its use are contained in TM 3-6665-319-10, Water Testing Kit. Chemical Agents: M272. The results of the test are strictly qualitative (tell only what is present; not how much), and in the case of pH, tell only whether the pH is above or below six.

The AN-M2 kit has the following capabilities and features:

(a) Detect these chemicals in dangerous amounts:

| CW Agent<br>Name | <br>Symbol | Amount<br>(mg/l) | Remarks |
|---|---|---|---|
| Cyanide | AC | 20.0` | as CN |
| Mustard | HD | 2.0 | -- |
| Lewisite | L | 2.0 | as As |
| Nerve | G/B | 0.02 | -- |

**NOTE**: Water containing CW agents in less than these concentrations is permissible for short durations of no more than 7 days and no more than five quarts of water per person per day.

(b) Test colors show good or bad water (pass/fail).

(c) As little as 20 minutes are needed to test the water, depending upon ambient weather conditions.

(d) Supplies are sufficient to run 25 tests for each agent from one full kit.

(e) Simulant CW agents are included in the kit to practice on for training purposes.

(f) Kit material is disposable. No refilis or repairs are required.

(g) The overall carrying case approximate measurements are:

| | |
|---|---|
| Length | 9.88 inches |
| Width | 6.25 inches |
| Height | 2.75 inches |
| Volume | 170 cubic inches |
| Weight | 2.4 pounds |

**NOTE**: The AN-M2 kit will be phased out and replaced by the AN-M272 kit.

(4) Refill Kit, Chemical Agent Detector, ABC/M30A. The M30A1 chemical agent detector refill kit is used to detect the presence of G and V agents (nerve agents) by enzymatic methods in concentration s as low as 0.02 ppm. Like the AN-M2 kit, it is a component of the water quality control set.

b. **Nonstandard Equipment**. The water chemistry kit shown in figure 4-6 is a commercial, nonstandard item of equipment which is sometimes purchased by " preventive medicine units or activities and by regional divisions of the US Army Environmental Hygiene Agency to enhance their water testing capabilities. The manufacturer of an item of this type normally publishes a detailed instruction manual that accompanies the kit and gives step-by-step instructions on the conduct of the tests and maintenance of the equipment. The kit illustrated in figure 4-6 uses two principal

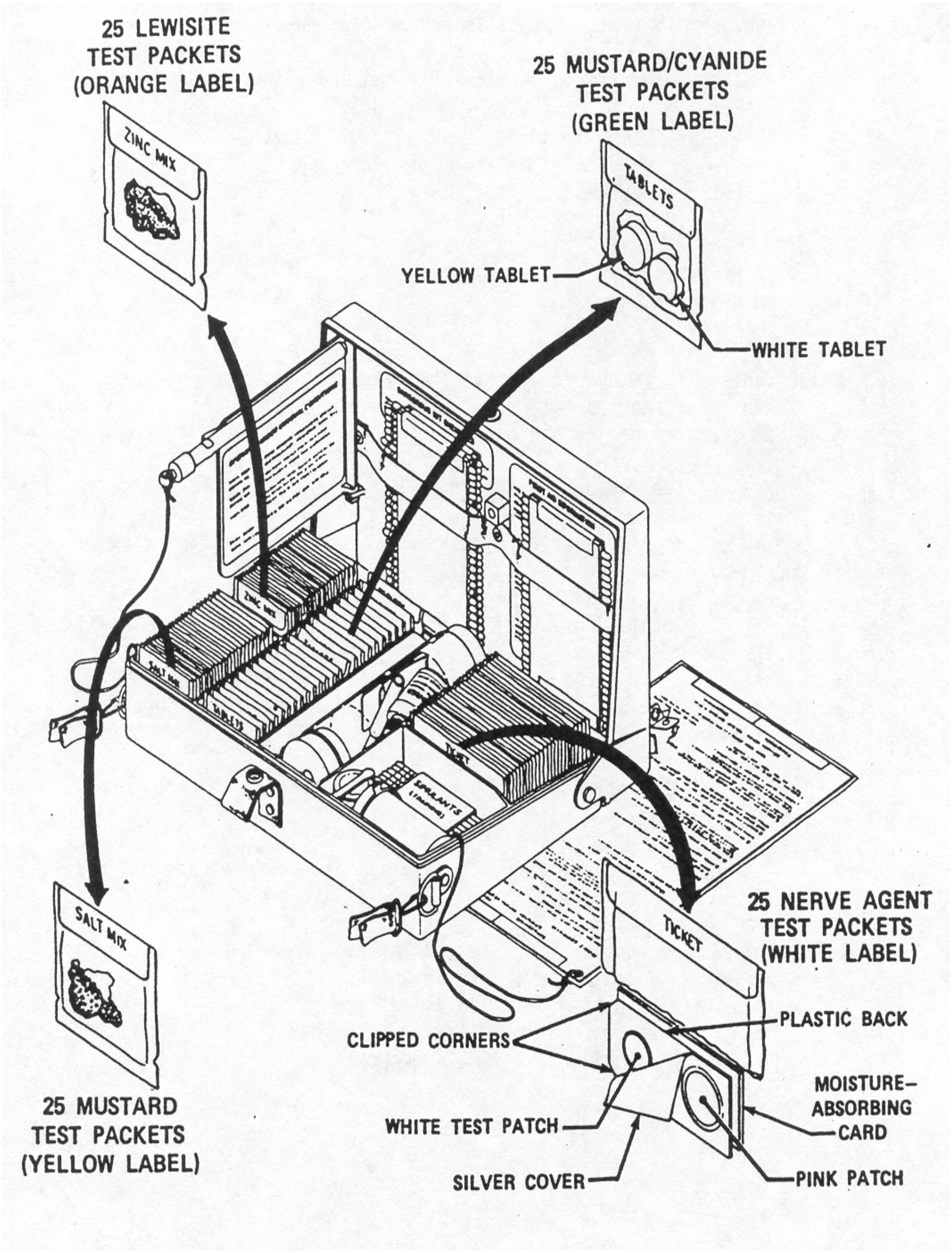


Figure 4-5A. Water testing kit, chemical agent AN-M272.

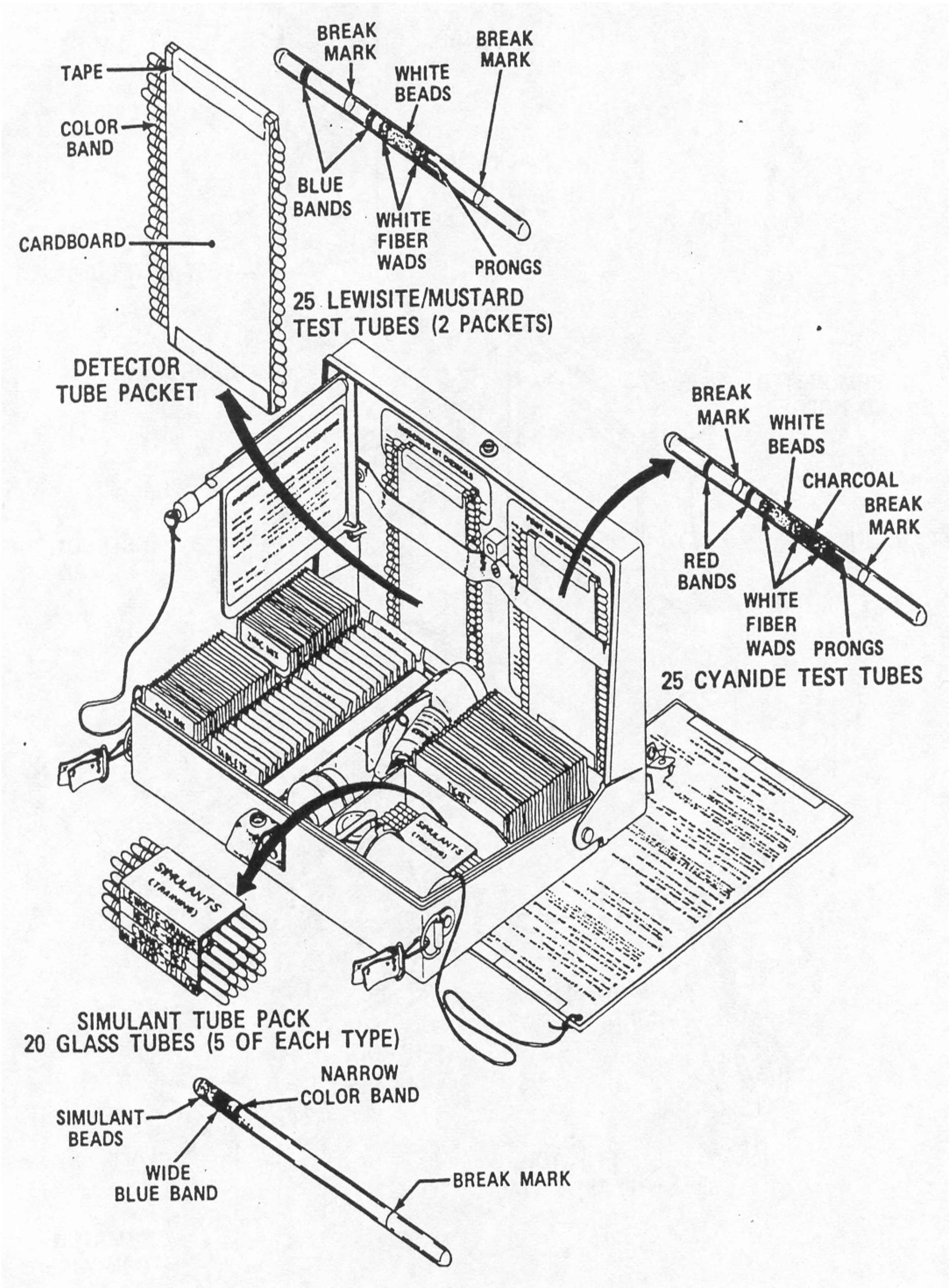


Figure 4-5B. Water testing kit, chemical agent AN-M272.

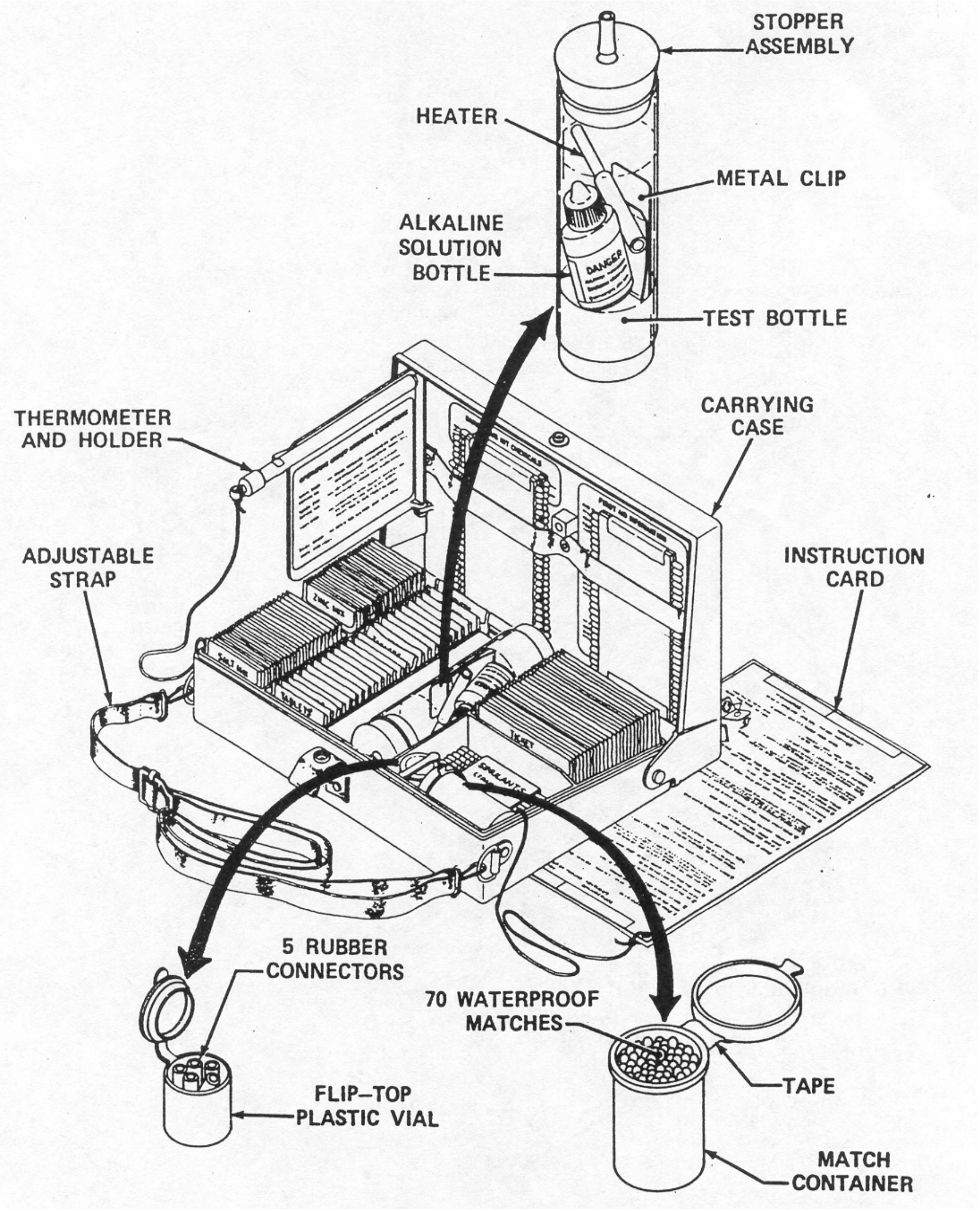


Figure 4-5C. Water testing kit, chemical agent AN-M272.

methods of analysis: colorimetric, in which a designated reagent is added to the water sample which is then placed in a general-purpose colorimeter; and titration, whereby an indicator reagent is added to the water sample and a measured amount of another reagent is added until the desired reaction occurs (usually a change in color). The general-purpose colorimeter includes a set of scales printed on cards--one for each test that can be made. Prior to conducting a test, the proper card is selected and inserted into the colorimeter. The instrument is then calibrated by adjusting the indicator needle so that it coincides with the zero on the scale being used. This kit is capable of performing the following tests:

- Alkalinity
- Carbon dioxide
- Chloride Oxygen
- Chromate
- Copper
- Fluoride
- Hardness
- Hydrogen sulfide
- Manganese
- Nitrate-nitrogen
- Chlorine pH
- Orthophosphate
- Metaphosphate
- Silica
- Sulfate
- Turbidity Iron

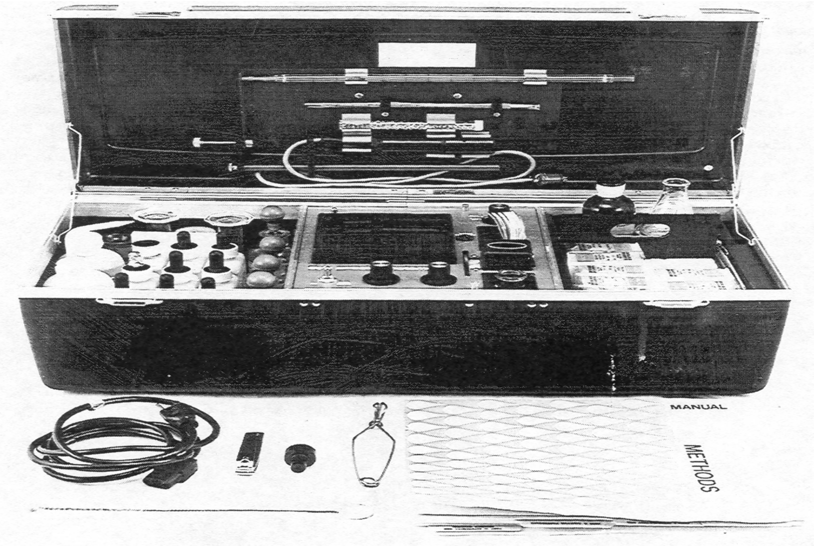


Figure 4-6. Water chemistry kit.

***Continue with Exercises***

**EXERCISES: LESSON 4.**

**INSTRUCTIONS**: Answer the following exercises by marking the lettered response that best answers the exercise, by completing the incomplete statement, or by writing the answer in the space provided at the end of the exercise.

After you have completed all the exercises, turn to "Solutions to Exercises" at the end of the lesson and check your answers. For each exercise answered incorrectly, reread the material referenced with the solution.

1. List the four physical characteristic standards for turbidity, color, odor, and taste and state whether or not they are closely related to consumer acceptance.

    ______________________________________________________________

    ______________________________________________________________

    ______________________________________________________________

    ______________________________________________________________

2. Which of the following chemical concentrations constitutes grounds for:

    a. 0.1 mg/l lead.

    b. 230 mg/l sulfate.

    c. 0.04 mg/l arsenic.

    d. 8.6 mg/l nitrate.

3. Which chemical concentration is in excess of the allowable secondary standard and would render a water supply undesirable?

    a. 240 mg/l sulfate.

    b. 230 mg/l chloride.

    c. 0.009 mg/l arsenic.

    d. 550 mg/l total dissolved solids.

4. In what way would the concentrations in 3, above, affect the quality of the water? They could or would:

   a. Cause diarrhea.

   b. Cause frothing.

   c. Affect the taste.

   d. Cause liver damage.

   e. Cause poisoning in breast-fed babies.

5. Although all radioactivity in drinking water is detrimental to health, the body is able to tolerate a slightly greater quantity of ______________________ emitters than of _________ emitters.

6. Which beta concentration in excess of 1,000 uuc/l is grounds for rejection of the water supply unless complete analysis dictates that exposure would not be exceeded? ________________________________.

7. Under which of the following conditions would a concentration of 6.0 mg/l of cyanide and 30 mg/l of magnesium be acceptable in drinking water?

   a. Garrison (CONUS).

   b. Long-term field conditions.

   c. Short-term field conditions.

   d. Fixed installations overseas.

8. Bottles used for collecting water samples for chemical analysis should meet which of the following requirements?

   a. Sterile.

   b. Chemically clean.

   c. At least 2-liters in capacity.

   d. Of dark glass to exclude light.

   e. Hooded to prevent contamination.

   f. Contain 0.02-0.05 g sodium thiosulfate.

9. Which form is used to annotate and accompany samples for chemical analysis?

   ____________________________.

10. Which of the following readings can be made using the standard color comparator?

   a. pH 1.0.

   b. pH 3.0.

   c. pH 6.5.

   d. pH 7.2.

   e. pH 8.0.

   f. 0.1 ppm Cl.

   g. 1.0 ppm Cl.

   h. 2.5 ppm Cl.

   i. 5.0 ppm Cl.

   j. 7.0 ppm Cl.

11. Using standard chemical and physical test equipment, the comparator's two glass tubes are referred as to the ___________and _______________.

12. Which glass tube reflects the natural color of the water? __________.

13. The difference in color between the ___________ and the __________________ is compared by means of a _____________.inside the comparator.

14. Water quality analysis sets are authorized for TOE:

    a. CONUS-wide.

    b. Company aid station.

    c. MAST general hospitals.

    d. Division medical battalion.

15. The WQAS-preventive medicine unit main components are:

    a. Acidity test kit.

    b. Conductivity meter.

    c. Turbidity test kit.

    d. Dissolved oxygen test kit.

16. What is the WQAS-Engineer designed to provide?

    a. Monitor the installed equipment.

    b. Notification as to the radioisotopes that are present.

    c. Information as to the type of purification equipment required.

    d. Immediate information about the presence of chemical contamination of water.

17. Which of the following things will the chemical agent water testing kit, AN-M272, do?

a. Detect the presence of radium 238 in raw water.

b. Detect the presence of calcium chloride in treated water.

c. Detect the presence of mustard in a sample of raw or treated water.

d. Determine the amount of nitrogen mustard (in ppm) present in raw water.

18. The AN-M272 testing kit can do four tests in ______ minutes.

19. In the collection of samples, after the bottle is rinsed it is filled to within ____________________________________________________________.

20. When collecting samples, what determinations could be indicated?

a. Iron, fluorides, cyanide, calcium, and nerve.

b. Fluorides, hardness, manganese, and sulfates."

c. Manganese, sulfates, hardness, and lewisites.

d. Hardness, carbonates, nerve agents, and manganese.

***Check Your Answers on Next Page***

## SOLUTIONS TO EXERCISES, LESSON 4

1. Turbidity
   Color
   Taste
   Odor
   Yes (para 4-2)

2. a (para 4-3a(6); tables 4-1, 4-2, 4-3)

3. d (para 4-3a(1), table 4-3)

4. a, c. (para 4-3b(1))

5. Strontium-90; betta. (para 4-5a)

6. gross beta concentration. (para 4-5b(3))

7. c (table 4-4)

8. b, c, e. (para 4-8a)

9. DD Form 710. (para 4-8b(4))

10. b, e, f, g, i. (para 4-9a(1))

11. blank; indicator. (para 4-9a(1))

12. blank. (para 4-9a(1))

13. blank ,indicator; prism. (para 4-9a(1))

14. d (para 4-9a(2))

15. a, d (para 4-9a(2)(b))

16. a, c, d (para 4-9a(2)(c))

17. d (para 4-9a(3))

18. 20 (para 4-9a(3)(c)).

19. one-half inch of the bottom of the neck of the bottle. (para 4-8b(3)).

20. c (para 4-8b(4))

**End of Lesson 4**

## LESSON ASSIGNMENT

**LESSON 5** Field Water Treatment.

**TEXT ASSIGNMENT** Paragraphs 5-1 through 5-12.

**LESSON OBJECTIVES** After completing this lesson, you should be able to:

5-1. Correctly measure the flow of a given water source.

5-2. Select the statement that correctly describes the procedures to operate field water purification equipment.

5-3. Select the correct amount of chemicals needed in a given situation to purify field water.

5-4. Select the statement that differentiates between erdlator and ROWPR units.

5-5. Select the best definition for reverse osmosis.

5-6. Identify the four chemical input pumps for reverse osmosis.

**SUGGESTION** After completing the assignment, complete the exercises at the end of the lesson. These exercises will help you to achieve the lesson objectives.

# LESSON 5

# FIELD WATER TREATMENT

## 5-1. GENERAL

The production of potable water for troop consumption is clearly a responsibility of the Quartermaster Corps. This responsibility includes water reconnaissance, development of water sources, treatment and distribution of potable water, quality control testing, and coordinating with Army Medical Department (AMEDD) agencies or units on inspection and testing procedures. The AMEDD is responsible for inspecting water points and facilities, conducting necessary tests, and making recommendations on water sources, treatment, and disposal of by-products of treatment. While the preventive medicine specialist need not be a trained and qualified operator of water purification equipment, he must have sufficient familiarity with the equipment and its operation to enable him to inspect a water point and evaluate its operation. The concepts discussed in this lesson should be considered from the standpoint of an environmental health specialist conducting an inspection of an engineer water point.

## 5-2. DETERMINING WATER SOURCE ADEQUACY

One of the basic requirements of a water source is that the quantity be sufficient to meet the needs of the troops that must be supplied from the source. Several methods are available to the environmental health specialist for estimating the quantity of water from a given source.

a. **Impounded Waters**. Where the water source is an impounded body of water such as a lake, pond, or a reservoir, the volume of water contained may be roughly approximated by multiplying the surface area (in square feet) by the average depth in feet. (**Note**: If the surface area is given in acres, multiply the number of acres by 43,560 to convert to square feet.). The result, expressed in cubic feet, may be multiplied by 7.48 (1 cubic foot = 7.48 gallons) to obtain the volume or capacity in gallons. More accurate means of measurement are available; however, they require a more detailed knowledge of the contours of the reservoir below the water level and are beyond the scope of this subcourse (and beyond the preventive medicine specialist's responsibility). For very small bodies of water, it may be more practical to determine the rate of flow at the outlet as described in subparagraph c, below.

b. **Ground Waters**. If a water source is a well with a pump, or a spring which has been dammed or prepared as in figure 5-1, the flow can be measured as it leaves the discharge pipe provided the pipe is horizontal, flowing full, and without contractions and/or enlargements. The flow in such a pipe may be determined by a formula (see figure 5-2); or by tables (see Table 5-1) when the vertical distance remains constant.

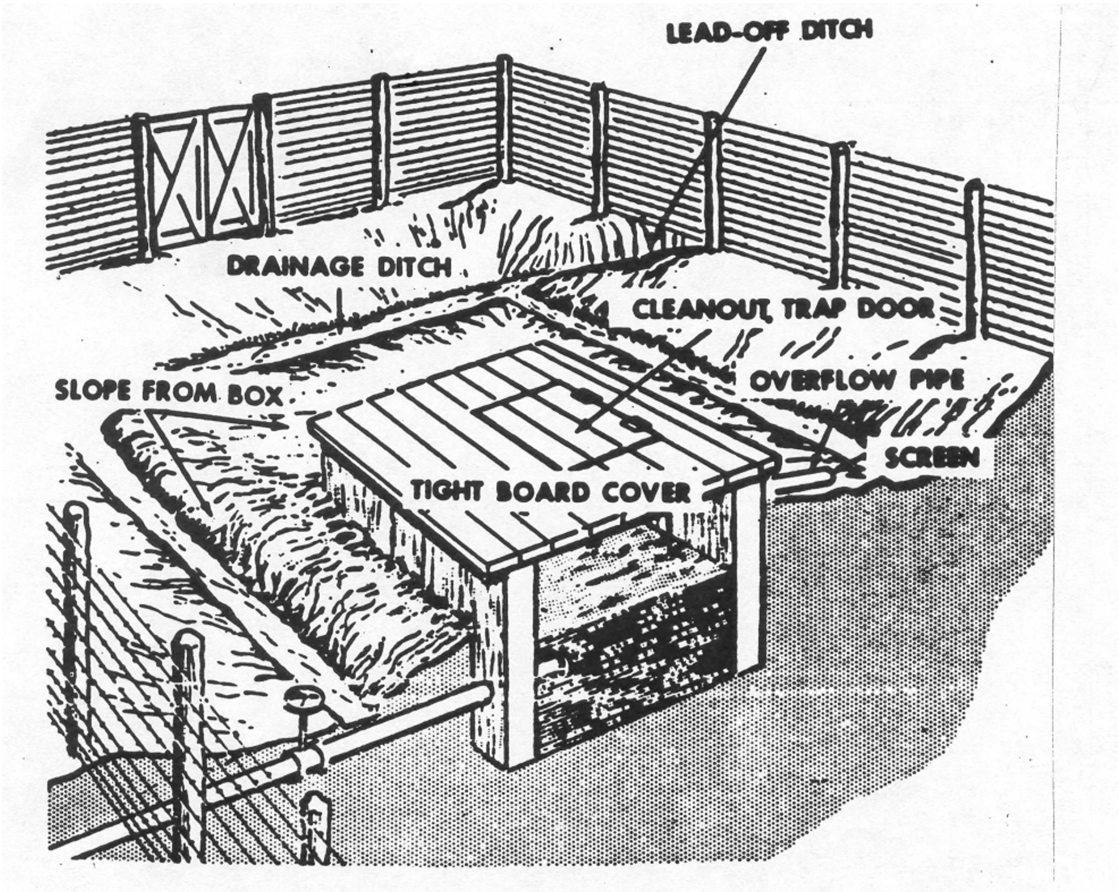


Figure 5-1. Spring inlet.

**Note. Jet must be full-flowing + contraction or Enlargement.**

**Flow in gpm =** $\mathbf{\dfrac{2.83\,D^2\,X}{\sqrt{Y}}}$

**D = Inside diameter of pipe**
**X = Horizontal distance in inches**
**Y = Vertical distance in inches**

**Example, using formula:**

**Given: A 3-inch diameter standard pipe (D) = 3.07”) held 16 inches from ground (X – 28”) 16” X determined by measurement (X = 28”).**

$$\frac{2.83 \times 3.07^2 \times 28}{\sqrt{16}} = \frac{2.83 \times 9.4 \times 28}{4} = 187 \text{ gpm}$$

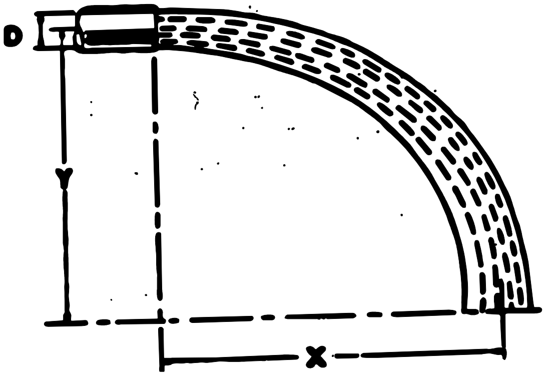


Figure 5-2. Flow of water through horizontal pipe.

**GPM FOR Y=12" AND VARIOUS VALUES OF X**

| Distance X= | 8" | 10" | 12" | 14" | 16" | 18" | 20" | 22" | 24" | 26" |
|---|---|---|---|---|---|---|---|---|---|---|
| D = I.61" | | | | | | | | | | |
| 1 1/2" Std pipe | 17 | 21 | 25 | 30 | 34 | 38 | 42 | 47 | 51 | 55 |
| D = 2.07" | | | | | | | | | | |
| 2" Std pipe | 28 | 35 | 42 | 49 | 56 | 63 | 70 | 77 | 84 | 91 |
| D = 4.03" | | | | | | | | | | |
| 4" Std pipe | 106 | 132 | 159 | 185 | 212 | 238 | 264 | 291 | 318 | 344 |

| Distance X = | 28" | 30" | 32" | 34" | 36" | 38" | 40" | 42" | 44" | 46" | 48" |
|---|---|---|---|---|---|---|---|---|---|---|---|
| D=I .61" | | | | | | | | | | | |
| 1 1/2" Std pipe | 59 | 64 | 68 | 72 | 76 | 80 | 85 | 89 | 93 | 97 | 102 |
| D = 2.07" | | | | | | | | | | | |
| 2" Std pipe | 98 | 105 | 112 | 119 | 126 | 133 | 140 | 147 | 154 | 160 | 167 |
| D = 4.03" " | | | | | | | | | | | |
| 4" Std pipe | 371 | 397 | 424 | 450 | 477 | 503 | 530 | 530 | 556 | 583 | 609 |

Table 5-1. Discharge of water from full-flowing horizontal pipes.

c. **Streams**. Several methods are available to the preventive medicine specialist for measuring the flow of a moving stream--a very common source of field water supplies. Two methods will be discussed here--the v-notch weir and the floating stick.

(1) <u>V-notch weir</u>. A weir is a baffle made of wood or metal, which is constructed across a waterway in the same manner as a dam, for raising the water level or in order to retard, divert, or measure the flow. A weir used to measure the flow has

an opening at the top through which the water flows in such a manner that the head (vertical height of the water surface above the opening) can be measured. The openings in a weir may be of many shapes--rectangular, parabolic, trapezoidal, v-notch, and various combinations of these shapes. One of the easiest to construct and most versatile weirs is the 900 v-notch weir. This type of weir yields accurate measurements of flow in the range from about 25 to 2,000 gallons per minute. For flows less than 50 gallons per minute, the 60 ° v-notch weir is more accurate. For flows greater than 500 gallons per minute, the rectangular weir is more accurate. Figure 5-3 illustrates the principle of the 90° v-notch weir. The notch should be beveled--preferably with a metal strip--toward the direction of the flow, so that the water crests over a sharp edge. The notch is cut at a right angle (90°) with the vertical axis bisecting the angle as shown in the figure. For optimum accuracy, the following dimensions are critical:

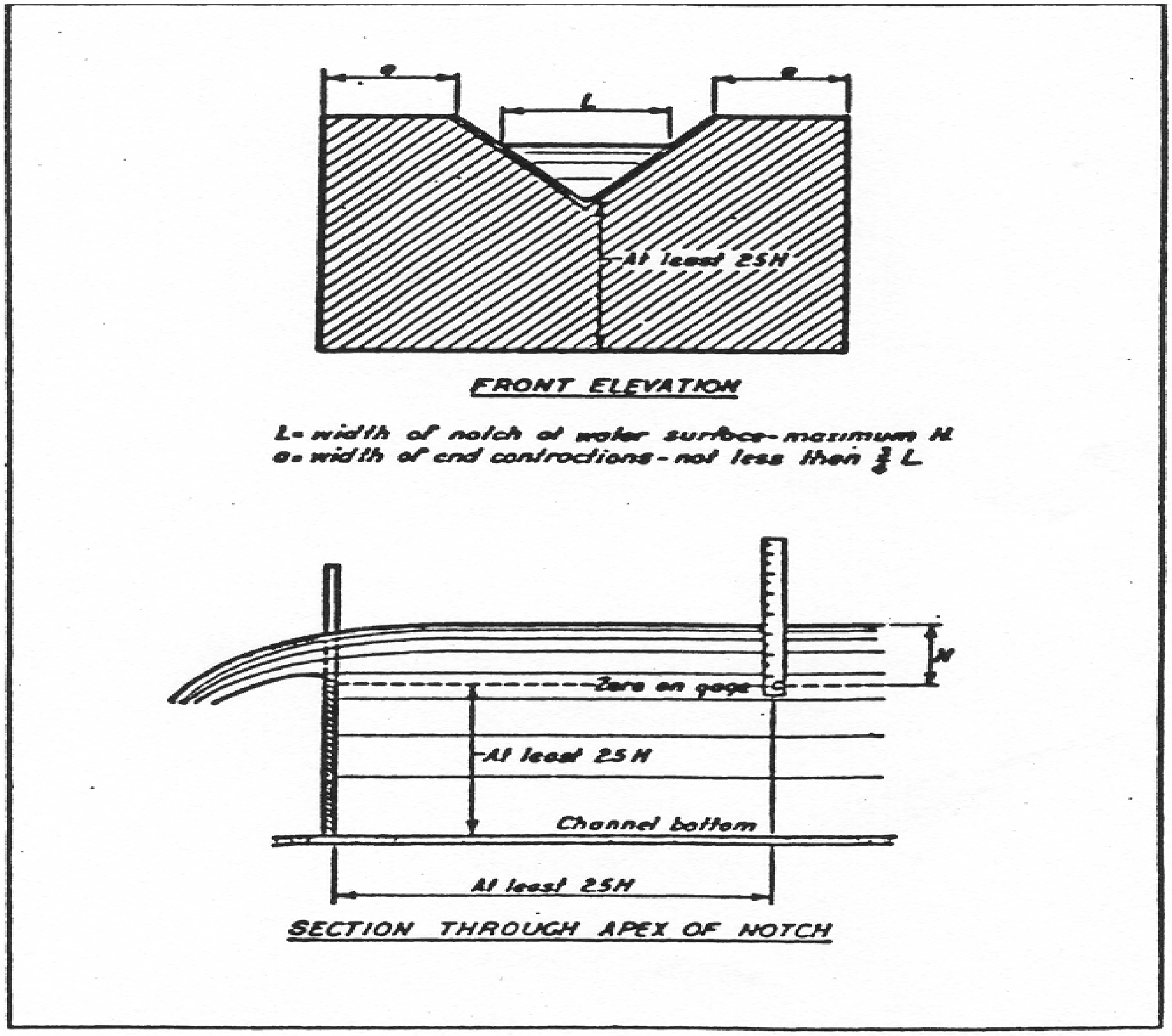


Figure 5-3. Critical dimensions for 90° v-notch weirs.

(a) The head (H) must be measure upstream from the weir at a distance equivalent to at least 2.5 times H.

(b) The depth of the water below the notch must be at least 2.5H.

(c) The end contractions on either side of the notch (a) must be not less than 3/4 L (width of the notch at the water surface with maximum head).

**NOTE**: Table 5-2 may be used to convert a measured head in inches to discharge in gallons per minute. This table is based on the formula: $Q = 1130 H^{2}.47$, where Q = quantity of water in gallons per minute and H = measured head in feet.

| Head (H) Inches | Discharge (Q) (gpm) | Head (H) inches | Discharge (Q) (gpm) | Head (H) inches | Discharge (Q) (gpm) |
|---|---|---|---|---|---|
| 1" | (2) | 7" | 300 | 16" | 2,310 |
| 1/4 | (4) | 1/4 | 332 | 1/2 | 2,480 |
| 1/2 | (6) | 1/2 | 354 | 17" | 2,670 |
| 3/4 | (9) | 3/4 | 383 | 1/2 | 2,880 |
| 2" | (12) | 8" | 413 | 18" | 3,080 |
| 1/4 | (17) | 1/4 | 451 | 1/2 | 3,290 |
| 1/2 | 24 | 1/2 | 486 | 19" | 3,530 |
| 3/4 | 30 | 3/4 | 520 | 1/2 | 3,760 |
| 3" | 37 | 9" | 555 | 20" | 4,000 |
| 1/4 | 45 | 1/4 | 594 | 1/2 | 4,250 |
| 1/2 | 53 | 1/2 | 632 | 21" | 4,500 |
| 3/4 | 65 | 3/4 | 684 | 1/2 | 4,770 |
| 4" | 76 | 10" | 725 | 22" | 5,060 |
| 1/4 | 88 | 1/2 | 815 | 1/2 | 5,340 |
| 1/2 | 100 | 11" | 910 | 23" | 5,640 |
| 3/4 | 114 | 1/2 | 1,040 | 1/2 | 5,950 |
| 5" | 130 | 12" | 1,130 | 24" | 6,280 |
| 1/4 | 149 | 1/2 | 1,250 | 1/2 | 6,580 |
| 1/2 | 166 | 13" | 1,380 | 25" | 6,900 |
| 3/4 | 183 | 1/2 | 1,520 | | |
| 6" | 204 | 14" | 1,650 | | |
| 1/4 | 225 | 1/2 | 1,810 | | |
| 1/2 | 247 | 15" | 1,970 | | |
| I3/4 | 276 | 1/2 | 2,120 | | |

Table 5-2. Discharge of water over 90° v-notch weir.

(2) <u>Floating stick method</u>. The floating stick method of measuring stream flow is an approximate, simple method that may be employed by the preventive medicine specialist with no equipment other than a measuring device (tape measure or yard stick) and a watch with a second hand. The principle involved is to measure the velocity of a stream by means of timing a floating stick as it moves along the surface,

then multiplying the cross-sectional area of the stream by the velocity to obtain the rate of flow. The formula used in this determination is:

$Q = .85\ AV$;
$Q$ = quantity of water in cubic feet per second ($ft^3/sec$)
$A$ = the cross-sectional area of the stream in square feet, and
$V$ = the velocity in feet per second (ft/sec).

The flow in $ft^3/sec$ may be converted to gallons per minute (gpm) by multiplying by 448.8 $\left(\frac{1\ ft^3}{sec} = \frac{7.48\ gal}{ft^3} \times \frac{60\ sec}{min} = 448.8\ gpm\right)$.

A commonly used formula is $a = 6.4 \times A \times V$. The value 6.4 is a multiplication of the factor .85 by the conversion factor of 7.48 gal per $ft^3$. The procedure is as follows:

(a) Mark off a measured course where the stream is uniform in depth, width, and grade. If possible, a straight segment of the stream should be used. Drop a cork, small stick, or other light object into the center of the stream and record the time in seconds required to float between two points. Divide the distance traveled (in feet) by the time (in seconds) to obtain the velocity. Since the velocity at the surface of a stream is greater than the average velocity, the factor .85 used in the formula converts the surface velocity to average velocity. The deeper the stream, the velocity approximation is more accurate.

(b) Determine the cross-sectional area of the stream by measuring the depth at several points in order to construct a profile (see figure 5-4). The area of the cross section may then be computed using any of the common geometric formulas for calculating areas.

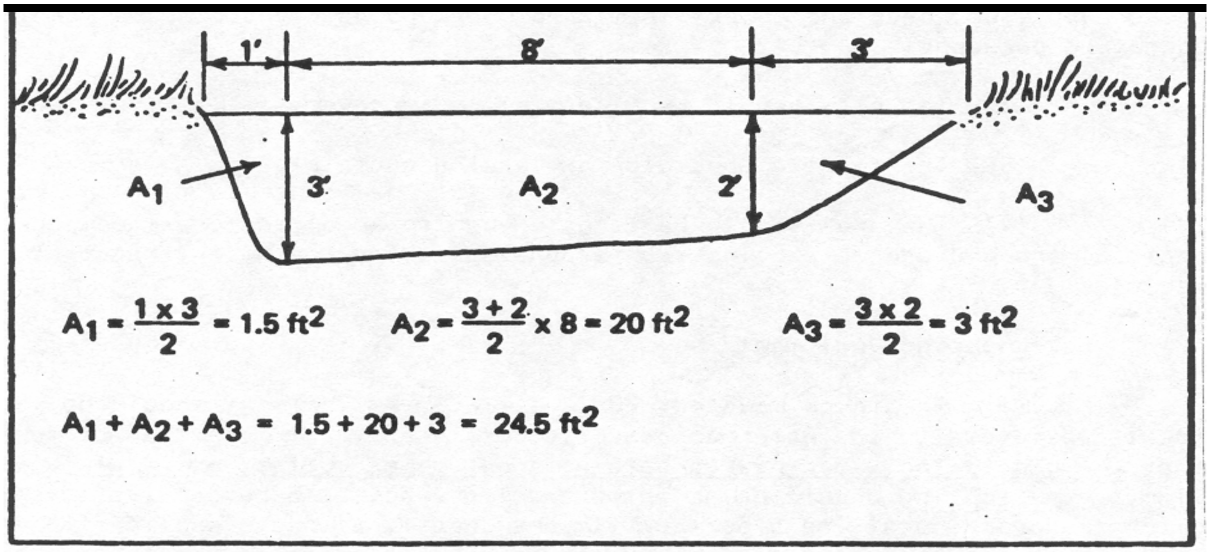


Figure 5-4. Determining cross-sectional areas.

(c) Determine flow in cubic feet per second by multiplying velocity by cross-sectional area. Example:

$A = 24.5\ ft^2$
$V = 0.5\ ft/sec$
$Q = .85 \times 24\ 5\ ft^2 \times 0.5\ ft/sec = 10.4\ ft^3/sec.$

The flow in $ft^3/sec$ may then be converted to gallons per minute by multiplying by 448.8: 10.4 ft3/sec x 448.8 gal/ft3 = 4,668 gpm (4,667.52).

## 5-3. OPERATION OF FIELD WATER PURIFICATION EQUIPMENT

Field water purification equipment was briefly discussed in Lesson 1. The following paragraphs describe in considerably more detail the flow of water through the erdlator and the specific operations that take place. It is once again emphasized that the preventive medicine specialist need not be a trained erdlator operator; however, the more knowledge he has of the operation of the equipment, the better able he will be able to inspect a water point and make recommendations for improvement.

## 5-4. INSTALLATION OF WATER PURIFICATION EQUIPMENT

Figure 5-5 illustrates a typical field water purification unit (WPU) installation. The following points are important in the proper selection and setting up of the unit:

a. **Site Selection**. Although it is not always possible under tactical conditions to select an ideal site for the WPU, the site selected should meet as many of the following requirements as possible:

(1) The site should provide natural camouflage; access to roads, water supply sources, and power lines, and surrounding bivouac areas for operating personnel.

(2) The site should require minimum improvements.

(3) The terrain should be as level as possible.

(4) The area should be large enough to accommodate all component parts of the WPU and to provide turn-around space for the water transporting vehicles.

b. **Locating Equipment**.

(1) The truck mounted WPU (see figure 5-5, circle A) should be located as close to the water as possible, preferably not more than 50 feet away. Avoid taking water near a bathing area, sewer outlet, or latrine. A firm, level footing should be selected and improved, as necessary, by digging ditches and/or installing blocks or timbers under the wheels and leveling jacks. The van body housing the WPU should be

leveled using the four leveling jacks provided. The unit should be properly grounded using a 30-inch metal rod (see figure 5-5, circle B).

**WARNING**

Static electricity and leakage currents from electrical equipment builds up in the trailer, truck, and van body, and can cause injury or death to personnel by electrical shock if the equipment is not properly grounded.

(2) The trailer mounted generator (see figure 5-5, circle C) set should be positioned not more than 50 feet from the WPU, leveled, and properly grounded as in (1) above.

(3) The raw water pump (see figure 5-5, circle D) should be placed near the water source, not more than 50 feet from the WPU, on a firm, level footing of planks or timbers. If necessary, two raw water pumps may be placed in series. The maximum suction lift of each pump is 20 feet.

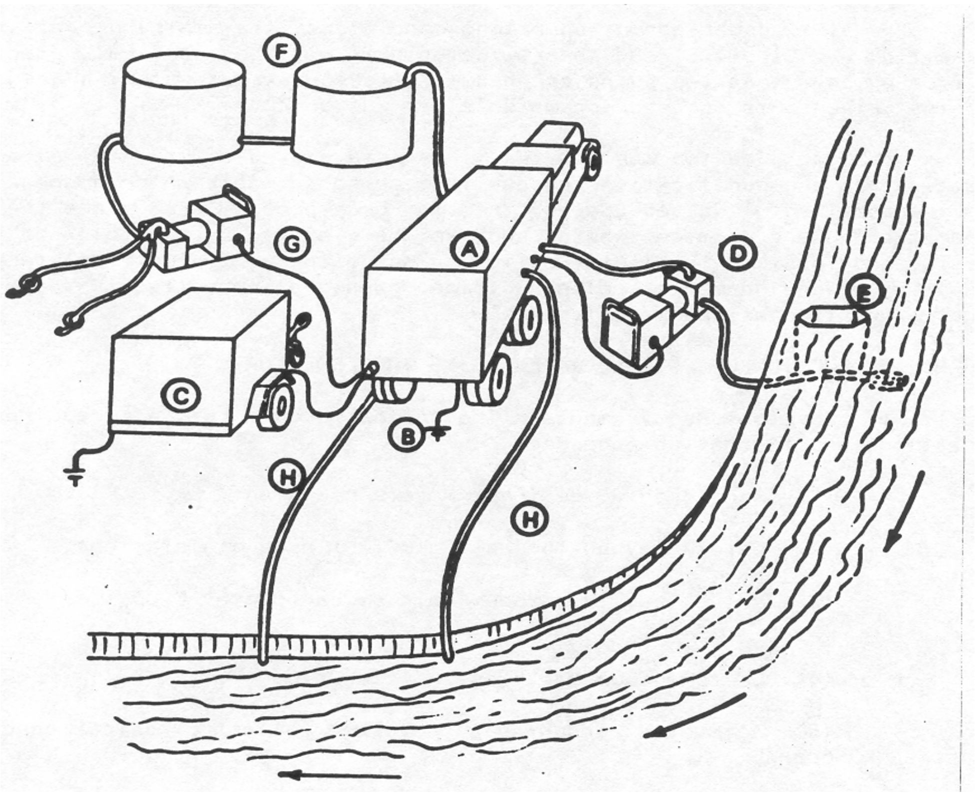


Figure 5-5. Typical field WPU installation.

(4) The raw water suction hose is positioned by means of a float so that the strainer is well below the surface of the water, but off the bottom. If the water at the source is 6 feet deep or deeper, the suction strainer should be approximately 3 feet below the surface (see figure 5-5, circle E). It should always be at least 4 inches below the surface.

**CAUTION**: If air is sucked into the strainer, the capacity of the pump will be reduced and floc floatation in the erdlator tank will result. Dirt, sand, or other foreign matter will damage the equipment, resulting in loss of production and costly repair.

(5) The collapsible water storage tanks (see figure 5-5, circle F) should be located on the filter effluent side of the unit as near to the WPU as possible. They should be placed on firm, level ground or on a raised platform. The surface of the foundation should be covered with a ground cloth to protect the bottoms of the tanks from mildew, mold, or damage. Both tanks should be the same level so that water will flow from one to the other by gravity.

(6) Under normal operating conditions, the distribution pump (see figure 5-5, circle G) and the raw water pump will be identical, electrically driven pumps. When two pumps are required to supply raw water, a gasoline engine driven pump is used for water distribution.

(7). The two wastewater lines (see figure 5-5, circle H) divert the wastes from the purification process to a suitable wastewater disposal area. In the continental United States, this may be a problem area since the wastes from the WPU are chemical wastes and must be disposed of according to Federal, state, and local environmental pollution guidelines. The unit sanitary engineer or environmental science officer should be consulted in the event that a question arises in this area.

## 5-5. PRODUCTION OF POTABLE WATER USING THE ERDLATOR

a. **Chemical Requirements**. The following chemicals are required in the treatment and filtration process:

(1) Ferric chloride ($FeCl_3$) as a coagulant.

(2) Calcium hypochlorite ($Ca(OCl)_2$) as a disinfectant.

(3) Pulverized limestone (calcium carbonate--$CaCO_3$) as a coagulant aid.

(4) Diatomaceous earth as a filter aid.

(5) Activated carbon as an absorber to control objectionable tastes and odors.

The chemicals are mixed proportionally with water in accordance with an established base charge. The base charge is the concentration of mixture or solution expressed as the amount of chemical in a measured quantity of water prepared for the chemical feeder.

**b. Water Treatment Process**. Figure 5-6 illustrates the flow of water through the WPU, which, in general terms, is as follows:

(1) Raw water is pumped from its source through the aspirators into the erdlator assembly, which will be discussed in detail in paragraph 5-7. A portion of the raw water entering the erdlator assembly is diverted through the chemical slurry feeder.

(2) Calcium hypochlorite and ferric chloride solutions, as well as pulverized limestone slurry (including activated carbon, if required), are added to the erdlator assembly through separate tubes from the chemical solution and chemical slurry feeders, respectively, as explained in paragraph 5-6.

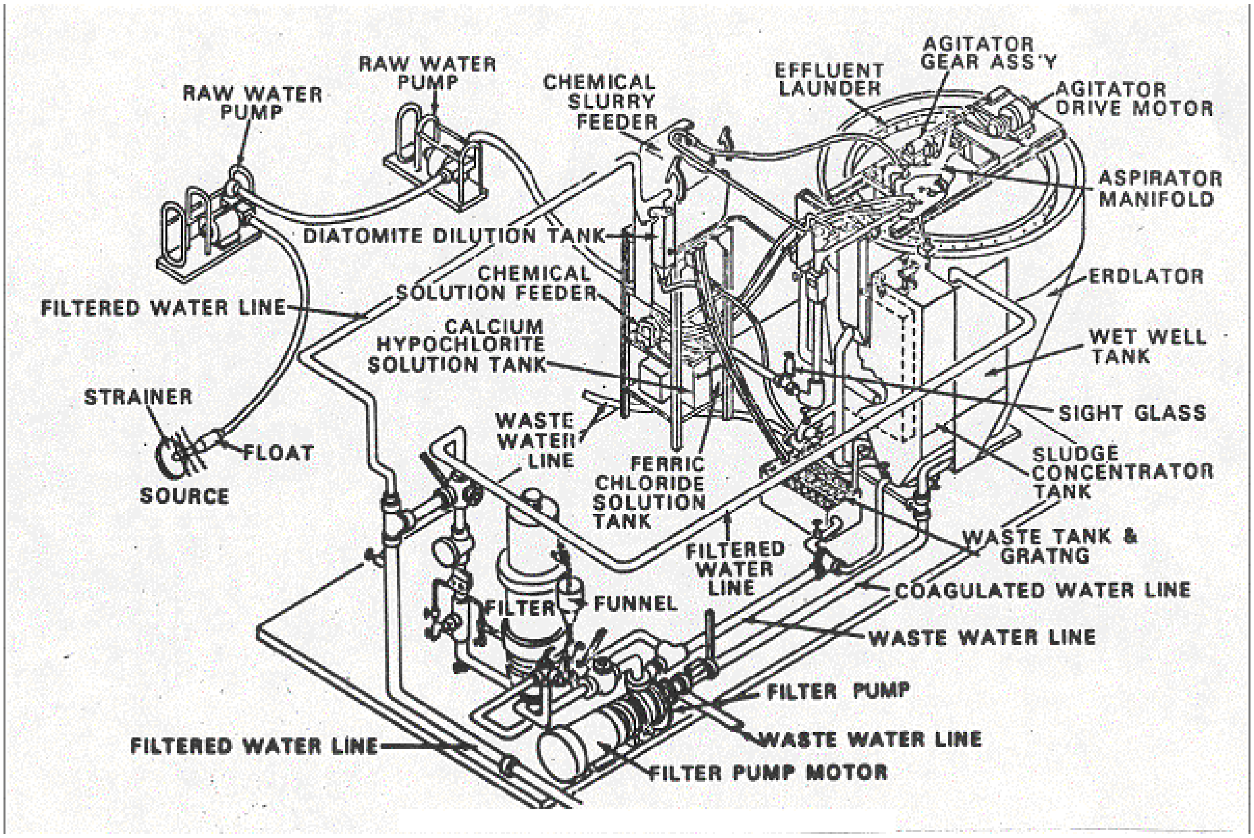


Figure 5-6. Flow diagram.

(3) Coagulated water is pumped from the wet well tank of the erdlator assembly by means of the filter pump, to the diatomite filter. Initially, during the precoat operation, filtered water is recirculated from the filter back to the wet well tank. After precoat is completed and normal filtering begins, the filtered water is pumped directly to the storage tanks. A small portion of the filtered water is diverted through the diatomite dilution tank on the side of the chemical slurry feeder tank to the line supplying coagulated water to the filter pump (see para 5-8).

(4) Waste water lines provide drainage from the chemical slurry feeder tank to the wastewater tank and from the erdlator assembly, wet well tank, sludge concentrator tank, and diatomite filter to two wastewater outlets in the van body. The waste lines are painted red.

## 5-6. CHEMICAL FEEDING

Chemicals for treatment are fed by means of the chemical feed equipment (see figure 5-7). Two chemical solution tanks at the bottom of the unit supply ferric chloride and calcium hypochlorite. The chemical slurry feeder, at the top of the unit, contains two compartments, which supply diatomaceous earth to the filter and pulverized limestone to the coagulant (erdlator assembly).

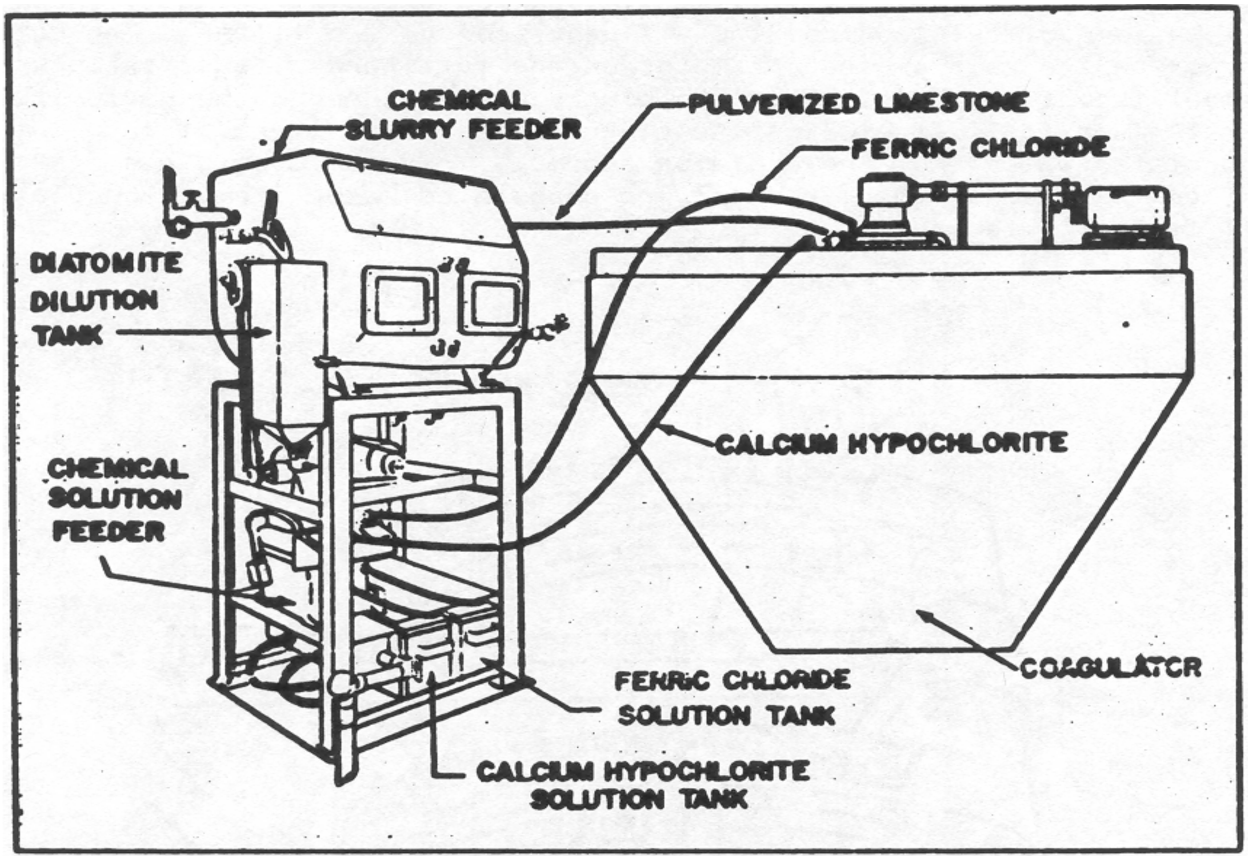


Figure 5-7. Chemical feed equipment.

a. **Ferric Chloride and Calcium Hypochlorite**. At the beginning of the operation, the WPU operator prepares a base charge of ferric chloride by mixing a predetermined quantity of dry ferric chloride with water. The proportion of chemical to water is prescribed by the appropriate technical manual (TM) for the equipment in use (1/2 lb $FeCl_3$ per gal for the 1,500 gph WPU; 1 lb per gal for the 3,000 gph WPU). The chemical solution is placed in the lower right hand chemical solution tank. A base charge of calcium hypochlorite is then prepared in the same manner (1/8 lb per gal for the 1,500 gph WPU; 1/4 lb per gal for the 3,000 gph WPU) and placed in the lower left hand chemical solution tank. Never mix the two chemicals as they produce a greenish yellow chlorine gas that is irritating, disagreeable, and toxic. While the WPU is in operation, the chemical solutions are fed to the erdlator tank by means of the chemical solution feeder at a rate prescribed in the TM (see para 5-10). The rate of feed is set on the chemical solution feeder controls (see figure 5-8). The operator may have to vary the rate from time to time, depending on the quality of the treated water. The operator must also monitor the amount of solution in the tanks and recharge each one when the solution level drops to about 4 1/2 inches from the bottom of the tank. Each chemical solution tank holds approximately 5 gallons.

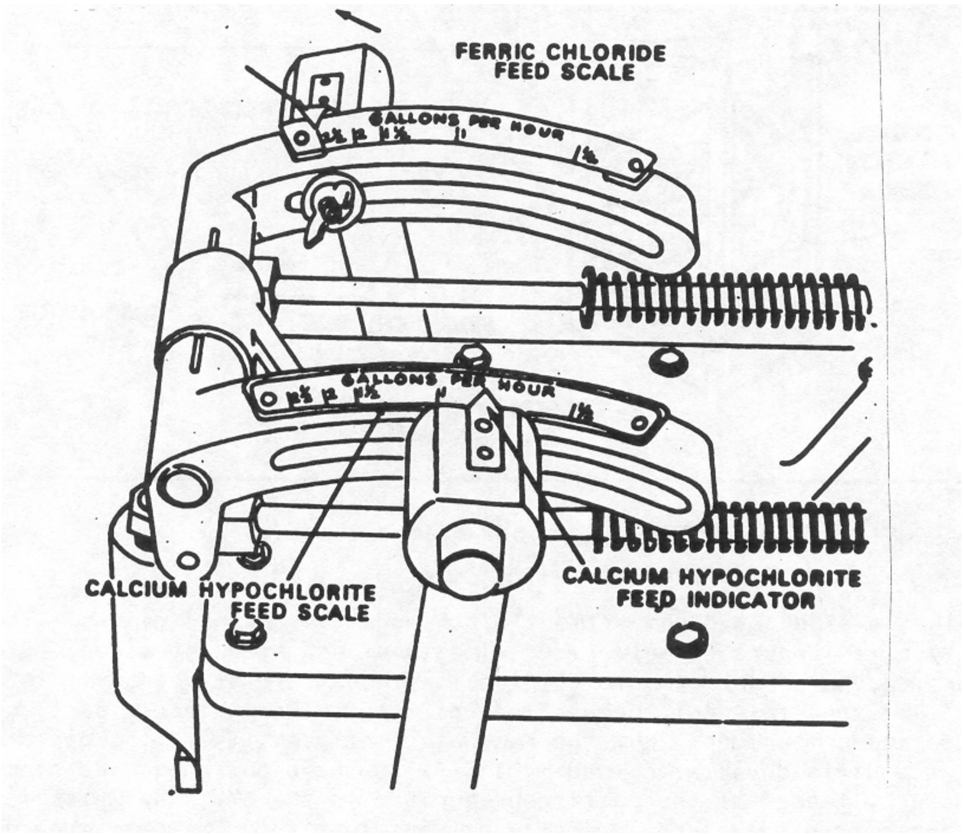


Figure 5-8. Chemical solution feeder controls.

b. **Pulverized Limestone**. An initial charge of limestone slurry is prepared in the right hand compartment of the chemical slurry feeder. The concentration is 1 pound of pulverized limestone per gallon of water. Since the compartment holds approximately 14 gallons, the initial charge is 14 pounds of limestone to a full compartment of water. Raw water is continuously supplied to the compartment from the raw water influent line. The operator sets the rate of feed variator (see figure 5-9) on the right hand side of the chemical slurry feeder at the setting prescribed in the TM. The water level remains constant in the slurry compartment, but the slurry becomes more diluted; therefore, it must be recharged with dry chemical every hour.

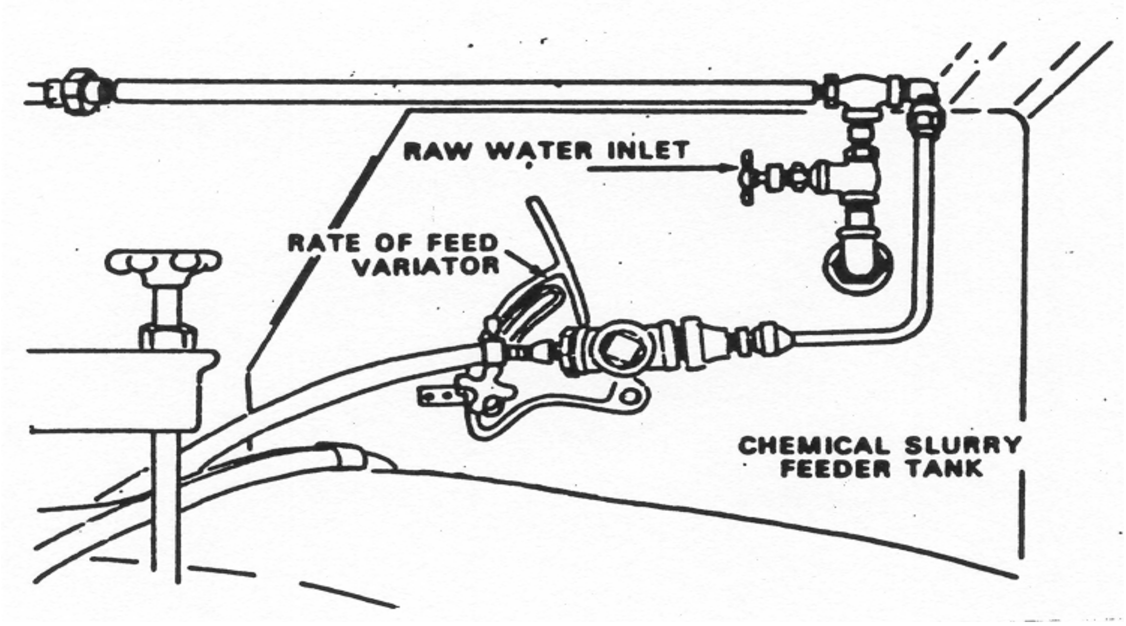


Figure 5-9. Chemical slurry feeder controls (right view).

c. **Activated Carbon**. If the coagulated water has an objectionable color, taste, or odor, activated carbon is added to the limestone slurry compartment at the rate of 1/10 pounds per gallon of water (base charge of 1.4 pounds).

d. **Diatomaceous Earth**. Diatomaceous earth slurry for precoating the filter is applied directly to the filter through the precoat funnel (see para 5-8). Once the filter is in operation, additional diatomite slurry is added to the coagulated water to maintain the porosity of the filter. This diatomite slurry is fed by means of the chemical slurry feeder. The diatomite slurry compartment, located in the upper left hand section of the chemical slurry feeder (see figure 5-7), is filled (14-gallon capacity) with filtered water that is recirculated from the effluent side of the filter. The rate of feed is set on the rate of feed variator on the left hand side of the slurry compartment (see figures 5-7, 5-9). The slurry passes through the diatomite dilution tank on the left side of the slurry compartment where it is diluted with coagulated water from the erdlator assembly. The diluted diatomite slurry then is piped to the line carrying coagulated water from the erdlator wet well to the filter pump (see figure 5-6).

## 5-7. COAGULATION

Coagulation of the raw water takes place in the erdlator assembly, or coagulator (see figure 5-10). The operation is essentially as follows:

a. Raw water is pumped from its source through the aspirators (see figure 5-10, circle A) into the influent launder (see figure 5-10, circle B) from which it overflows into the mixing zone (see figure 5-10, circle C) within the down comer tube (see figure 5-10, circle D). The aspirators aerate the water, which improves coagulation.

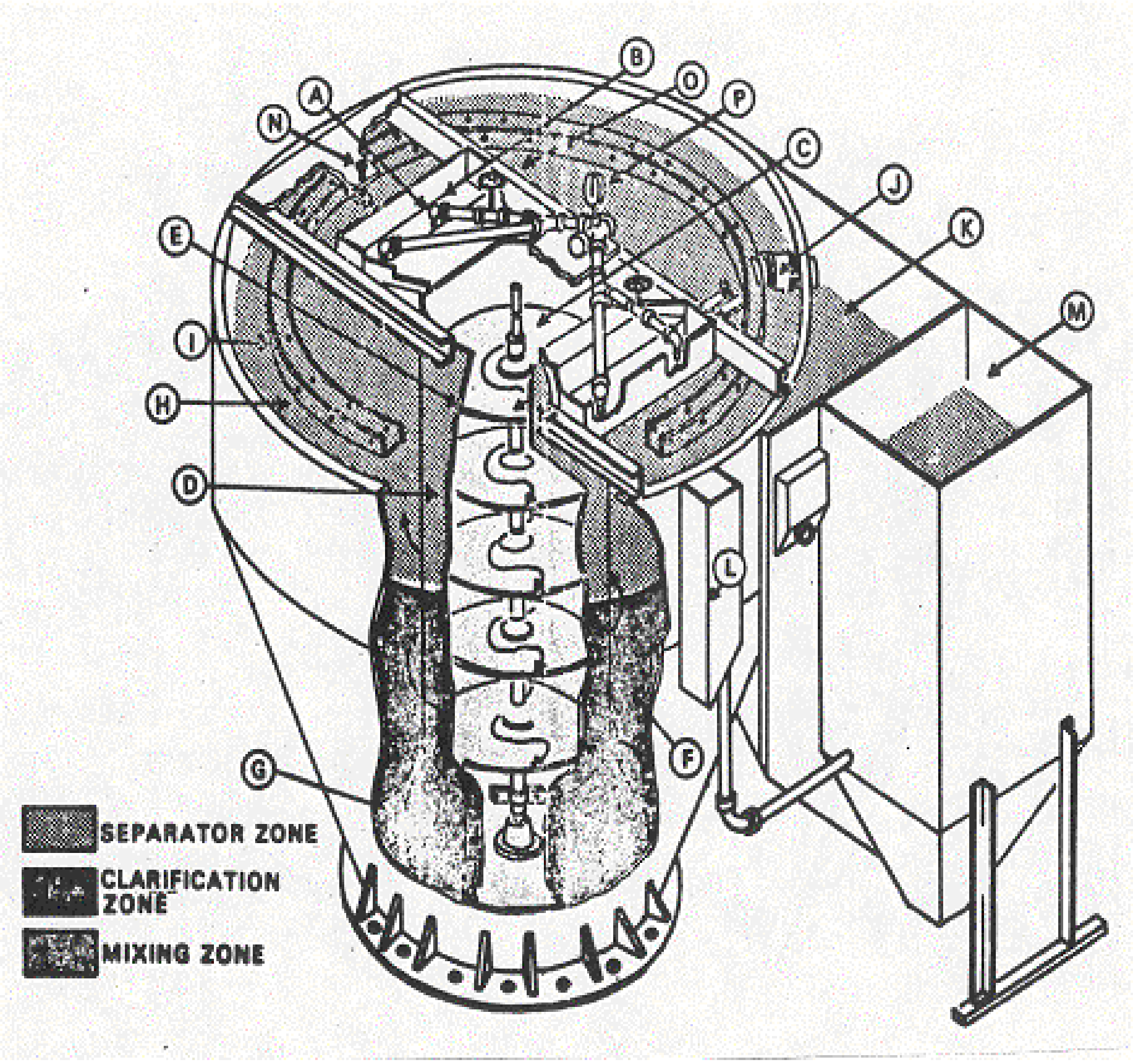


Figure 5-10. Cross-section of the erdlator assembly.

b. Ferric chloride, calcium hypochlorite, pulverized limestone, and (when necessary) activated carbon are introduced directly into the mixing zone by the chemical feeding equipment (see figure 5-7). As the raw water descends through the mixing zone, it is mixed with the chemicals by the circular disks (see figure 5-10, circle E) that impart a rotary motion to the liquid. This turbulence also helps in the formation of floc.

c. As the water reaches the bottom of the down comer tube and flows into the clarification zone (see figure 5-10, circle F), a series of shallow baffles (see figure 5-10, circle G) deflect the flow and impart a counter rotary movement. The velocity is thus reduced, but it is still sufficient to maintain a slight rotary movement.

d. The floc (also referred to as slurry or sludge) appears as small, grayish-rust colored particles floating about in suspension in the lower portion of the erdlator. These particles are slightly heavier than water, so that in the upper portion of the erdlator tank, or separator zone elements, water is recirculated to the wet well tank and the flow controller valve (see figure 5-11, circle D) is set on a rate of flow which wiIl just hold the coating on the elements (10 gpm).

e. Clear water at the top of the erdlator tank is collected in the effluent launder (see figure 5-10, circle I) that acts as a double-edged weir. From the effluent launder, the clear water passes through a discharge tube (see figure 5-10, circle J) into the wet well tank (see figure 5-10, circle K) that provides limited storage for coagulated water and acts as a sump for the filter pump. An overflow pipe in the wet well tank permits operation of the erdlator at rated capacity when the filter is stopped. A float valve connected to the raw water line permits raw water to enter the erdlator assembly when the water in the wet well falls below a preset level. When this occurs, a warning light and warning buzzer are actuated to alert the erdlator operator of the condition.

f. The slurry level is controlled by a continuous withdrawal of a small amount of slurry from the top of the slurry blanket by means of a draw- off port through the slurry weir box (see figure 5-10, circle L) into the sludge concentrator tank (see figure 5-10, circle M). The sludge concentrator tank functions as a small auxiliary clarifier. It provides a longer holding period for slurry concentration and permits settling of slurry in the bottom of the tank for continuous or intermittent drainage to waste.

## 5-8. FILTRATION

The construction and operation of a diatomite filter was discussed in paragraph 1-14. The following discussion will amplify the details of filtration in the WPU during the three phases of operation: precoat, filtration, and backwashing.

a. **Precoat**. Before water can be filtered, it is necessary to precoat the filter elements with diatomaceous earth. The erdlator operator prepares slurry consisting of 1/2-pound diatomaceous earth in one gallon of coagulated water and pours it into the precoat funnel (see figure 5-10, circle A). The filter pump is then started and coagulated water from the erdlator wet well tank (see figure 5-6) is introduced into the filter. Filtered water is recirculated back to the wet well tank until precoating is completed in order to ensure that no unfiltered or partially filtered water is pumped into the storage tanks. This may be determined by observing the filter elements through the filter window (see figure 5-11, circle B). Initially, the water inside the filter appears cloudy as the diatomite particles move about in suspension. As precoating continues, the water gradually becomes clearer. When the precoating process is completed, the filter elements can be viewed through the window. Each filter will be covered by a white film of diatomite.

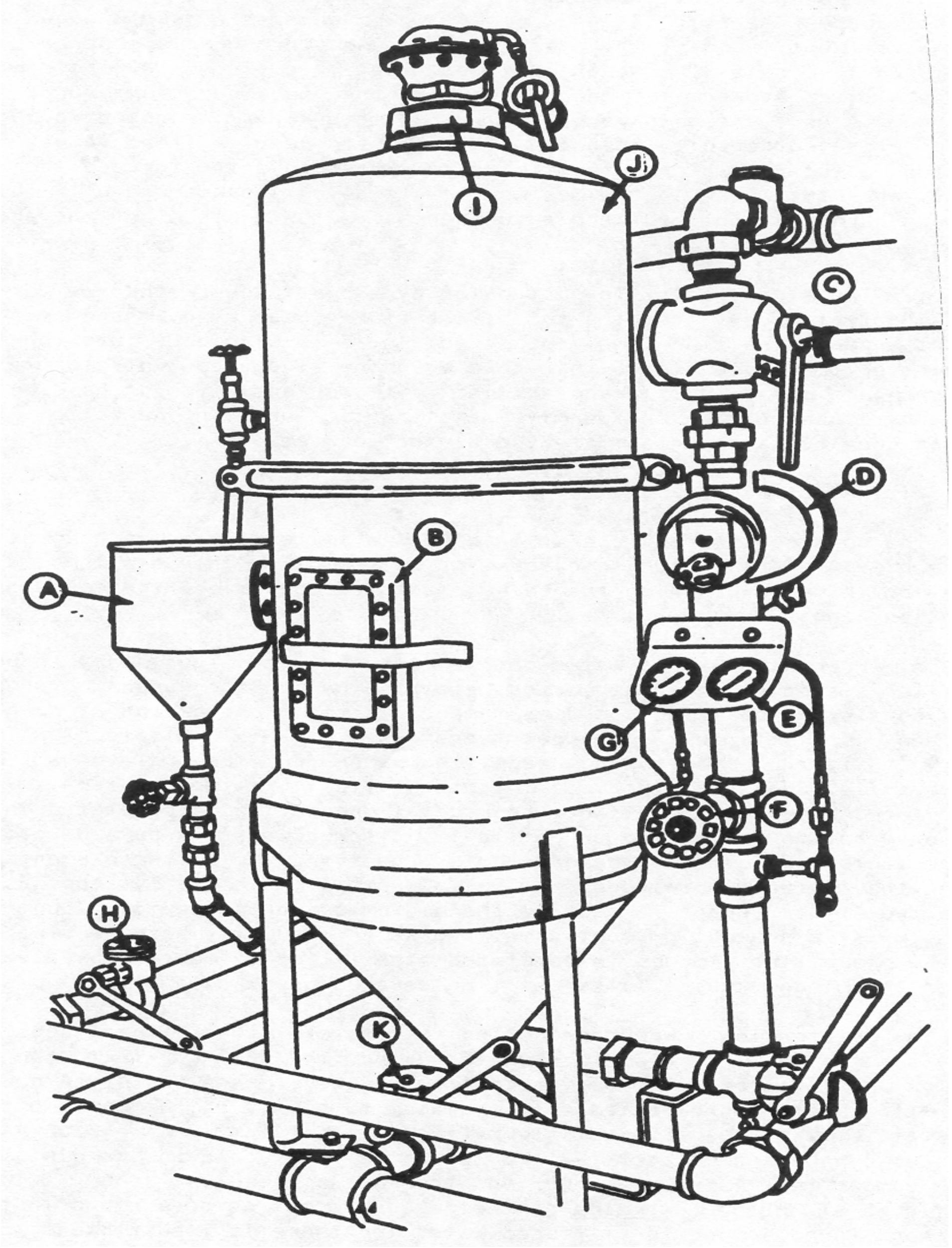


Figure 5-11. Diatomite filter and related parts.

b. **Filtration**. When precoating is complete, the effluent control valve (see figure 5-11, circle C) is switched from the RECIRCULATE to the FILTER position and filtered water begins to flow to the storage tanks. A portion of the filtered water is diverted to the diatomite slurry compartment in the upper left side of the chemical slurry feeder (see figures. 5-6, 5-7). A base charge of 7 pounds of diatomite (1/2 lb per gal) is added to the diatomite slurry compartment (see para 5-6d) and the rate of feed variator (see figure 5-9) on the left side of the feeder is set as prescribed in the TM. When there is no demand for filtered water (or there is insufficient water in the wet well tank), but it is desired to maintain the coating on the filter.

c. **Backwashing**. The filter elements must be backwashed and the filter tank drained whenever the filter elements become so clogged as to interfere with normal operation. This condition is indicated whenever the flow through the filter stops or when the effluent pressure gauge (see figure 5-11, circle E) reading drops to 5 pounds per square inch (psi). (Normal operating pressure is approximately 30 psi.) To backwash the filter, the effluent control valve (see figure 5-11, circle F) is closed; the filter pump is operated until the influent pressure gauge (see figure 5-11, circle G) reads the same as the filter effluent gauge (see figure 5-11, circle E). The pump is then stopped and the influent control valve (see figure 5-11, circle H) is closed. Then the air release valve (see figure 5-11, circle I) is opened (BACKWASH position), releasing the air compressed in the filter dome (see figure 5-11, circle J) and in the plastic cups within the filter elements, thus forcing water in a reverse direction through the filter cake. This sudden reversal of water usually dislodges all the filter cake and foreign material. If it does not, the elements must be disassembled and cleaned. After backwashing, the filter drain (see figure 5-11, circle K) and the influent control valve (see figure 5-11. circle H) are opened and the pump is operated for at least one minute to flush the filter.

**NOTE**: Backwash water should never be drained into a soakage pit or returned to the water source.

## 5-9. ELECTRICAL CONTROLS

The electrical controls for operating the WPU are on the door of the electrical control cabinet (see figure 5-12), which is located just forward of the erdlator assembly. The electrical controls are as follows:

a. The low level warning light, located above the control cabinet (see figure 5-12, circle A), turns on automatically when the water in the erdlator wet well tank falls below a preset level. It is a red light, which is accompanied by a buzzer to provide an audio warning. A toggle switch (see figure 5-12, circle B), located on the left side of the door, is provided to turn off the warning light and buzzer.

b. An ammeter (see figure 5-12, circle C) and a voltmeter (see figure 5-12, circle D) are provided to indicate the current and voltage outputs, respectively, of the main generator.

c. Six start-stop button switches (see figure 5-12. circle E) are used to start and stop the slurry feeders, filter pump, erdlator agitator, distribution pump, raw water pump, and solution feeders.

**NOTE**: The operations described in paragraphs 5-4 through 5-9, above, are intended as a brief familiarization with the operation of the WPU and NOT as a substitute for the detailed instructions contained in the TM pertaining to the particular item of equipment in use.

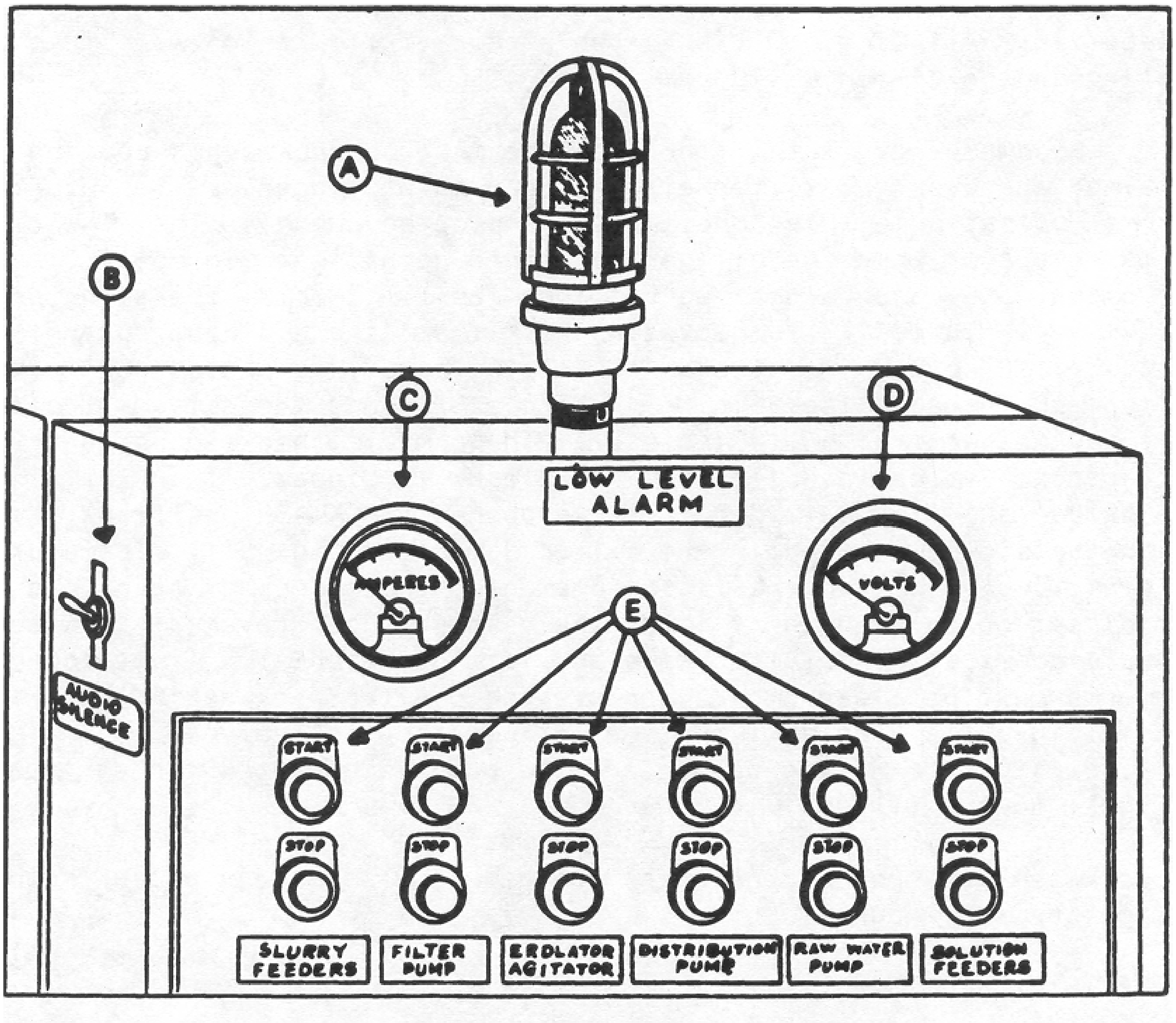


Figure 5-12. Electrical control cabinet.

## 5-10. DETERMINING CHEMICAL DOSAGES

The TM for each model WPU prescribes the chemical dosages required for proper treatment under normal conditions. Since the chemical composition of water will vary from time to time, these dosages vary. The base charge, which is the initial mixture of chemical and water added to the chemical solution or slurry feeder (see para 5-6), remains constant. The rate of feed, which is set on the feeder controls (see figs. 5-8 and 5-9), varies with the chemical characteristics of the particular water being treated and is adjusted during operation to obtain optimum results.

a. **Calibration Charts**. Mounted on the control cabinet of the WPU, for ready reference, are four calibration charts identical to those in the TM to be used for determining the base charge and feeder control setting for each chemical used by the erdlator. Figure 5-13 illustrates the calcium hypochlorite calibration chart for the 1,500 gph WPU.

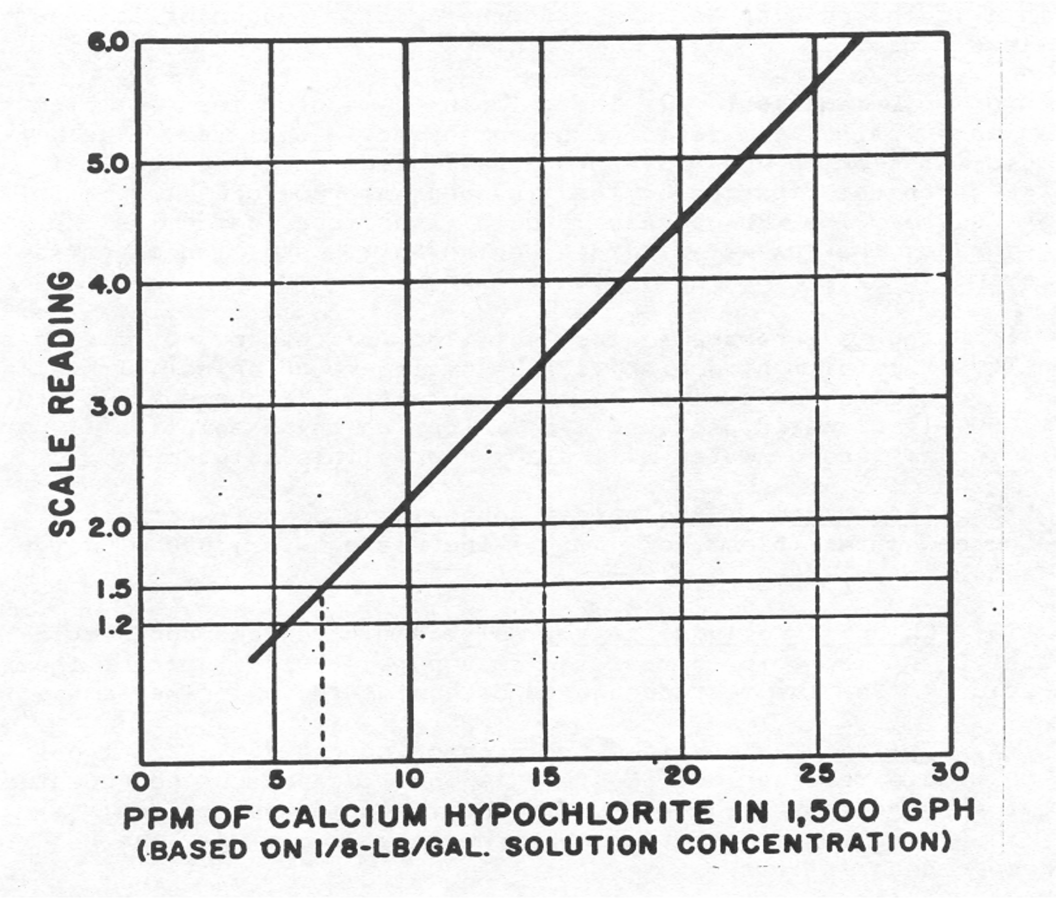


Figure 5-13. Calcium hypochlorite solution calibration chart.

(1) Base charge. Referring to the information under the chart, it can be seen that the chart is based on 1/8 pounds calcium hypochlorite per gallon of water. This is the strength of the base charge placed in the chemical solution tank and the strength of the recharge solution added when the solution level drops to about 4 1/2 inches from the bottom of the tank.

(2) Rate of feed. The vertical scale on the chart is the SCALE READING corresponding to the graduations on the feeder controls. The horizontal scale is graduated in ppm and expresses parts of chemical introduced into a million parts of raw water. The diagonal line, or curve, correlates a given dosage in ppm with a corresponding scale reading in gallons of solution per 'hour (gal/hr). To determine the scale reading for a desired dosage, read the calibration chart by locating the specified ppm of chemical " on the horizontal scale; trace a vertical line up to meet the curve; then trace a horizontal line to the left to the SCALE READING. For example, using figure 5-13 determine the scale reading for an application of hypochlorite solution at a strength of 7 ppm. (**Note**: This means seven parts of calcium hypochlorite--not chlorine--per million parts of water.)

(a) Interpolate between 5 ppm and 10 ppm on the horizontal scale to find 7 ppm.

(b) Read vertically to the curve.

(c) Read horizontally to the left, to a SCALE READING of 1.5 gal/hr. This is the reading to be set on the calcium hypochlorite feed indicator (see figure 5-8).

b. **Chlorine Demand Test**. If the chlorine demand of the raw water is higher than anticipated, the settings given in the TM will very likely result in a finished water, which does not have a sufficient chlorine residual. This will require batch chlorination of the finished water before it may be consumed or issued. The WPU operator should, therefore, determine the chlorine demand of the raw water before beginning the erdlator operation. Chlorine demand is determined as follows:

(1) Reagent. Prepare a stock solution, or reagent, by mixing a known quantity of calcium hypochlorite (70 percent available chlorine) with a known quantity of the best water available. A mixture of 7.14 grams of $Ca(C10)_2$ in 1 liter (1,000 ml) of water produces a 5,000 ppm chlorine solution (1 oz (wt) of $Ca(Cl0)_2$ in 4 liters of water will also produce this solution).

(2) Test dosage. Add a test dosage of known strength to a 1-liter sample of the raw water (5 ppm, or 1 ml of the reagent to 1,000 ml water, is normally used.)

(3. Chlorine residual test. Wait 30 minutes and run a chlorine residual test using the color comparator (see para 4-10). Subtract the chlorine residual from the test dosage to determine the chlorine demand.

(4) Validitv. If a measurable chlorine residual is not obtained after the 30-minute test period, the test is invalid and must be repeated by increasing the reagent by 5 ppm each time until a chlorine residual is obtained. If, for example, the tests were repeated two times, the results would be recorded as follows:

Test dosage, 2 x 5 ppm = 10.0 ppm $C1_2$
$Cl_2$ residual = 5.0 ppm $Cl_2$

$Cl_2$ demand 5.0 ppm $Cl_2$

(5) Application. To determine the calcium hypochlorite dosage required, use the same basic formula (dosage = demand + residual). If a residual of 1 ppm is required, and the demand is 5 ppm (as in (4) above), the dosage to be applied is 6 ppm chlorine. Since $Ca(ClO)_2$ is only 70 percent available chlorine, the dosage of $Ca(Cl0)_2$ required is 6 = 8.6 (9) 0.7 ppm. Entering the $Ca(Cl0)_2$ calibration chart at a concentration of 9 ppm, the required scale reading is 2.0. This is the setting for the calcium hypochlorite solution feeder.

c. **Coagulation Dosage Test**. The coagulation test enables the WPU operator to determine the approximate dosage of ferric chloride for coagulation before starting the erdlator operation, thus minimizing the number of adjustments during operation. The test equipment includes four 200 ml jars with screw caps in a device that permits inverting or shaking all jars together (see figure 5-14). The laboratory version of this device includes several beakers with an electrically operated stirring device in each beaker. The procedure is as follows:

(1) All four jars to be tested are rinsed with water and filled to the 200 ml mark.

(2) Add one measuring spoonful (0.05 g) of pulverized limestone to each jar.

(3) Add 1 drop of $FeCl_3$ solution (component of water quality control set) to the first jar, 2 drops to the second jar, 3 drops to the third, and 4 drops to the fourth.

(4) Cap all jars tightly and shake the entire unit vigorously for 15 seconds.

(5) Gently, agitate the solutions by inverting the entire unit for 5 minutes at the rate of 7 to 10 inversions per minute.

(6) Allow the unit to stand for 5 minutes, observing the floc, its settling rate, and the clarity of the water above the flocculent layer.

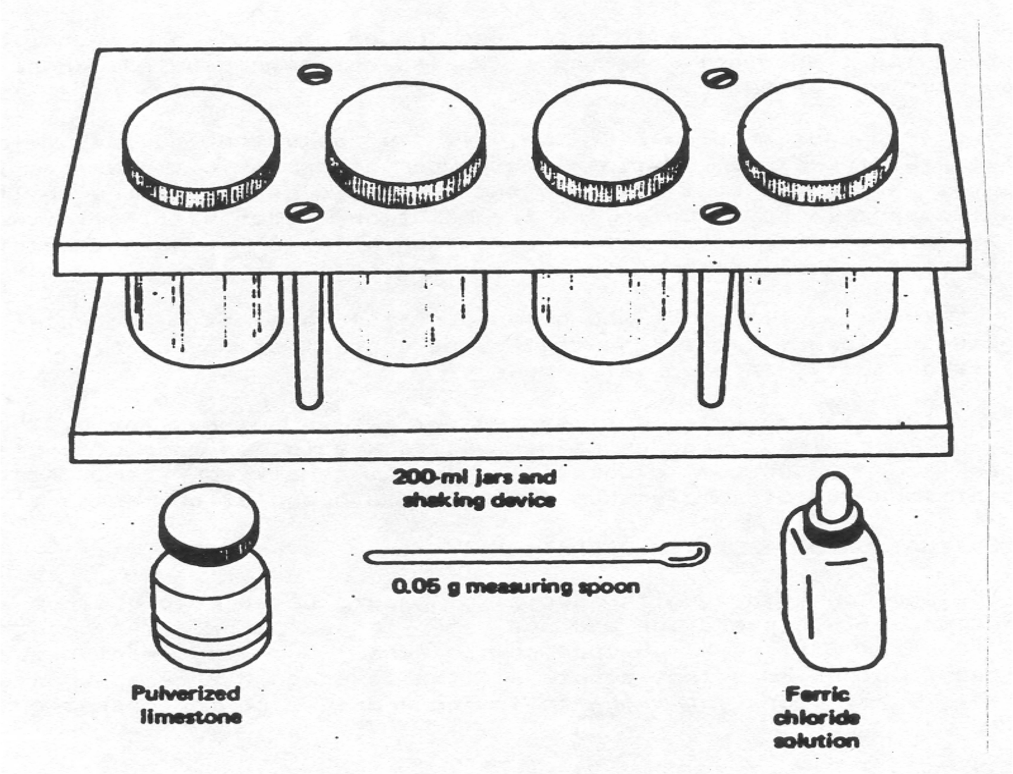


Figure 5-14. Coagulation dosage test equipment

(7) The sample with the least number of $FeC1_3$ drops showing clear water above the flocculent layer contains the optimum coagulant concentration for the water being tested.

(8) Each drop of $FeCl_3$ solution is equivalent to 10 ppm in a 200 ml sample; therefore, multiply the number of drops in the sample jar selected as having the best settling rate by 10 to determine the optimum coagulant dosage in ppm. Determine the solution feeder setting in the same manner as for $Ca(Cl0)_2$ described in paragraph 5-10a(2) using the ferric chloride solution calibration chart.

(9) If, after (6) above, none of the jars has clear water above the flocculent layer, repeat the test using concentrations of 4, 5, 6, and 7 drops, respectively, in step (3), above.

(10) If the water quality control set is not available, the above test may be improvised using as reagent a stock solution made of 2 grams of $FeCl_3$ per liter (2,000 ppm) of distilied or demineralized water. Adding 1 ml of reagent to a 200 ml sample thus represents a coagulation dosage of 10 ppm.

## 5-11. EVALUATION OF ERDLATOR OPERATION

The environmental health specialist should be able to observe a water purification unit in operation and evaluate its operation. Many of the things he will look for will be based upon common sense, such as cleanliness and orderliness. Other important points will be based on a general knowledge of the principles of operation. The following are some common operational checks.

a. **Water Quality**. The basic and essential criterion for evaluating the operation of a WPU is the quality of the water.

(1) Chlorine residual and DH. The inspector should determine the FAC residual and pH of the finished water in the storage tanks. If the FAC is less than the values discussed in paragraph 2-7 (or as prescribed by competent medical authority), additional calcium hypochlorite must be added manually as described in paragraph 2-10c (batch chlorination). A 30-minute contact time should be allowed before the water is consumed.

(2) Color, taste, and odor. If the finished water has an objectionable color (other than as described in (3), below), odor, or taste, activated carbon should be added to the limestone compartment of the slurry feeder in the amount prescribed by the appropriate TM.

(3) Appearance of coagulated water in erdlator. The appearance of the coagulated water at the top of the erdlator tank (above the slurry blanket) is an indication of whether chemicals are being fed at the proper rate.

(a) If the coagulated water appears cloudy, it is an indication that more ferric chloride should be added.

(b) If the coagulated water above the slurry blanket has a reddish color, it indicates too much ferric chloride.

(c) If the water looks clear, but large particles are rising and the blanket looks light and fluffy, the limestone slurry feed rate should be increased.

(d) If a sample of slurry from the bottom of the sludge concentrator tank contains visible quantities of limestone, excessive limestone application is indicated and the limestone slurry rate should be decreased.

b. **Operating Controls**

(1) Effluent launder. The effluent launder of the erdlator assembly (see figure 5-10, circle I) must be level at all times. If it is level, water from the erdlator tank will flow into it uniformly around the entire circumference. If the launder is not level, it may be leveled by turning one or more of the effluent launders adjustable support rods (see figure 5-10, circle N).

(2) Sight glass. A sight glass is located on the raw water influent line (see figure 5-6) just prior to the point where the water enters the erdlator. The presence of excessive air bubbles in the sight glass indicates air in the suction line. The suction line should be checked for leaks from the strainer (which may not be sufficiently submerged) to the pump. Foreign matter may also be observed through the sight glass.

(3) Preaeration. The aspirator aeration manifold above the erdlator tank provides aeration of the raw water entering the influent launder. This manifold is equipped with two gate valves (see figure 5-10, circle 0) and a pressure gage (see figure 5-10, circle P). The normal operating pressure with both valves open is 5-7 psi. If the pressure rises above this reading, it indicates that the aspirators are clogged or the valves are closed. Cleaning the aspirators or opening the valves, as appropriate, may remedy this. If numerous air bubbles are observed on the surface of the water in the erdlator tank, it indicates that the water is supersaturated with dissolved gases. This may be remedied by partially closing one or both valves, thus increasing the pressure and obtaining better aeration.

(4) Slurry blanket rotation. The slurry blanket in the erdlator must be kept rotating. Banking of the slurry blanket on the outer perimeter of the tank indicates too much rotation. Insufficient rotation is indicated by lack of movement of the slurry blanket. The rotation is increased or decreased by moving the agitator drive belt (see figure 5-6) to a larger or smaller groove of the motor pulley.

(5) Slurry level and sludge removal. After several hours of continuous operation, the amount of slurry in the erdlator tank will increase until the slurry blanket

reaches the slurry draw-off port (see figure 1-7) where it flows through the slurry weir box (see figure 5-10, circle L) to the sludge concentrator tank (see figure 5-10, circle M). The level of the slurry blanket in both the erdlator tank and the sludge concentrator tank is regulated by the sludge concentrator valves (see figure 1-7). The slurry level in the sludge concentrator tank should be maintained even with the top rim of the circular baffle, and the slurry blanket in the erdlator tank should be kept at a level which will keep the slurry draw-off port just visible.

(6) Wet well warning buzzer and light. The operation of the wet well warning buzzer and red light indicates that the water in the wet well is low. This could be caused by any of the following:

(a) Suction strainer clogged.

(b) Raw water hoses damaged or clogged.

(c) Raw water pump fails to deliver sufficient water.

(d) Aspirators clogged.

(e) Valves not properly positioned.

(7) Filter operation check. Should any of the following occur, the filter should be backwashed and flushed.

(a) Large areas of the filter elements are not covered with diatomaceous earth.

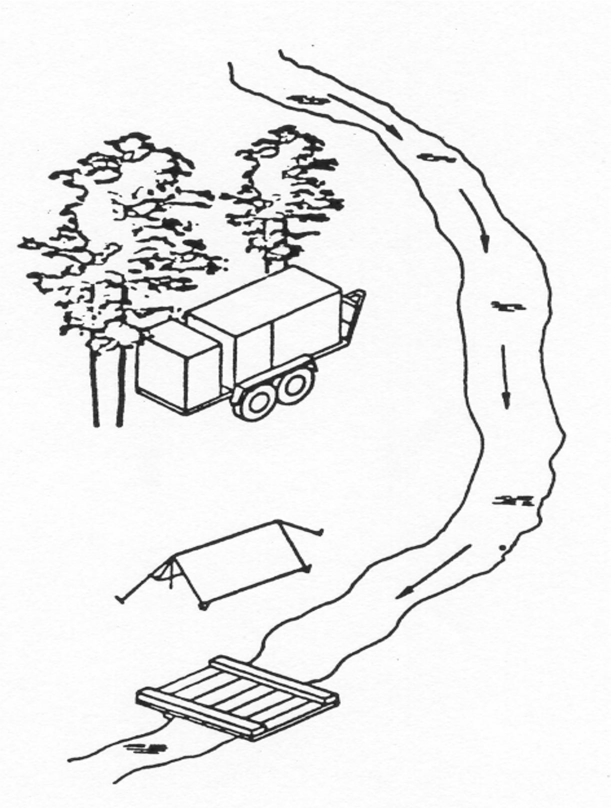
(b) Suspended material is visible in the filtered water or the water appears cloudy.

(c) The effluent pressure gage (see figure 5-11, circle E) indicates less than 4 psi.

(d) The filtered water flow drops noticeably, indicating that it is no longer practical to continue the filter run.

## 5-12. INSTALLATION OF REVERSE OSMOSIS WATER PURIFICATION EQUIPMENT

Figure 5-15 illustrates a typical ROWPU site selection. When choosing the site to set up and run the ROWPU. Remember to follow these important procedural points:



Initial setup location.

Figure 5-15. ROWPU Site selection.

a. **Site Selection**. It may not always be possible to select the best site under tactical conditions. However, many of these requirements should be met for optimum success.

(1) If a stream is going to be used as the raw water source, park the ROWPU trailer upstream from camp.

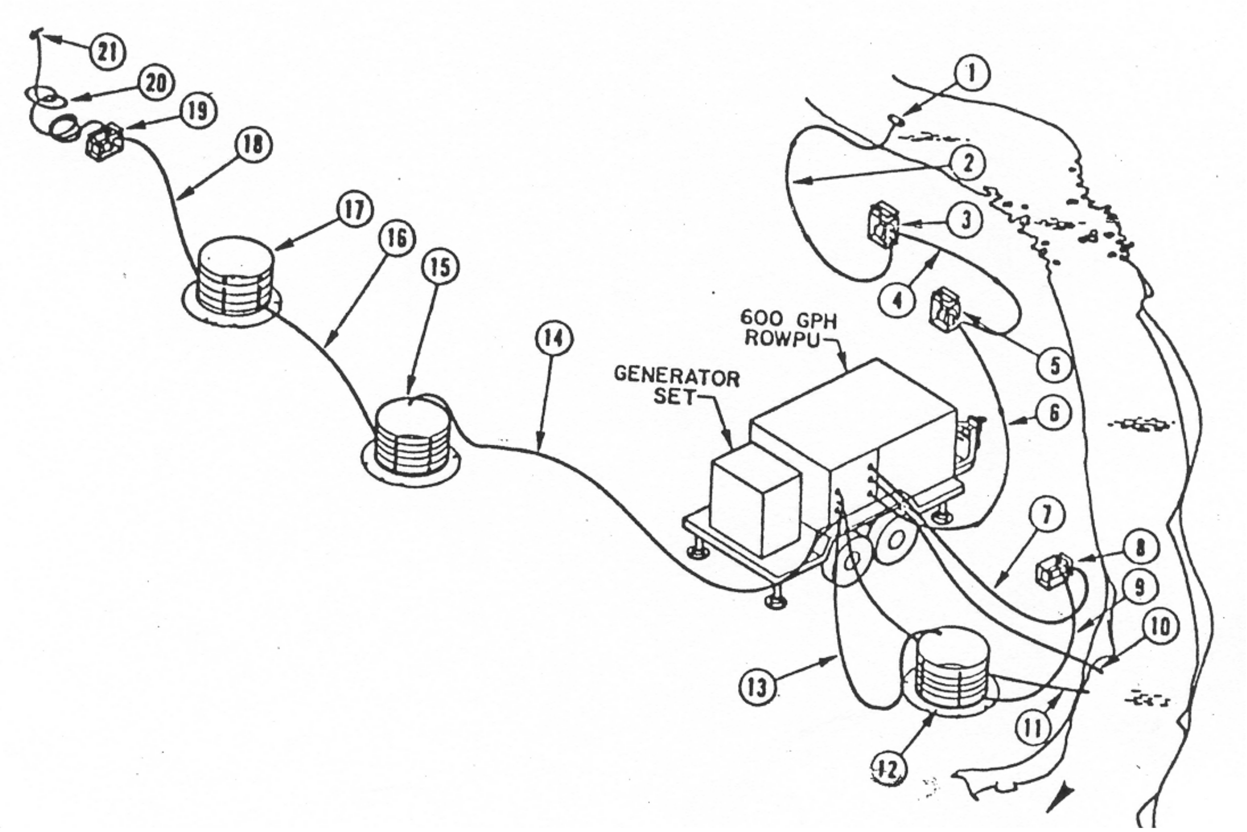
(2) Raw water hoses can reach about 75 feet. Be sure to park the ROWPU trailer close enough so that the hoses reach the stream or lake.

(3) Ensure that the ground is solid and level to house the ROWPU and any other equipment.

(4) Take advantage of finished roads.

(5) Take advantage of a nearby forest or cover.

b. **Locating Equipment**. Figure 5-16 illustrates the setup of a typical ROWPU installation. Figure 5-17 displays the ROWPU water processing block diagram. The circled numbers for figures 5-16 and 5-17 represent the ROWPU sequential process and a brief description of each number follows. Depicted in figure 5-18 is the equipment included in the ROWPU. Illustrations of the ROWPU equipment components: raw water, water distribution, backwash pumps, tubes and chemical feed pump, the entire control panel, and the TOS meter are located in figures 5-19 Parts A, B, C and D.



1. Float and strainer
2. Three inch, hard rubber hoses
3. Raw water pump
4. Two 1½ inch, hard rubber hoses
5. Raw water pump
6. Three 1½, canvas hoses
7. Backwash canvas hose
8. Backwash pump
9. Backwash 2-inch, hard rubber hose
10. Wastewater 2-inch canvas hose
11. Vent vessels
12. Collapsible 1, 500 gallon tank
13. Brine 2-inch, canvas hose
14. Two 1½ inch, hard rubber hoses
15. Collapsible 1,500 gallon tank
16. Product water 1½ inch, hard rubber hose
17. Collapsible 1,500 gallon tank
18. Product 1½ inch, hard rubber hose
19. Distribution pump
20. Product water 1½ inch, canvas hose
21. Distribution nozzle

Figure 5-16. Typical field ROWPU installation.

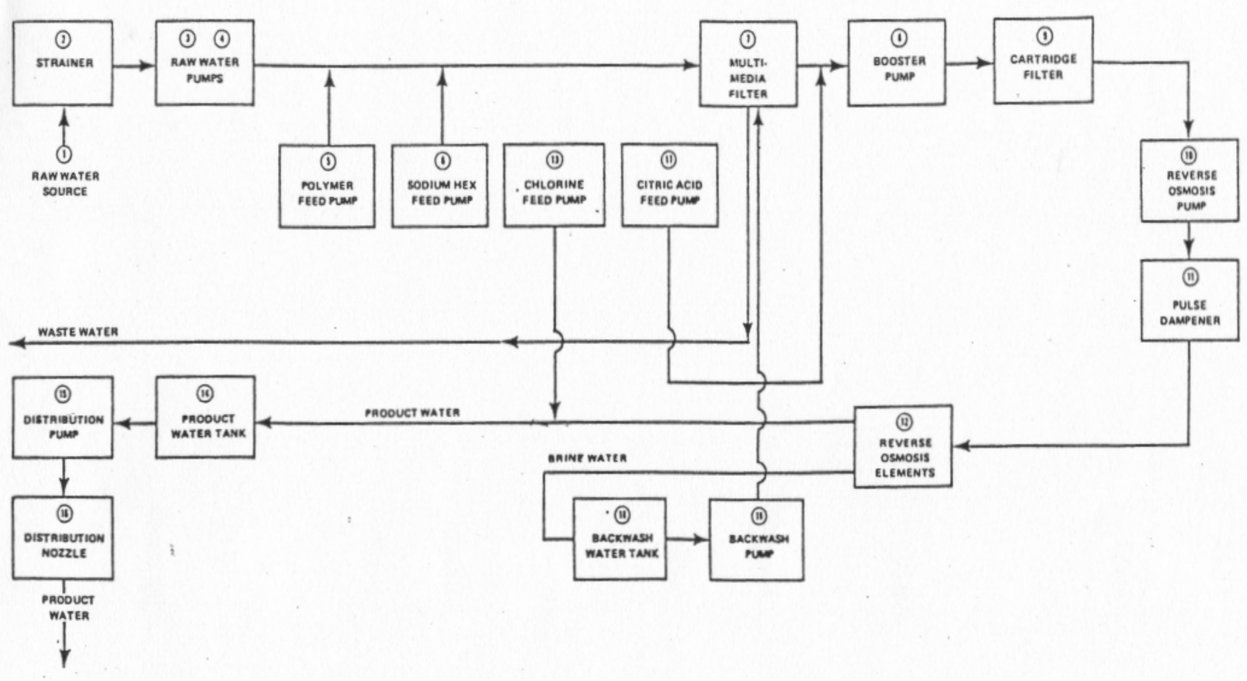


Figure 5-17A. ROWPU processing block diagram.

(1). Raw water source. Whenever water could be found in sufficient quantity to meet company requirements. Water must be free of chlorine.

(2). Strainer. A screen on the end of a suction hose to keep leaves, plants, stones, fish, and dirt out of the pumps and filters of the ROWPU.

(3) (4). Raw water pumps. Draw water from source and pump it into ROWPU under pressure.

(5). Polymer feed pump. Adds polymer (polyellctrolyte) solution to raw water to collect small pieces of floating solid matter into groups large enough to be removed by the multimedia filters.

(6). Sodium hex feed pump. Feeds diluted sodium hex (sodium hexametaphosphate) to raw water to prevent scaling.

(7). Multimedia filter. First stage of filtering for raw water.

(8). Booster pump. Forces filtered water from multimedia filter through the cartridge filter.

(9). Cartridge filter. Second stage of filtering. Very small particles are filtered from water coming out of multimedia filter.

(10). Reverse osmosis (RD) pump. Forces filtered water under high pressure through RD pump.

(11). Pulse dampener. A ball-shaped metal tank used to reduce pulses in water flow caused by pistons of RD pump.

(12). RO elements. Rolls of thin films that separate dissolved solids from the raw filtered water.

(13). Chlorine feed pump. Adds chlorine to product water to kill bacteria to make water in tanks drinkable.

(14). Product water tanks. Storage containers for product (drinkable) water.

(15). Distribution pump. Pumps drinkable water from produced water tank into the water-carrying vehicle or container.

(16). Distribution nozzle. Used for filling user's container with drinkable water coming from product water tanks by way of the distribution pump.

(17). Citric acid feed pump. Adds diluted citric acid (tricarboxylic) to filtered water to maintain the desired pH for the RO process to take place.

(18). Backwash water tank. Stores brine water used for flushing the multimedia filter.

(19). Backwash pump. Pumps brine backwards from backwash tank through the multimedia filter to flush out accumulated dirt and recirculates citric acid solution through the RO elements to clean them.

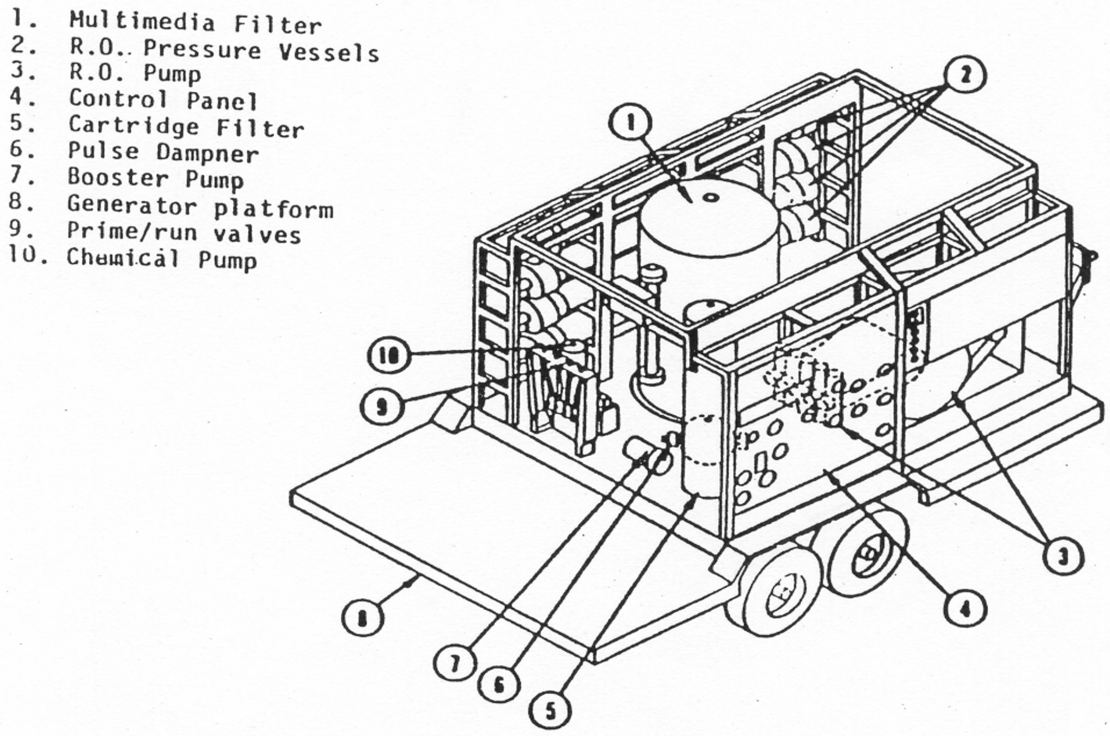
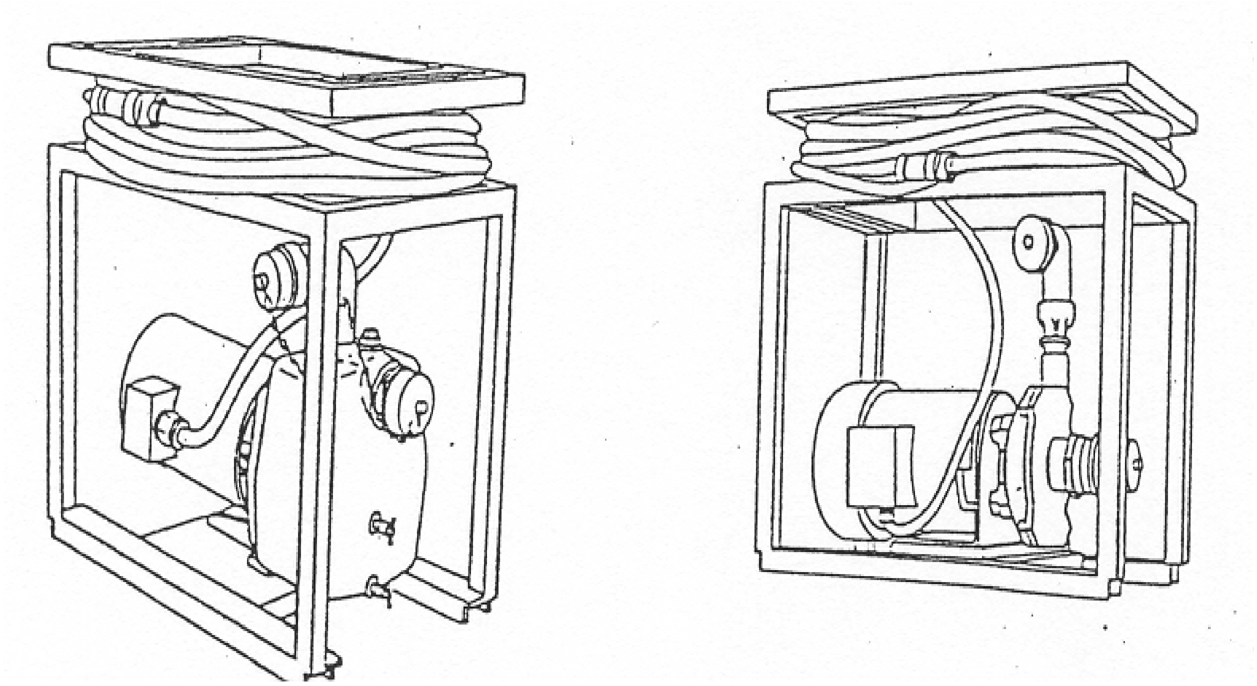
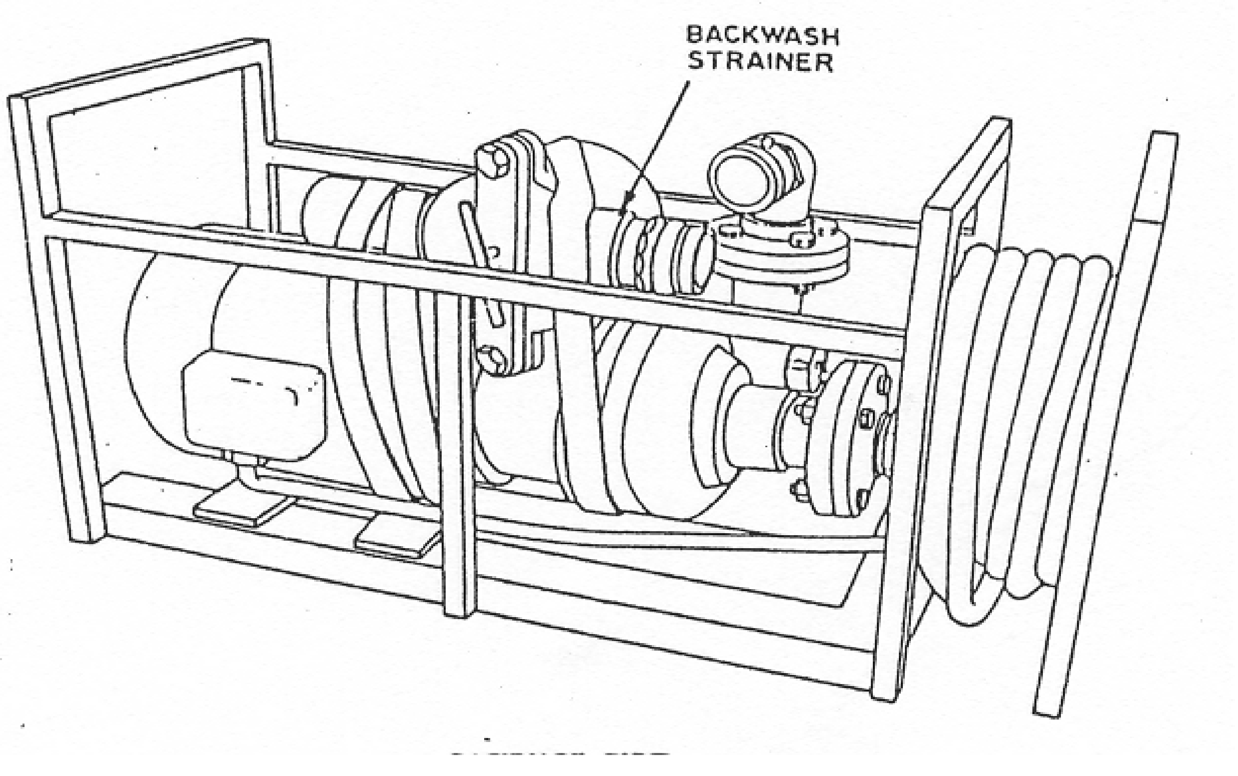


Figure 5-18. Rear view of ROWPU (generator removed).



RAW WATER PUMP (2 USED) Water Distribution Pump



A Raw water, water distribution, and backwash pumps.

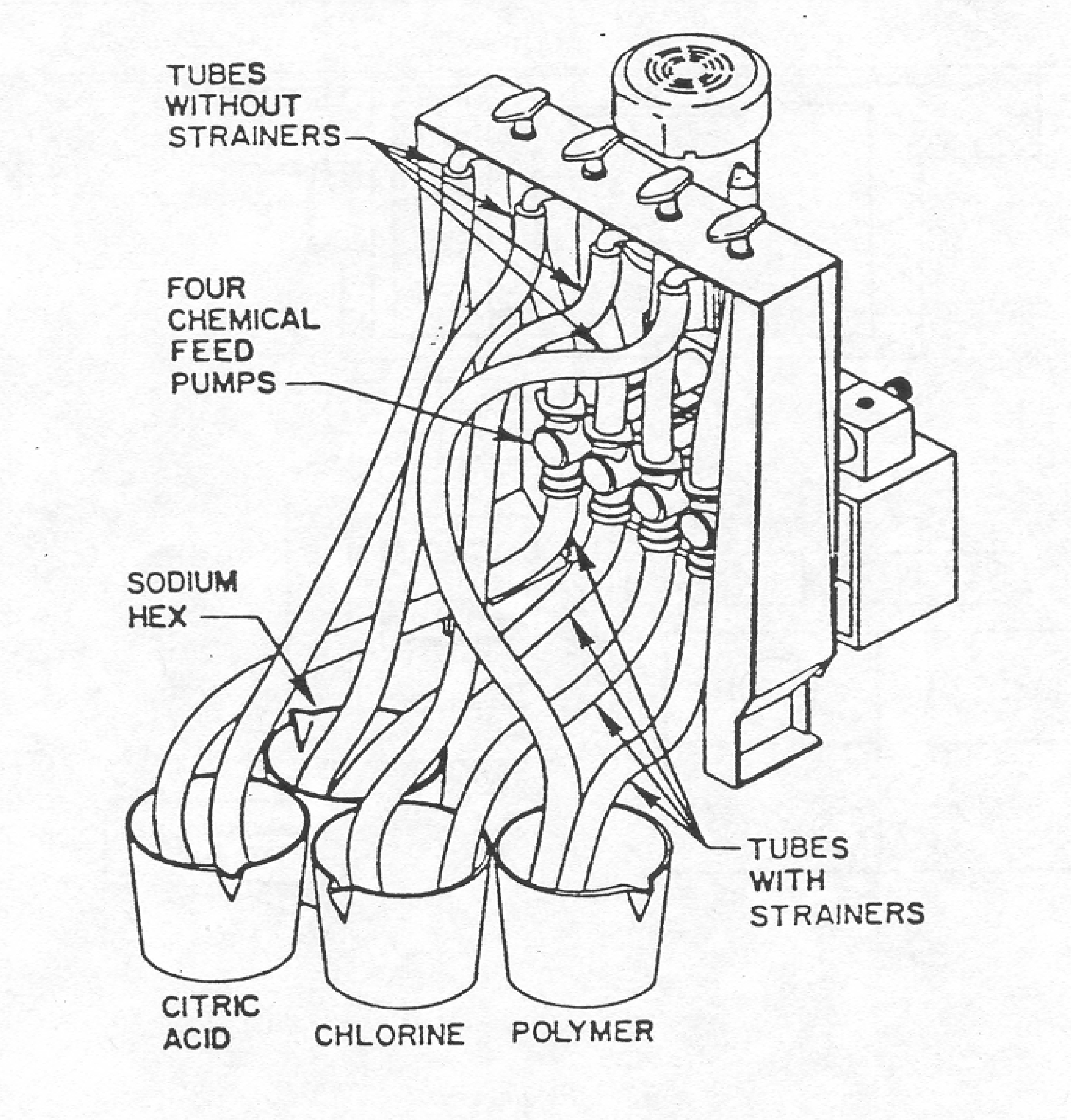
Figure 5-19. ROWPU equipment components

(1). Clear tube with inside support, to POLYMER.

(2) Yellow tube, to SODIUM HEX.

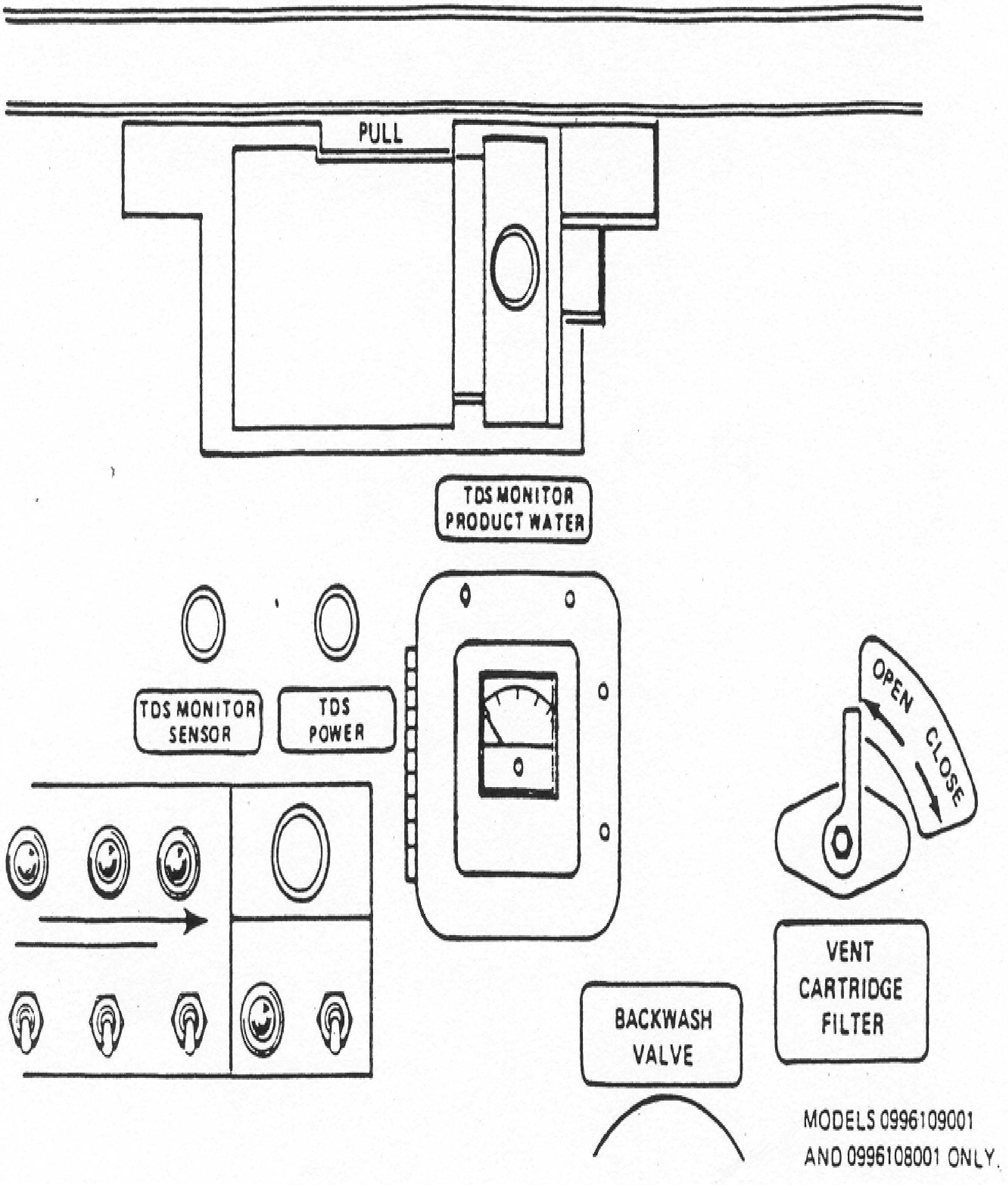
(3). Regular clear tube, to CHLORINE.

(4). Black tube, to CITRIC ACID.



B. Tubes attached to chemical feed pump.

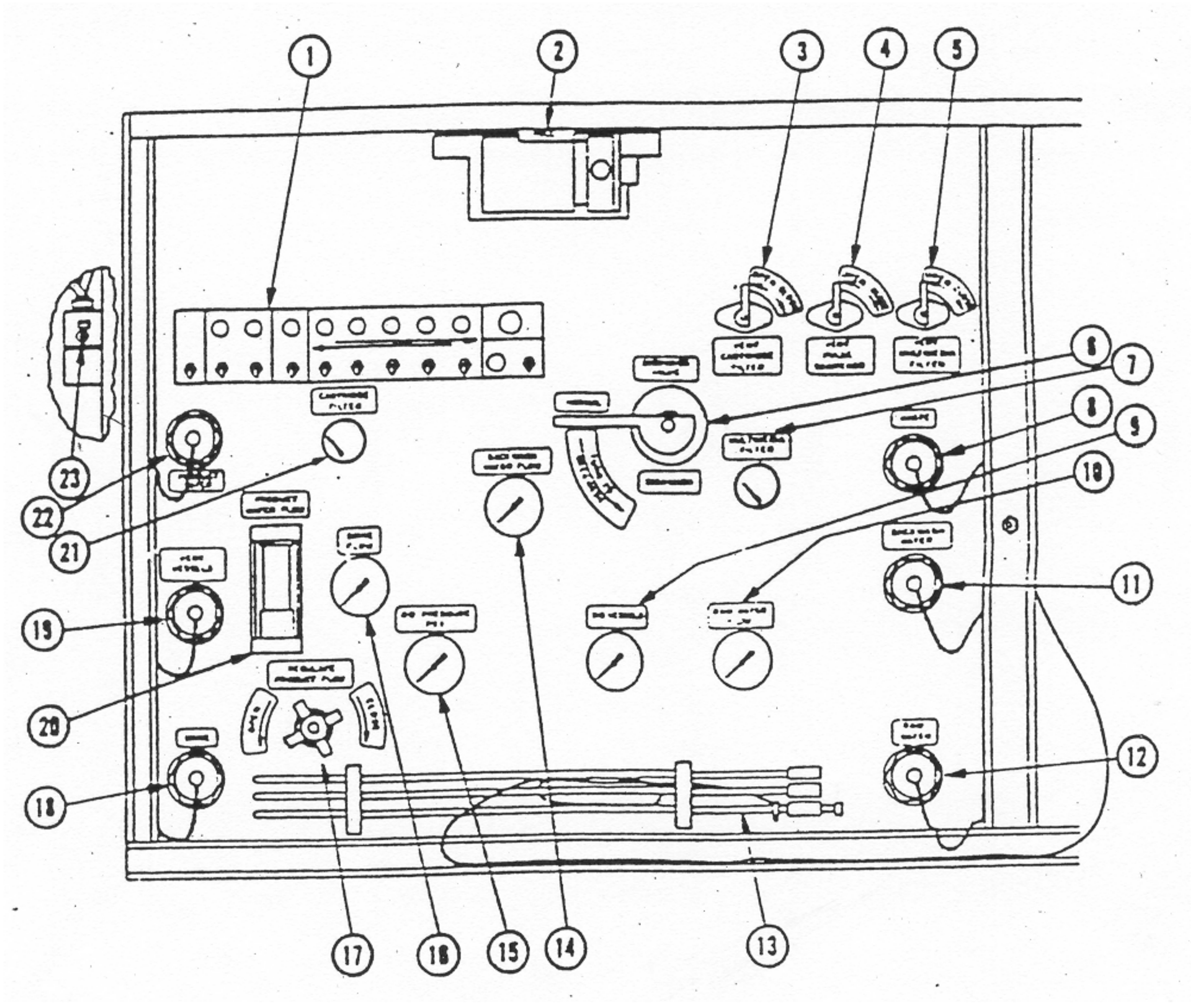
Figure 5-19. ROWPU equipment components (continued).



C TDS meter

Figure 5-19. ROWPU equipment components (continued).

1 Contra1 Box Assembly
2. Raw Water
3: Vent Cartridge Filter
4. Vent pulse Dampener
5. Vent Mu1t1media Filter
6. Backwash Valve
7. Mu1timedia Filter Gage
8. Waste
9. R.O. Ves.se1s Gage
10. Raw Water Flow Meter
11. Backwash Water
12. Panel Light
13. Ground Rods
14. Backwash Water Flow Gage
15. R.O. Pressure P.S.I. Gage
16. Brine Flow Meter
17. Regulate Product Flow Valve
18. Brine
19. Vent Vessels
20. Product Water Flow
21. Cartridge Filter Gage
22. Product 'Water
23. R:O. Element Cleaning Switch



D. Control panel.

Figure 5-19. ROWPU equipment components (continued).

c. **Function of ROWPU Main Components**.

(1) Water intake. The suction hose strainer prevents large pieces of trash from entering the system; while the float holds the suction hose strainer between surface and bottom of the raw water source. The raw water pump draws raw water through the suction hose strainer and sends it under pressure to the multimedia filter.

(2) Chemical input. The chemical feed metering pump assembly draws chemical solutions from cans and injects them into water at various points in the purification system. The chemical feed metering pump motor provides power for four chemical feed metering pump drive units that are illustrated in figure 5-23. These units are as follows:

(a) The Polymer drive unit adds polymer solution to raw water. Polymer solution collects small pieces of floating solid matter into groups large enough to be removed by the multimedia filter. This is a clear tube with inside support.

(b) The sodium hex drive unit adds sodium hex to raw water. Sodium hex prevents scaling. This is a yellow tube.

(c) The citric acid drive unit adds citric acid to output of multimedia filter prior to ROWPU shutdown. Citric acid removes scaling developed in the system during operation. This is a black tube.

(d) The chlorine feed pump uses calcium hypochloride to disinfect the water. This is a regular clear tube.

(3) Filtration. The raw water flow meter indicates the rate of flow of water drawn in by raw water pumps. The backwash valve, in the normal position, allows raw water to enter the multimedia filter and closes the backwash line. When the backwash valve is in the backwash position, it allows brine to enter the multimedia filter and closes the raw water line. There are two stages of filtration. These stages are:

(a) First filtration stage. The multimedia filter control valve (MMFCV) routes the flow of water into and out of the multimedia filter. During normal ROWPU operation, the MMFCV raw water from the backwash valve to the top of the multimedia filter while routing filtered output from the bottom of the multimedia filter to the booster pump. During backwash, the MMFCV routes two flows of water. It routes brine from the backwash valve to the bottom of the multimedia filter as it routes contaminated water from the top of the multimedia filter out of the ROWPU, through the waste outlet on the front panel. The MMFVC also changes the flow rate during different stages of backwash. The multimedia filter performs the first stage of filtration. It removes most of the dissolved solids. The multimedia filter gage indicates differential pressure across the multimedia filter. The vent multimedia filter valve releases air from the multimedia filter while the filter is filling during the ROWPU startup. The booster pump forces output of multimedia filter through the cartridge filter.

(b) Second filtration stage. The cartridge filter performs the second stage of filtration by removing very small dissolved solids. The cartridge filter gage indicates differential pressure across the cartridge filter. The vent cartridge filter valve releases air from the cartridge filter while the filter is filling during ROWPU startup. A low-pressure switch senses pressure in the output line from the cartridge filter. When the line pressure drops below 10 psi this causes the reverse osmosis pump to shut down and the reverse osmosis pump low-pressure indicator to light.

(c) Third filtration stage. The reverse osmosis pump develops high pressure needed to force output of the cartridge filter through the reverse osmosis elements. A rupture disk ruptures to relieve pressure if pressure reaches 1425 psi, as indicated on the reverse osmosis pressure psi gage. This rupture prevents damage to the system if the high-pressure relief valve fails to open and/or if the high-pressure switch fails to shut down the reverse osmosis pump. The pulse damper reduces the pulsing effect of the reverse osmosis pump. It also smooths the flow of water through the reverse osmosis elements. The vent pulse dampener valve releases air from the pulse dampener while the pulse dampener is filling during the reverse osmosis startup. The high-pressure relief valve opens to relieve pressure if the pressure in the line, between the pulse dampener and the reverse osmosis elements goes above 1100 psi. There is a high-pressure switch, which senses pressure in the line between the pulse dampener and the reverse osmosis elements. If pressure rises above 1250 psi and the high-pressure relief valve fails to open, this causes the reverse osmosis pump to shut down and the reverse osmosis pump high-pressure indicator to light. The reverse osmosis pressure psi gage indicates output pressure of the reverse osmosis pump. The reverse osmosis elements perform the final stage in filtration. Water from the pulse dampener flows into the outer shell of one pressure vessel. Inside the pressure vessel, pure water is forced into the two-filter elements through their permeable membrane surfaces. Water, still containing foreign matter, flows through the other three pressure vessels in series. In each pressure vessel, pure water is forced into the filter elements. The remaining unfiltered water (brine) flows out of the ROWPU for storage in the backwash water tank. Pure water flows out of the center of each pair of filter elements into a common pipe that carries the water out of the ROWPU for storage in the product water tanks. Connections between pressure vessels are different in the two models, but the operation is identical. The reverse osmosis vessels gage indicates differential pressure across the reverse osmosis elements.

(4) <u>Brine collection</u>. The brine flow meter indicates the salt of brine flow out to the backwash water tank. The backwash water tank collects the water rejected by the reverse osmosis elements (brine) for use in backwashing the multimedia filter and in cleaning the reverse osmosis elements. Controlling the flow of brine from the backwash water tank is the backwash tank valve. The backwash pump forces brine backward through the multimedia filter during backwash. Output from the multimedia filter is dumped out of the ROWPU through the waste hoses. When the backwash cycle is complete, the output from the backwash pump is connected to the vent vessels line. Brine mixed with citric acid is then forced through the reverse osmosis elements to clean them. The solution is returned to the backwash water tank and recirculated by the

backwash pump. Product water is sent to the backwash water tank during this procedure to keep the citric acid solution from becoming concentrated. The backwash pump strainer filters brine before it enters the multimedia filter or reverse osmosis elements. Indicating the rate of brine flow into the multimedia filter during backwash is the backwash water flow gage. The check valve prevents raw water from entering the backwash water line. During ROWPU startup, the vent vessels valve bypasses the reverse osmosis elements until the multimedia filter stabilizes. During element cleaning, the vent vessels valve passes brine/citric acid solution from the backwash pump to the reverse osmosis elements.

(5) Potable/drinking storage. The produce water sample ball valves provide samples of filtered water at input ends of the pressure vessels. The product water sample elliptic valves, in the normal position, pass the product water out of the reverse osmosis elements to the product water tanks. In the sample position, the valves direct the product water out of each reverse osmosis vessel as a sample. Design prevents shutdown of the water flow while switching between the normal and the sample position. The chemical feed metering pump chlorine drive unit adds chlorine to the product water to prevent bacteria growth. Controlling the rate of product water flow to the product water tanks is the regulate product flow valve. The check valve prevents back flow in the product line. The product water flow gage indicates the rate of product water flow to the product water tanks. The water meter (totalizer type meter) indicates the total amount of possible water produced by the ROWPU. There is an in-line TDS monitor that indicates the quality of the product water, calibrated in total dissolved solids (TDS). Two product water tanks store the product/potable water. A valve controls the flow of produce water from the first product water tank to the other.

(6) Water distribution. The distribution pump develops pressure to move the product water from the product water tanks through the distribution nozzle. This nozzle controls the rate of flow of the product water from the product water tanks to the user. Chemical and radiological filters overpack items used to remove chemical or radiological contaminants from the product water. Overpack contains all hardware and tubing needed to connect one or the other filters in line between the two product water tanks. This is only installed when needed. Operating life is 100 hours for either type of filter.

d. **Miscellaneous**.

(1) Chemical supplies. The operator should have ample quantities of chemical supplies on hand for his immediate operational requirements and evidence of additional quantities "due in" for future needs. Chemicals should be stored in a cool, dry place away from any fire hazard and segregated to preclude accidental mixing.

(2) Records and publications. In addition to the pertinent TM for the type of equipment in use, the operator should maintain the following records:

(a) DA Form 1712-R (Water Reconnaissance Report) (see figure 5-20)

(b) DA Form 1713-R (Daily Water Production Log--Erdlator) (see figure 5-21).

(c) DA Form 1713-1-R (Daily Water Production Log---ROWPU) (see figure 5-22).

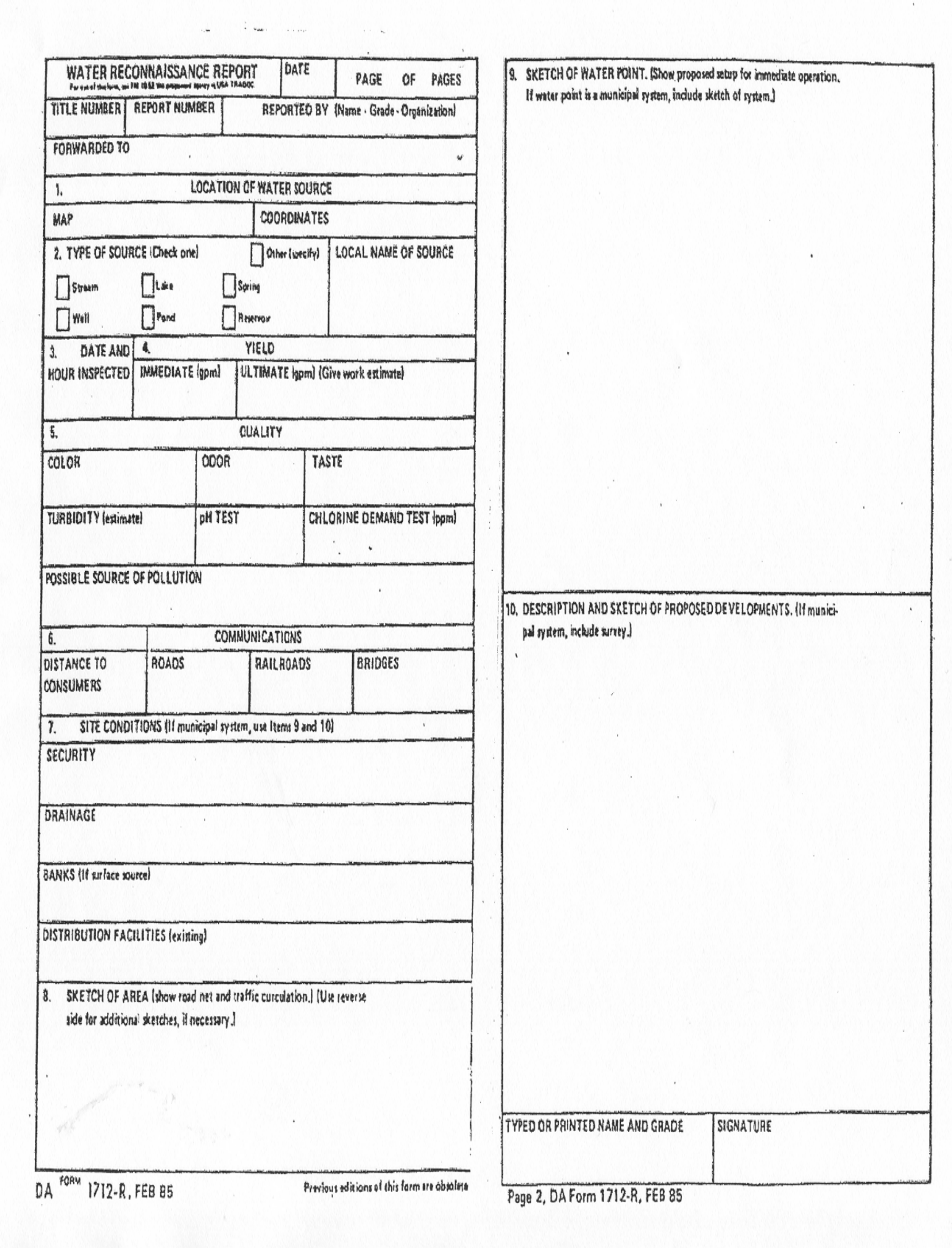
(d). DA Form 1714-R (Daily Water Distribution Log) (see figure 5-23).

(e) DA Form 1716-R (Water Point Daily Production Summary) (see figure 5-24).

(f) DA Form 1717-R (Water Point Daily Distribution Summary) (see figure 5-25).

(3) Test equipment. The operator should have all required test equipment in clean, serviceable condition.

(4) Operators. Sufficient personnel should be present to operate the equipment for extended time periods. Operators should be qualified in the operation of the equipment and the conduct of necessary tests. They should also be knowledgeable concerning the regulations and directives under which they are operating.



WATER RECONNAISSANCE REPORT
DATE
PAGE OF PAGES
TITLE NUMBER
REPORT NUMBER
REPORTED BY (Name - Grade - Organization)
FORWARDED TO

1. LOCATION OF WATER SOURCE
MAP
COORDINATES

2. TYPE OF SOURCE (Check one)
☐ Other (specify)
☐ Stream ☐ Lake ☐ Spring
☐ Well ☐ Pond ☐ Reservoir
LOCAL NAME OF SOURCE

3. DATE AND HOUR INSPECTED

4. YIELD
IMMEDIATE (gpm)
ULTIMATE (gpm) (Give work estimate)

5. QUALITY
COLOR
ODOR
TASTE
TURBIDITY (estimate)
pH TEST
CHLORINE DEMAND TEST (ppm)
POSSIBLE SOURCE OF POLLUTION

6. COMMUNICATIONS
DISTANCE TO CONSUMERS
ROADS
RAILROADS
BRIDGES

7. SITE CONDITIONS (If municipal system, use Items 9 and 10)
SECURITY
DRAINAGE
BANKS (If surface source)
DISTRIBUTION FACILITIES (existing)

8. SKETCH OF AREA (show road net and traffic curculation.) (Use reverse side for additional sketches, if necessary.)

DA FORM 1712-R, FEB 85
Previous editions of this form are obsolete

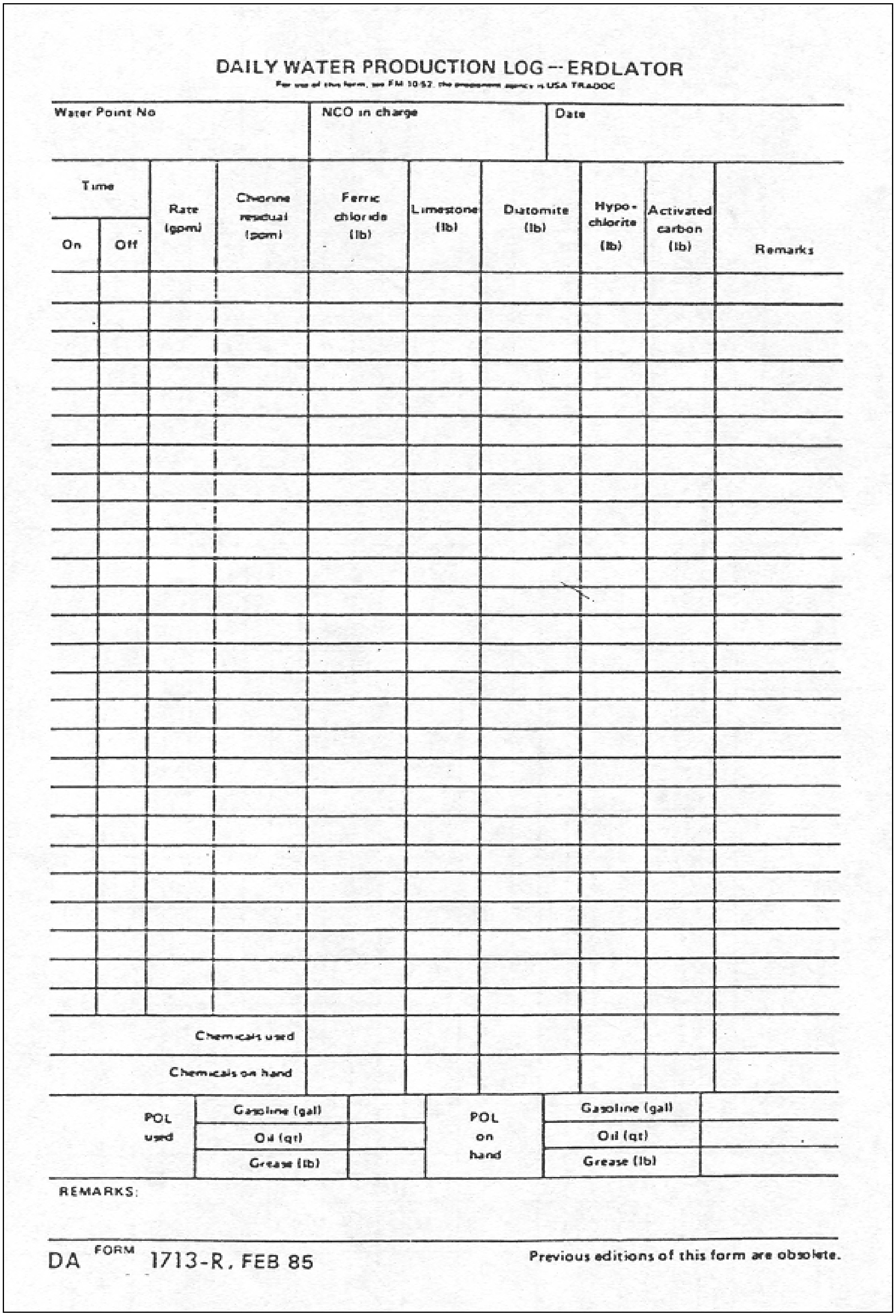
9. SKETCH OF WATER POINT. (Show proposed setup for immediate operation. If water point is a municipal system, include sketch of system.)

10. DESCRIPTION AND SKETCH OF PROPOSED DEVELOPMENTS. (If municipal system, include survey.)

TYPED OR PRINTED NAME AND GRADE
SIGNATURE

Page 2, DA Form 1712-R, FEB 85

Figure 5-20. DA form 1712-R (Water Reconnaissance Report).



DAILY WATER PRODUCTION LOG---ERDLATOR

For use of this form, see FM 10-52; the proponent agency is USA TRADOC

| | | |
|---|---|---|
| Water Point No | NCO in charge | Date |

| Time | | Rate (gpm) | Chlorine residual (ppm) | Ferric chloride (lb) | Limestone (lb) | Diatomite (lb) | Hypo-chlorite (lb) | Activated carbon (lb) | Remarks |
|---|---|---|---|---|---|---|---|---|---|
| On | Off | | | | | | | | |
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| Chemicals used | | | | | | | | | |
| Chemicals on hand | | | | | | | | | |

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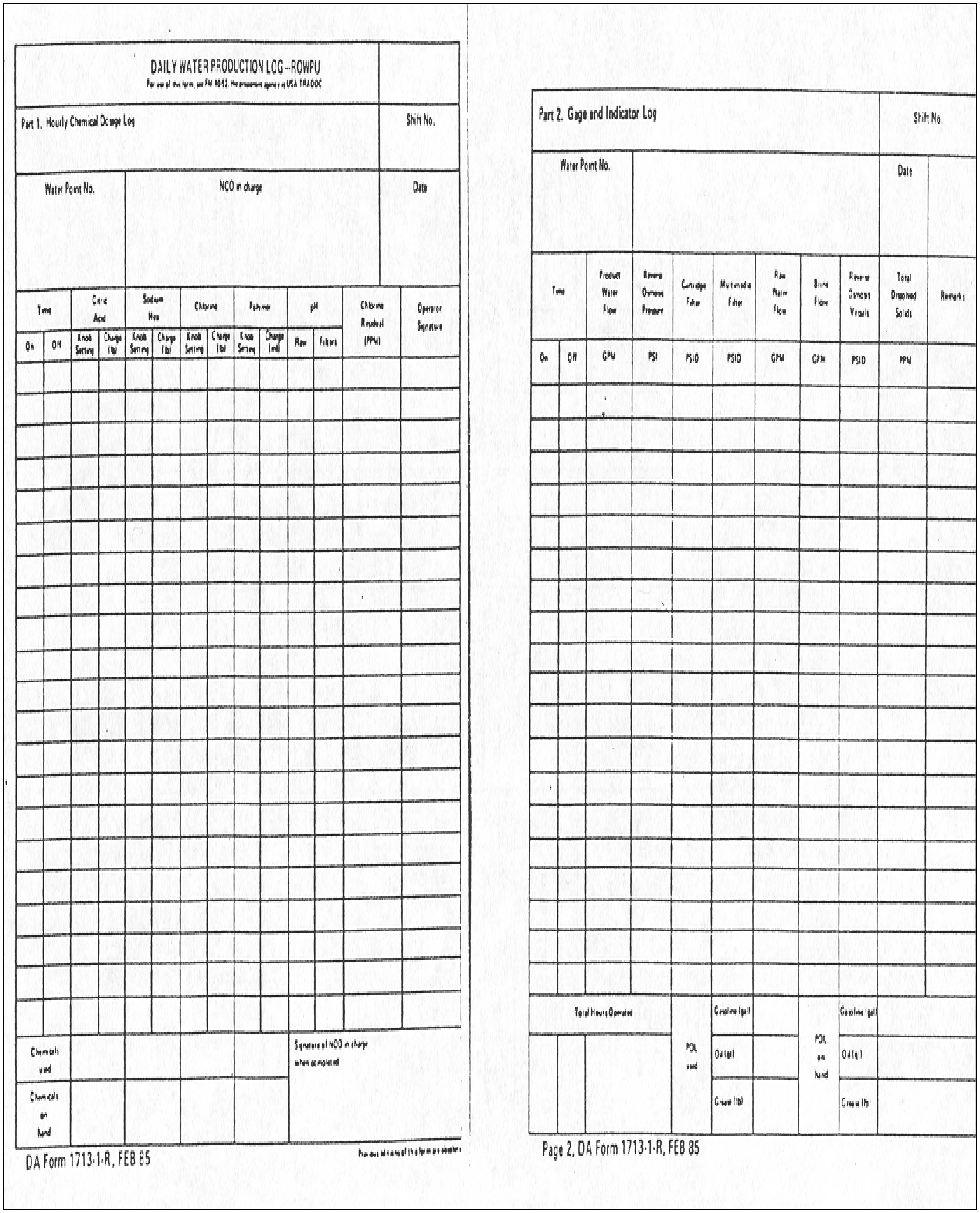
|---|---|---|---|---|---|
| POL used | Gasoline (gal) | | POL on hand | Gasoline (gal) | |
| | Oil (qt) | | | Oil (qt) | |
| | Grease (lb) | | | Grease (lb) | |

REMARKS:

DA FORM 1713-R, FEB 85

Previous editions of this form are obsolete.

Figure 5-21. DA Form 1713-R (Daily Water Production Log---Erdlator.



DAILY WATER PRODUCTION LOG--ROWPU

For use of this form, see FM 10-52; the proponent agency is USA TRADOC

Part 1. Hourly Chemical Dosage Log

Shift No.

Water Point No.

NCO in charge

Date

| Time | | Citric Acid | | Sodium Hex | | Chlorine | | Polymer | | pH | | Chlorine Residual (PPM) | Operator Signature |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| On | Off | Knob Setting | Charge (lb) | Knob Setting | Charge (lb) | Knob Setting | Charge (lb) | Knob Setting | Charge (ml) | Raw | Filters | | |
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|---|---|---|---|---|---|
| Chemicals used | | | | | Signature of NCO in charge when completed |
| Chemicals on hand | | | | | |

DA Form 1713-1-R, FEB 85

Previous editions of this form are obsolete

Part 2. Gage and Indicator Log

Shift No.

Water Point No.

Date

| Time | | Product Water Flow | Reverse Osmosis Pressure | Cartridge Filter | Multimedia Filter | Raw Water Flow | Brine Flow | Reverse Osmosis Vessels | Total Dissolved Solids | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|
| On | Off | GPM | PSI | PSID | PSID | GPM | GPM | PSID | PPM | |
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|---|---|---|---|---|---|---|---|---|
| Total Hours Operated | | | POL used | Gasoline (gal) | | POL on hand | Gasoline (gal) | |
| | | | | Oil (qt) | | | Oil (qt) | |
| | | | | Grease (lb) | | | Grease (lb) | |

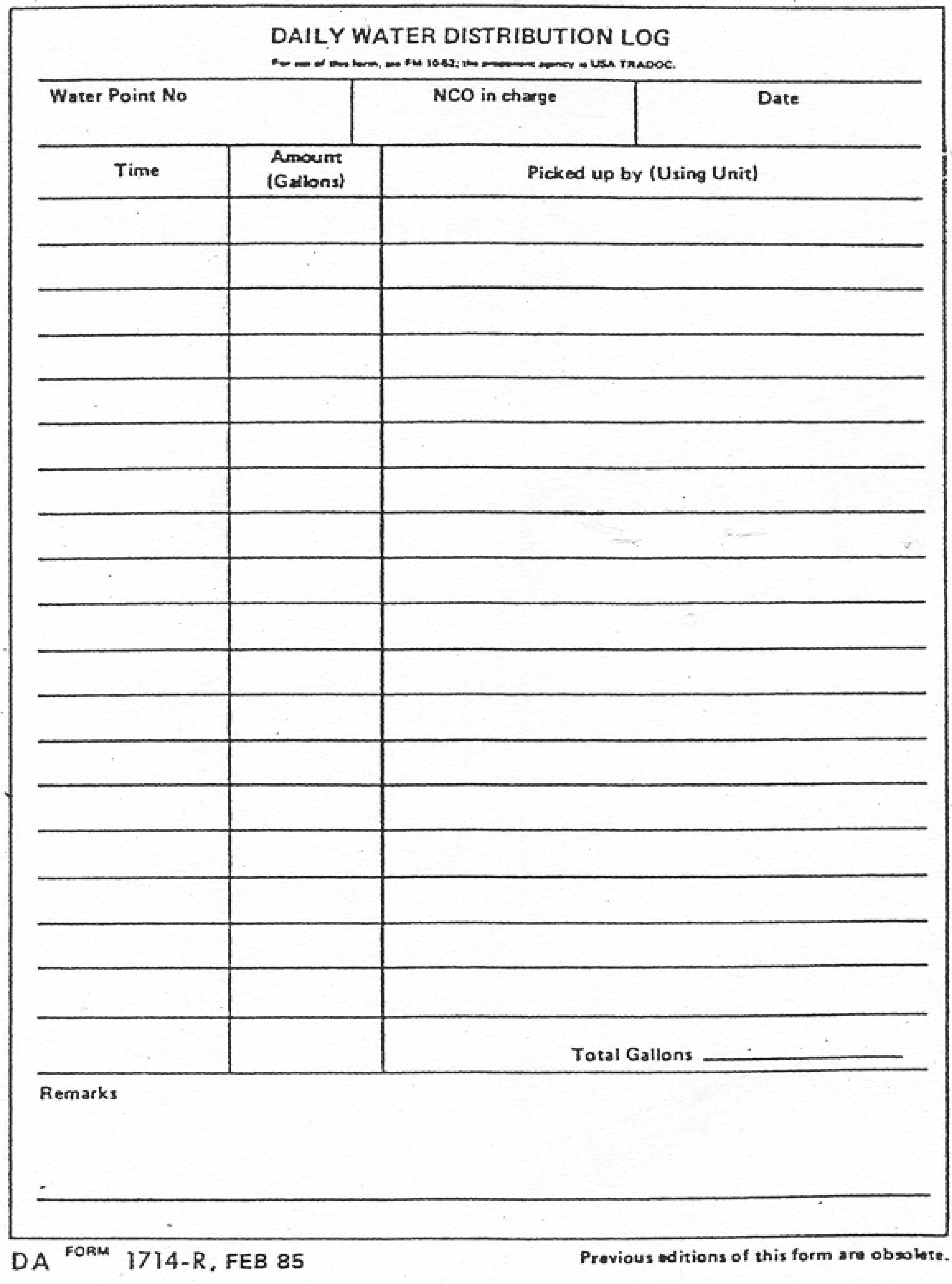
Page 2, DA Form 1713-1-R, FEB 85

Part 1. Erdlators of front of form.

Part 2. ROWPU back of form.

Figure 5-22. DA Form 1713-1-R

(Daily Water Production Log--ROWPU)



DAILY WATER DISTRIBUTION LOG

For use of this form, see FM 10-52; the proponent agency is USA TRADOC.

| | | |
|---|---|---|
| Water Point No | NCO in charge | Date |

| Time | Amount (Gallons) | Picked up by (Using Unit) |
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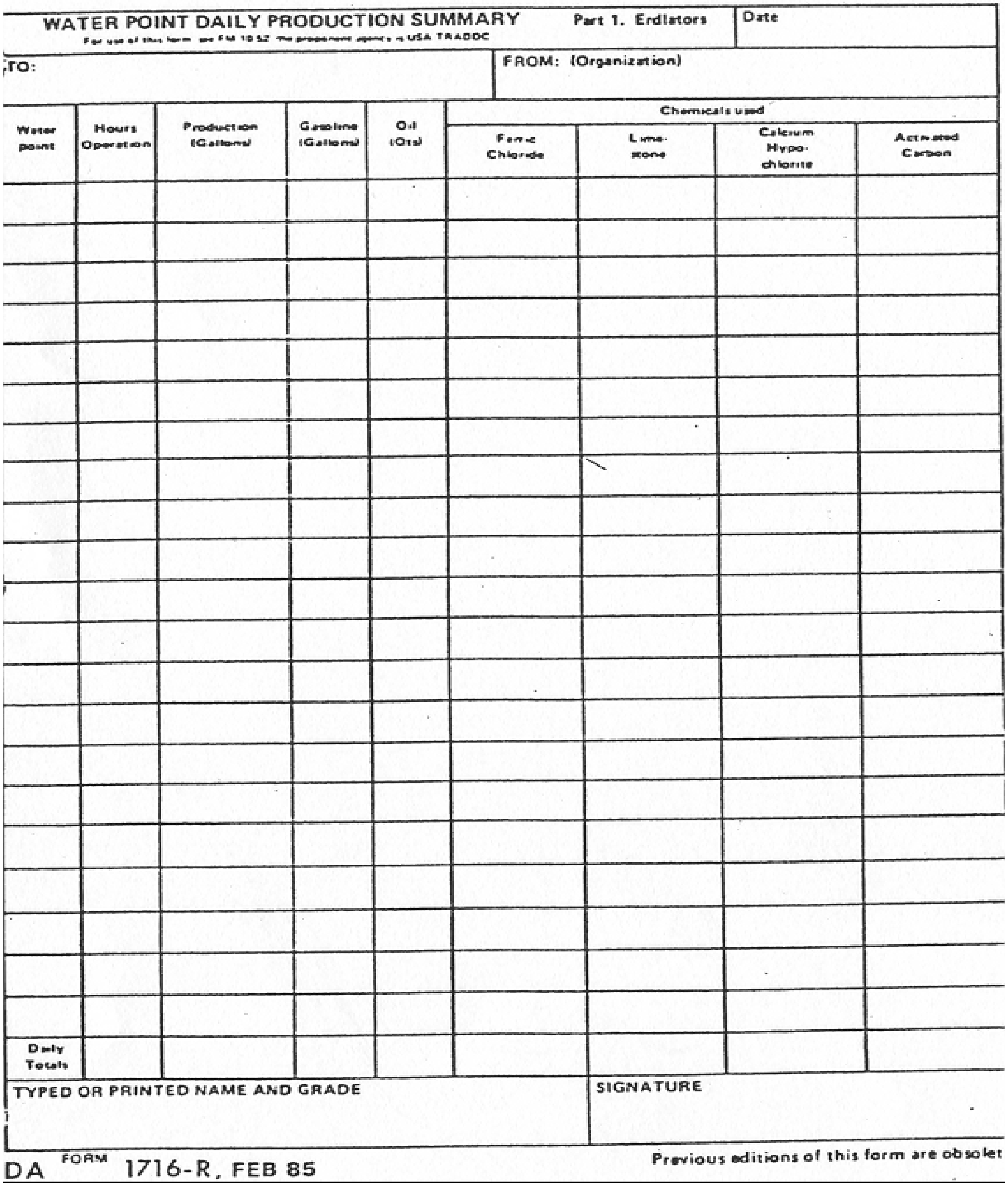
| | | Total Gallons ____________ |

Remarks

DA FORM 1714-R, FEB 85 Previous editions of this form are obsolete.

Figure 5-23. DA Form 1714-R (Daily Water Distribution Log).



WATER POINT DAILY PRODUCTION SUMMARY

For use of this form, see FM 10-52; the proponent agency is USA TRADOC

Part 1. Erdlators

Date

TO:

FROM: (Organization)

| Water point | Hours Operation | Production (Gallons) | Gasoline (Gallons) | Oil (Qts) | Chemicals used | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | Ferric Chloride | Lime-stone | Calcium Hypo-chlorite | Activated Carbon |
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| Daily Totals | | | | | | | | |

TYPED OR PRINTED NAME AND GRADE

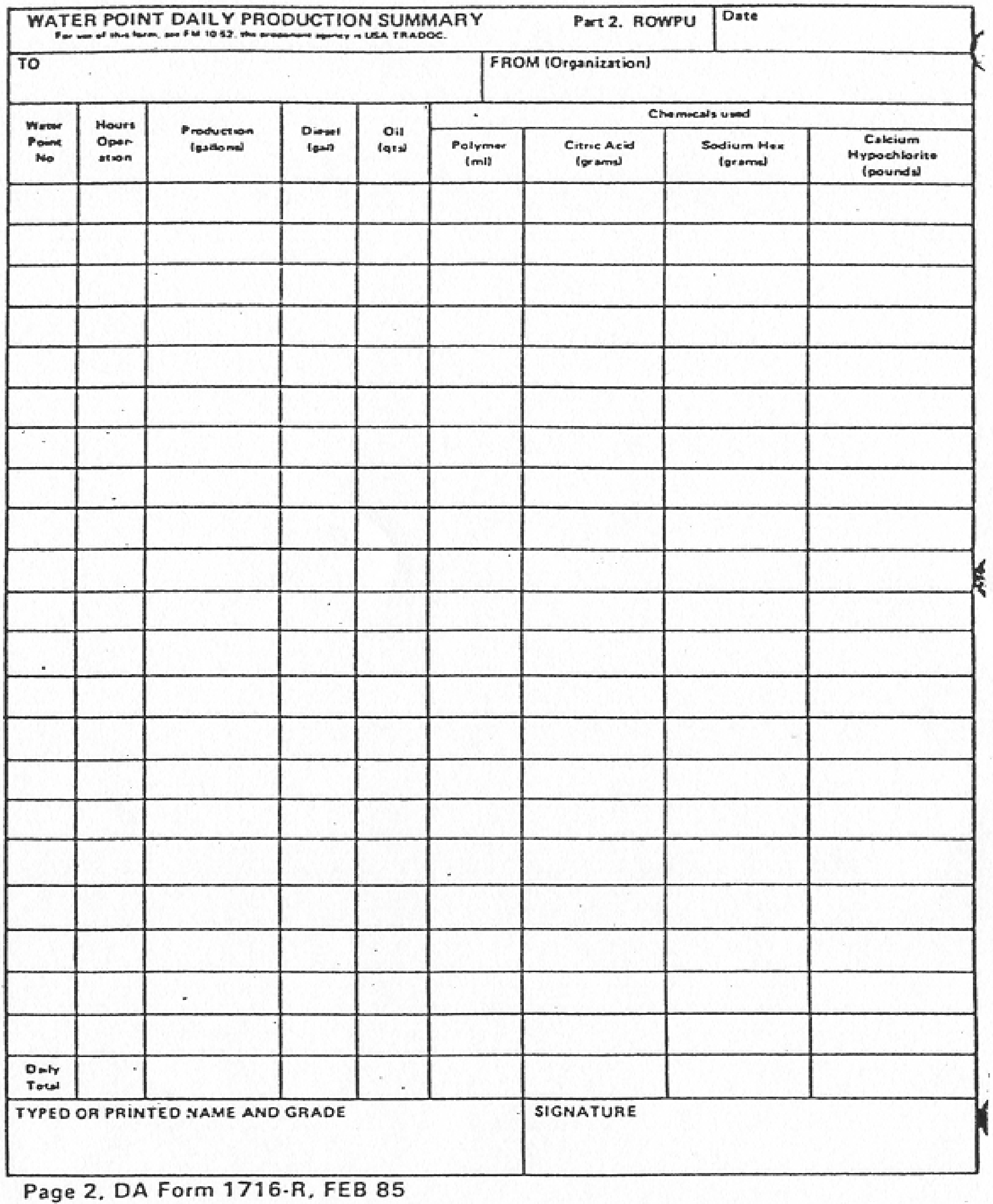
SIGNATURE

DA FORM 1716-R, FEB 85

Previous editions of this form are obsolet

Part 1. Erdlators of front of form.

Figure 5-24. DA Form 1716-R (Water Point Daily Production Summary)



**WATER POINT DAILY PRODUCTION SUMMARY** Part 2. ROWPU

For use of this form, see FM 10-52; the proponent agency is USA TRADOC.

Date

TO

FROM (Organization)

| Water Point No | Hours Operation | Production (gallons) | Diesel (gal) | Oil (qts) | Chemicals used | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | Polymer (ml) | Citric Acid (grams) | Sodium Hex (grams) | Calcium Hypochlorite (pounds) |
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| Daily Total | | | | | | | | |

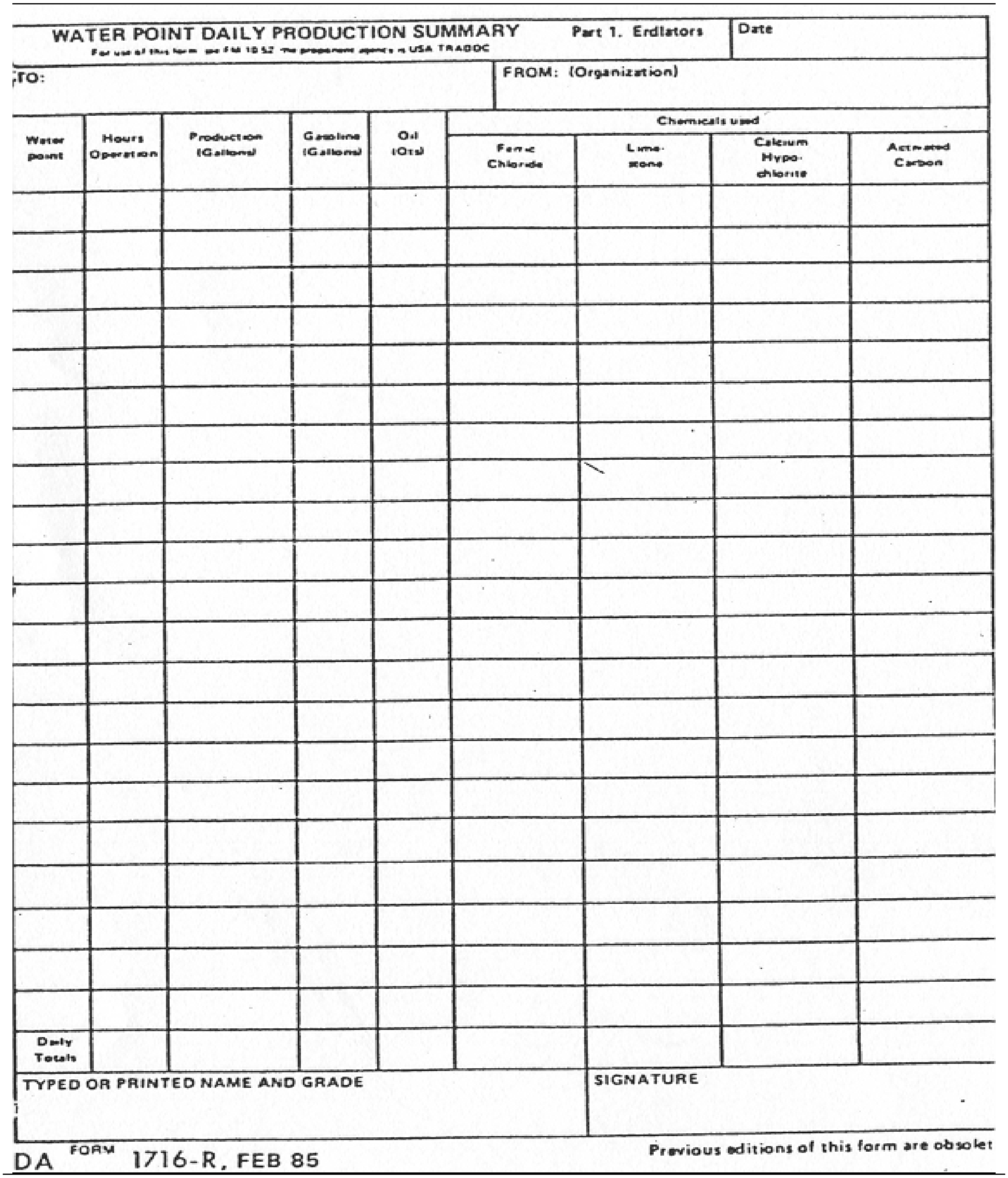
TYPED OR PRINTED NAME AND GRADE

SIGNATURE

Page 2, DA Form 1716-R, FEB 85

Part 2. ROWPU back of Form.

Figure 5-24. DA Form 1716-R (Water Point Daily Production Summary).



**WATER POINT DAILY PRODUCTION SUMMARY** Part 1. Erdlators

For use of this form see FM 10-52; the proponent agency is USA TRADOC

Date

TO:

FROM: (Organization)

| Water point | Hours Operation | Production (Gallons) | Gasoline (Gallons) | Oil (Qts) | Chemicals used | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | Ferric Chloride | Lime-stone | Calcium Hypo-chlorite | Activated Carbon |
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| Daily Totals | | | | | | | | |

TYPED OR PRINTED NAME AND GRADE

SIGNATURE

DA FORM 1716-R, FEB 85

Previous editions of this form are obsolet

Figure 5-24. DA Form 1716-R (Water Point Daily Production Summary).

*Continue with Exercises*

## EXERCISES, LESSON 5

**INSTRUCTIONS:** Answer the following exercises by marking the lettered response that best answers the exercise, by completing the incomplete statement, or by writing the answer in the space provided at the end of the exercise.

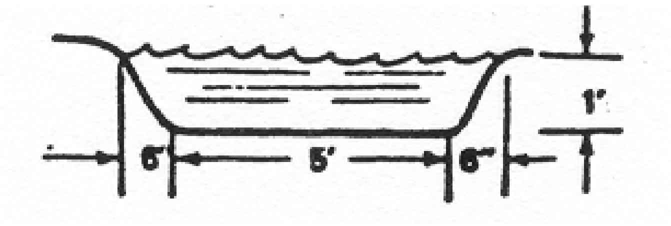
After you have completed all of these exercises turn to "Solutions to Exercises" at the end of the lesson and check your answers. For each exercise answered incorrectly, reread the material referenced with the solution.

1. If the head is 7 1/2 inches, what is the flow, in gpm, of a stream of water flowing over a 90º V-notch weir? _______________.

2. If it takes a floating stick 30 seconds to travel 60 feet down a stream, which are 10 feet wide and has an average depth of 3 feet, what is its rate of f low, in gpm? ___________________.

3. What is the capacity, in gpm, of a pump delivering water from a well, if the delivery pipe is horizontal, has an inside diameter of 2.07 inches, the horizontal axis of which is 12 inches above the ground, and which delivers a stream of water which impacts at a horizontal distance of 3 feet from the end of the pipe? __________.

4. If it takes a cork 10 seconds to travel 30 feet, what is the rate of flow of the stream whose cross section is depicted below? ________________.



5. If a 5-acre lake has an average depth of 15 feet, what is its capacity, in gallons? _________________________.

6. Which considerations are important for the proper selection of a field water purification unit site?

   a. Good view.

   b. Level terrain.

   c. Access to roads and power lines.

   d. Adequate buildings for housing personnel.

   e. Adequate utilities (sewer, water, and gas).

   f. Area large enough to accommodate all equipment.

7. The intake for a WPU should never be located near, and always upstream from:

   a Dams.

   b. Rapids.

   c. Latrines.

   d. Fishing areas.

   e. Bathing areas.

   f. Sewer outlets.

8. The raw water pump should be placed not more than ______ feet from the WPC.

9. The raw water suction hose should always be at least ___________ incles below the surface water.

10. How many feet should the suction strainer be below the surface if the water at the source is 6 feet deep?

11. Which of the following chemicals are required in the treatment and filtration process?

    a. Ferrous sulfate.

    b. Ferric chloride.

    c. Activated carbon.

    d. Sodium aluminate.

    e. Aluminum sulfate.

    f. Calcium carbonate.

    g. Sodium bicarbonate.

    h. Diatomaceous earth.

    i. Calcium hypochlorite.

12. Which two chemicals should not be mixed while chemical feeding the erdlator during the water treatment process?___________________________________.

13. What does the chemical solution feeder control for the erdlator unit? _________________________________.

14. The erdlator slurry feeder contains two compartments that supply ____________ and ____________________________ to the coagulant.

15. Which tank functions as a small auxiliary clarifer during coagulation? __________________________.

16. Which way does the water flow during backwashing? ______________________.

17. Diatomite slurry for precoating the filter elements is introduced through the:

    a. Precoat funnel.

    b. Wet well tank.

    c. Erdlator tank.

    d. Chemical slurry feeder.

18. Under which of the following circumstances is it appropriate to recirculate filtered water?

    a. While precoating the filter elements.

    b. When the warning light and buzzer indicate a low water level in the wet well tank.

    c. When the effluent pressure gage reading drops to about 5 psi.

    d. When there is no demand for water, but it is desired to maintain the coating on the filter elements.

    e. When the flow of water from the filter is greatly diminished, indicating clogged filter elements.

19. When finished water does not have sufficient chlorine residual, the water will require _____________ chlorination before it may be consumed.

20. What initial scale reading should be set on the calcium hypochlorite feeder control of a 1,500 gph WPU if a raw water has a chlorine demand of 5 ppm and the required chlorine residual is 2 ppm? _____ (gal/hr).

21. What is the chlorine demand if 1 ml of a 5,000 ppm chlorine stock solution is added to 1,000 ml of raw water, and after a 30-minute contact period the chlorine residual is 3 ppm? ____ ppm.

22. What is indicated if the coagulated water has a reddish color to it? ___________________________.

23. Where should the ROWPU trailer be located if a stream is to be used as a raw water source? ____________________________.

24. What is removed by the ROWPU multimedia filters when polymer solution is added to raw water? ______________________________________

25. List the four chemical feed metering pump drive units.

________________________ ________________________

________________________ ________________________.

26. Which filter removes most of the dissolved solids during the ROWPU first filtration stage? ______________________________.

27. The line pressure must drop below ________ psi before the reverse osmosis pump shuts down during the ROWPU second filtration phase?

28. Which elements perform the final stage in ROWPU filtration?
_______________________________________.

29. During the third filtration stage, the water, still containing foreign matter, flows through how many other pressure vessels? ______________________________.

30. What is the water called that is rejected by reverse osmosis elements, and what service does it serve? ________________________________________________
____________________________________________________________________.

***Check Your Answers on Next Page***

## SOLUTIONS TO EXERCISES, LESSON 5

1. 354 gpm (table 5-2c(1. 22,889 gpm Q = .85 AV

2. 22,889 gpm Q = .85 AV

   A = 10 ft + x 3 ft = 30 ft 2ft$^2$

   $$= (.85)\ (30\ \text{ft2})\ (2\ \text{ft/sec})\quad V = \frac{60\ \text{ft}}{30} = 2\ \text{ft/sec.}$$

   $$= \frac{51\ \text{ft3}}{\text{sec.}}$$

   = 51 X 7.48 gal X 60 sec = 22,888.8 (para 5-2c(2))

3. 126 gpm (figure 5-2 or table 5-1)

   $$\frac{2.83 \times (2.07) \times 36}{(1\ (12)\ 1/2)} = \frac{436.55}{3.464} = 126\ \text{gpm}$$

4. 6,294 gpm

   $$A1 = \frac{1' \times .5'}{2} = 0.25\ \text{ft}^2$$

   A2 = I' x .5'= 5.00 ft$^2$

   $$A3 = \frac{\text{I' X .5' = 0.25 ft}^2}{2}$$

   A = 5.5 ft$^3$

   Q = .85 AV
   = .85 x 5.5 ft2 x 3 ft/sec
   = 14.025 ft3/sec x 448.8 = 6294.41 gpm. (para 5-2)

5. 24,437,160 gal
   5 acres X 43,560 ft2/acre = 217,800 ft$^2$
   217,800 ft$^2$ X 15 ft = 3,267,000 ft$^3$
   3,267,000 ft$^3$ X 7.48 gal/ft$^3$ = 24,437,160 gal. (para 5-2a)

6. b, c, f. (para 5-4a)

7. c, e, f. (par a 5-4b (1) )

8. 20 (para 5-4b (3))

9. 4" (para 5-4b(4))

10. 3 (para 5-4b(4))

11. b, c, f, h, i. (para 5-5a)

12. calcium hypochlorite and ferric chloride. (para 5-6a)

13. The rate of feed. (para 5-6a)

14. diatomaceous earth and pulverized limestone. (paras 5-6, 5-6b, d)

15. sludge concentrator tank. (para 5-7f)

16. reverse flow. (para 5-8c)

17. a (para 5-8a)

18. a, b, d. (paras 5-8a,b; 5-7e)

19. batch. (para 5-10b)

20. 2.2 gal/hr 26

Chlorine demand = 5 ppm
Chlorine residual = 2 ppm
Chlorine dosage = 7 ppm
Calcium hypochlorite is 70 percent chlorine;
therefore,

$$\frac{7}{.70} = 10 \text{ ppm } Ca(CI0)_2$$

is required. 10 ppm = scale
reading of 2.2 (gal/hr) (see figure 5-13)

21. 2 ppm

$$\frac{\underline{5{,}000 \text{ ppm} \times 1 \text{ m}}}{1{,}000 \text{ ml}} = 5 \text{ ppm}$$

Chlorine dosage = 5 ppm
Chlorine residual = 3 ppm
Chlorine demand = 2 ppm (para 5-10b(4))

22. ferric chloride. (para 5-11a(3) (b)

23. upstream from camp. (para 5-12a(1))

24. small pieces of floating solid matter. (para 5-12b(5))

25. polymer, sodium hex, citric acid, and chlorine drive units.
(paras 5-12b,c and figure 5-23)

26. multimedia filter. (para 5-12c(3)(a))

27. 10 psi. (para 5-12c(3)(b))

28. reverse osmosis elements. (para 5-12c(3)(c))

29. other three pressure vessels. (para 5-12c(3)(c))

30. brine, backwashing the multimedia filter, and cleaning the RO elements
(para 5-120(4)).

**End of Lesson 5**

## LESSON ASSIGNMENT

| | |
|---|---|
| **LESSON 6** | Protection of Water Supplies. |
| **TEXT ASSIGNMENT** | Paragraphs 6-1 through 6-21. |
| **LESSON OBJECTIVES** | After completing this lesson, you should be able to: |

6-1. Identify basic criteria in selection of safe water sources.

6-2. Identify methods for protecting a water source against pollution.

6-3. Determine situations in which the hazard of a cross connection may exist

6.4. Identify means of correcting cross-connection hazards.

6-5. Identify the procedures for treating water contaminated by chemical, biological, and radiological agents.

**SUGGESTION** After completing the assignment, complete the exercises at the end of this lesson. These exercises will help you to archive the lesson objectives.

# LESSON 6

# PROTECTION OF WATER SUPPLIES

## Section I. WATER SOURCE PROTECTION

### 6-1. GENERAL

Characteristics of water sources and general considerations in the selection of a water source were briefly discussed in paragraph 1-8. In this section, the emphasis will be placed on ensuring the sanitary quality of the source selected. Since most military water supply sources are surface waters, followed in frequency by wells or springs, the discussion will center around these sources. Although the first consideration in selecting a water source is obtaining a source with sufficient quantity, every effort must be made to find one that provides the best possible quality. Once a source is selected, it must be developed and maintained so as to preserve or improve the sanitary quality. This is very true in that the enemy may try to induce chemical, biological, and/or radiological contaminates.

### 6-2. SURFACE WATER SUPPLIES

a. **Sources of Contamination**. Many surface waters are contaminated with domestic wastewater, industrial wastes, surface runoff, and drainage from cultivated land and farm yards. Contamination of these kinds may be minimized by the following methods:

(1) Limiting access to the immediate surrounding area by constructing fences and walls.

(2) Planting grass on all possible surfaces draining into the water.

(3) Constructing diversion ditches to prevent wastes from discharging into the water source.

b. **Selection of Intake Points**. An intake point should be selected at which the water is as clear and deep as possible. The strainer on the suction hose should be at least 4 inches below the water level. This precaution reduces the possibility of clogging the strainer with floating debris or drawing air into the suction line. In deep water, improvised floats may be devised to support the strainer (an aluminum float is a standard component of the WPU). An anchor should be provided to prevent excessive movement of the float, and sufficient slack should be provided in the intake hose to permit normal movement. Figure 6-1 illustrates two improvised floats. Where the water is too shallow to use a float, several methods may be used to prevent foreign matter

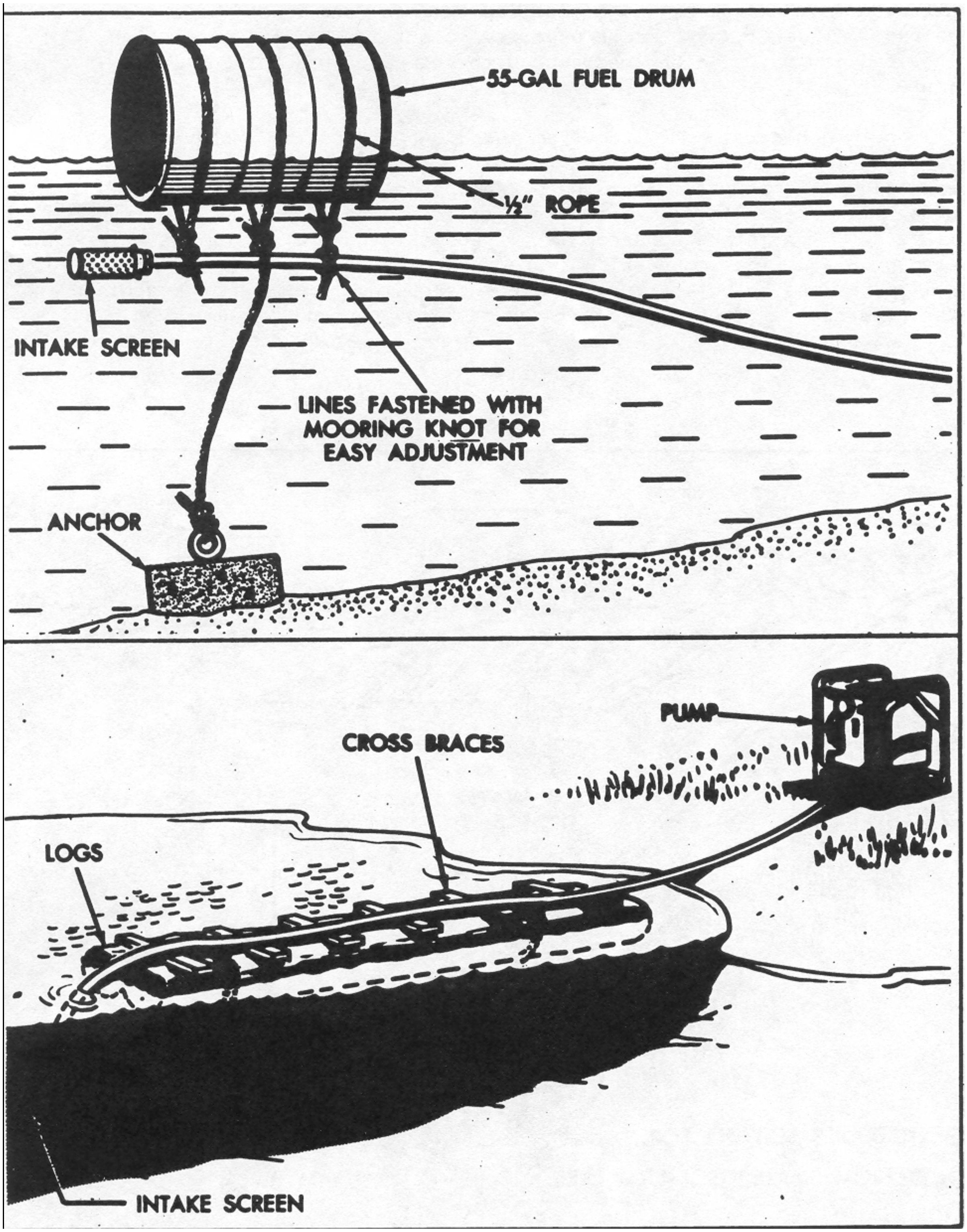


Figure 6-1. Improvised floats for intake screens.

from entering the strainer. The strainer and intake hose can be secured to a post or pile (see figure 6-2). In water less than 4 inches deep, a pit can be dug to increase the depth (see figure 6-3). The screen is surrounded by gravel to prevent collapse of the sides of the pit, to shield the screen from damage by large floating objects, and to act as a coarse strainer. A bucket may also be used to protect the intake screen. An improvised dam may also be constructed to increase the depth of water in a stream.

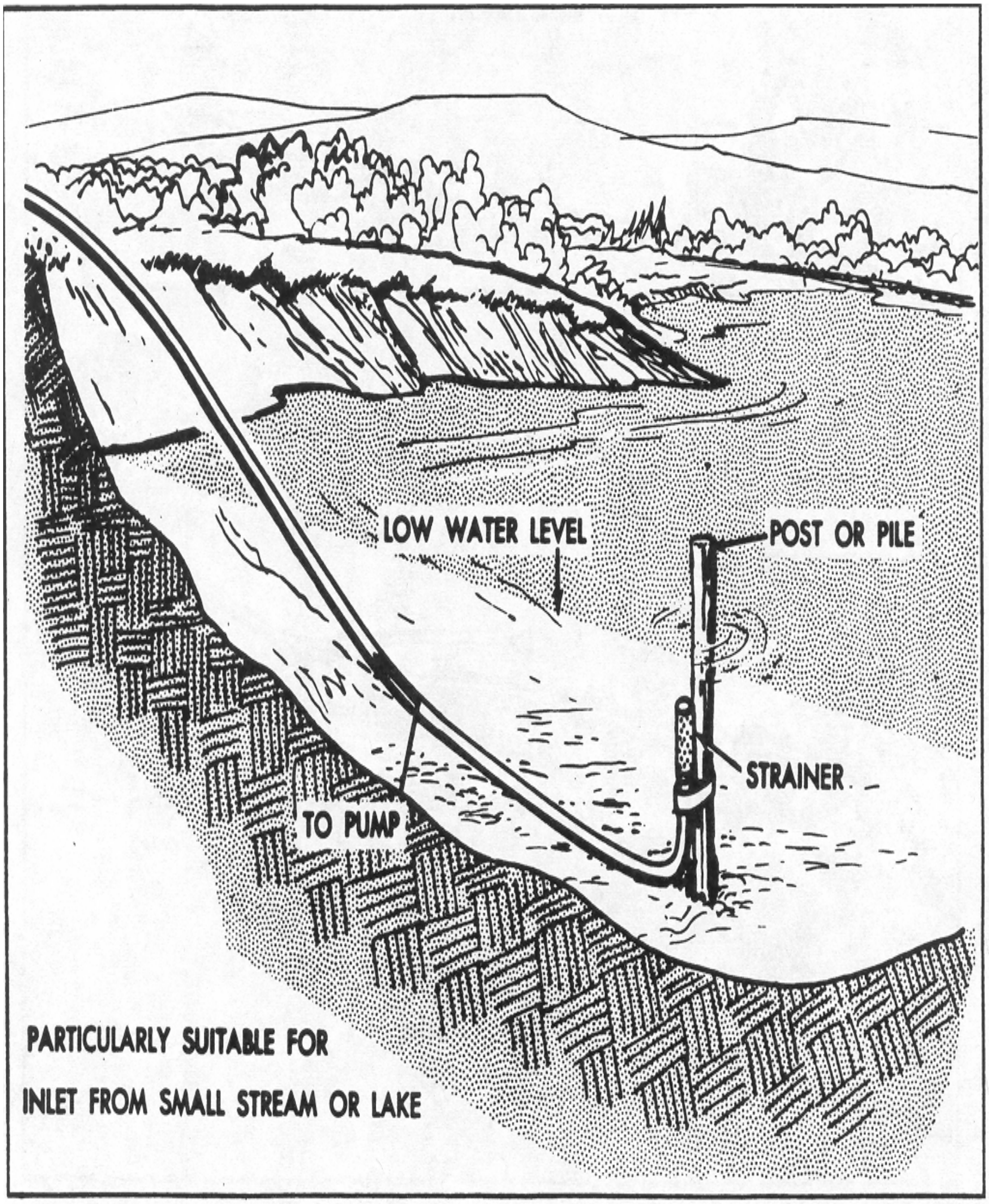


Figure 6-2. Intake secured to post.

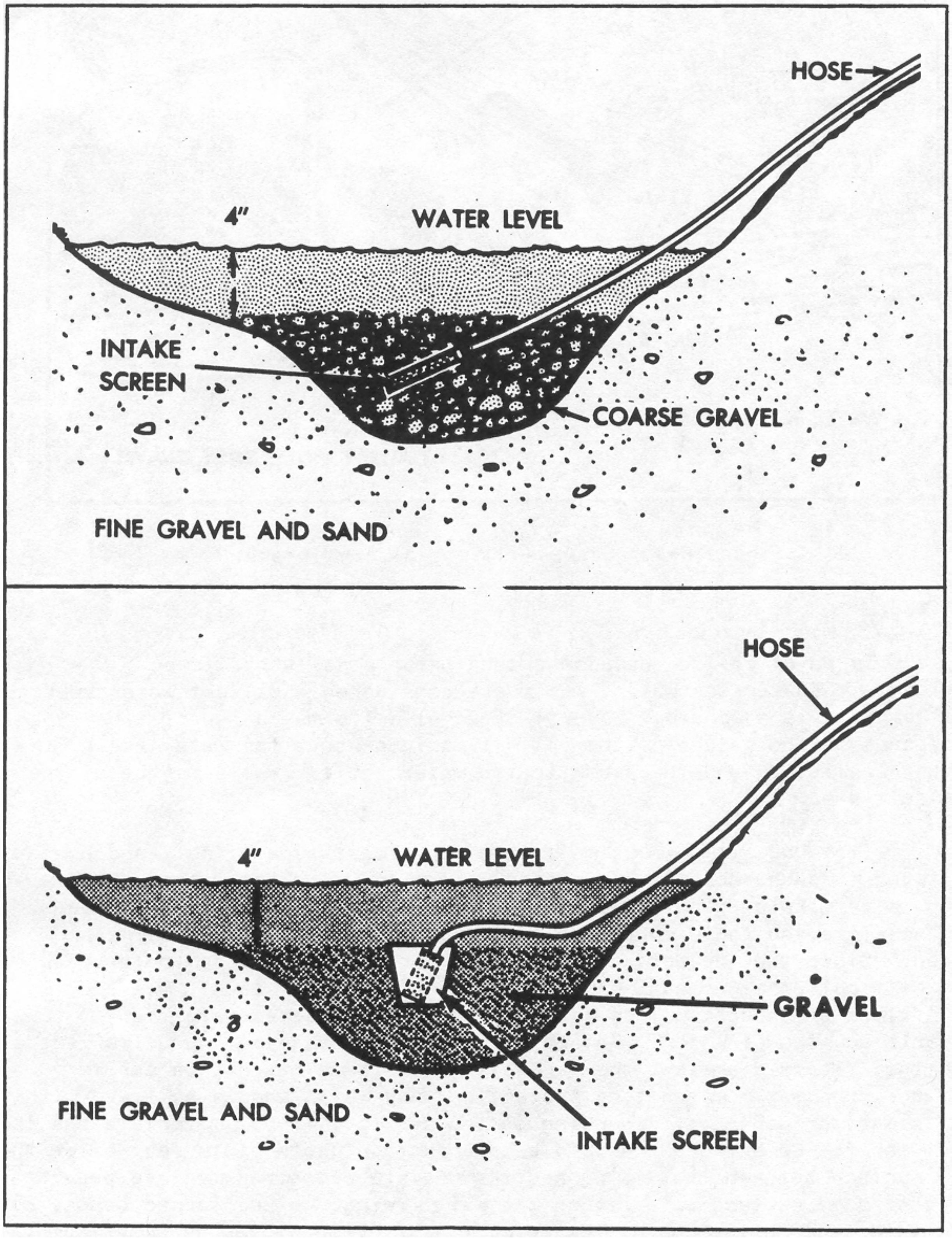


Figure 6-3. Surface intake in gravel-filled pit.

c. **Turbid Water**. Water from muddy streams can be improved in quality by digging intake galleries along the bank. A trench is dug along the bank deep enough so that water from the stream percolates through the soil into the trench. The trench is filled with gravel to prevent the sides from collapsing. The intake strainer is placed in the gravel below the water line (see figure 6-4). The amount of work required to construct the gallery is justified by the reduction in the amount of chemicals needed to coagulate the water, the reduced frequency of filter backwashing, and the improved quality of the water obtained.

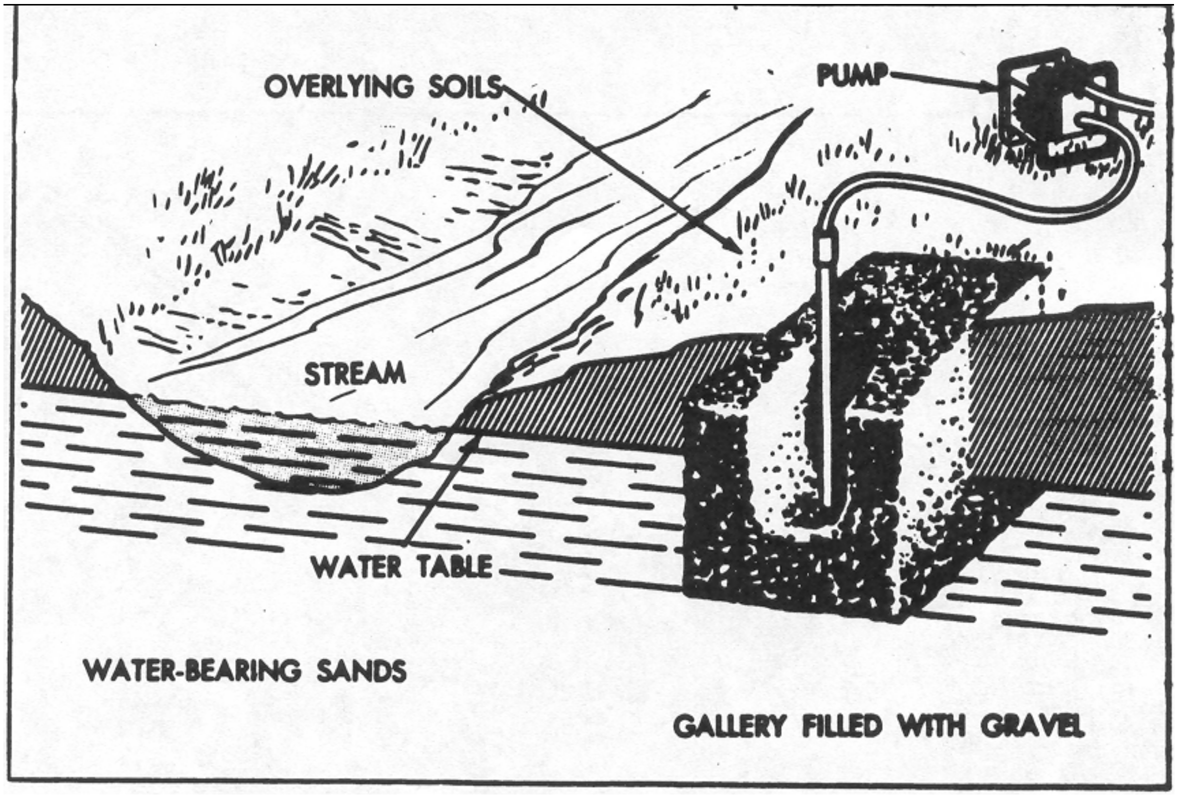


Figure 6-4. Gravel-filled gallery intake.

## 6-3. WELLS

a. **Types of Wells**. Because ground water usually has fewer contaminants than surface water, wells are considered excellent water sources, if the quantity is adequate. Several types of wells may be used. The type used depends on the nature of the soil formations above the water table, the equipment available, and the depth to the water table. Wells may be of the following types:

(1) Dug wells. Dug wells are the oldest type of well and are still found in abundance in rural areas worldwide where the water table is not so deep as to make digging impractical. Dug wells are usually excavated by hand; therefore, no tools more sophisticated than a pick and shovel are required. Since they do not penetrate very far into the water table because of the difficulties in manual excavation below the water level, many dug wells fail in times of drought. They are, therefore, considered relatively

unreliable sources of water. An additional disadvantage of dug wells is that, due to their large diameter, they are difficult to maintain in a sanitary condition. For maximum sanitary protection, dug wells should be lined with brick, stone, or concrete, depending on the availability of materials and the cost of labor. Cement grout should be placed to a depth of 10 feet below the ground surface between the lining and the undisturbed embankment to prevent the entrance of surface water along the well lining. A reinforced concrete slab should enclose the top of the well. The slab should slope away from the center to preclude surface waters (see figure 6-5) entering the well. As in all wells, the opening for the drop pipe of the pump should have a sanitary seal to prevent contamination from entering.

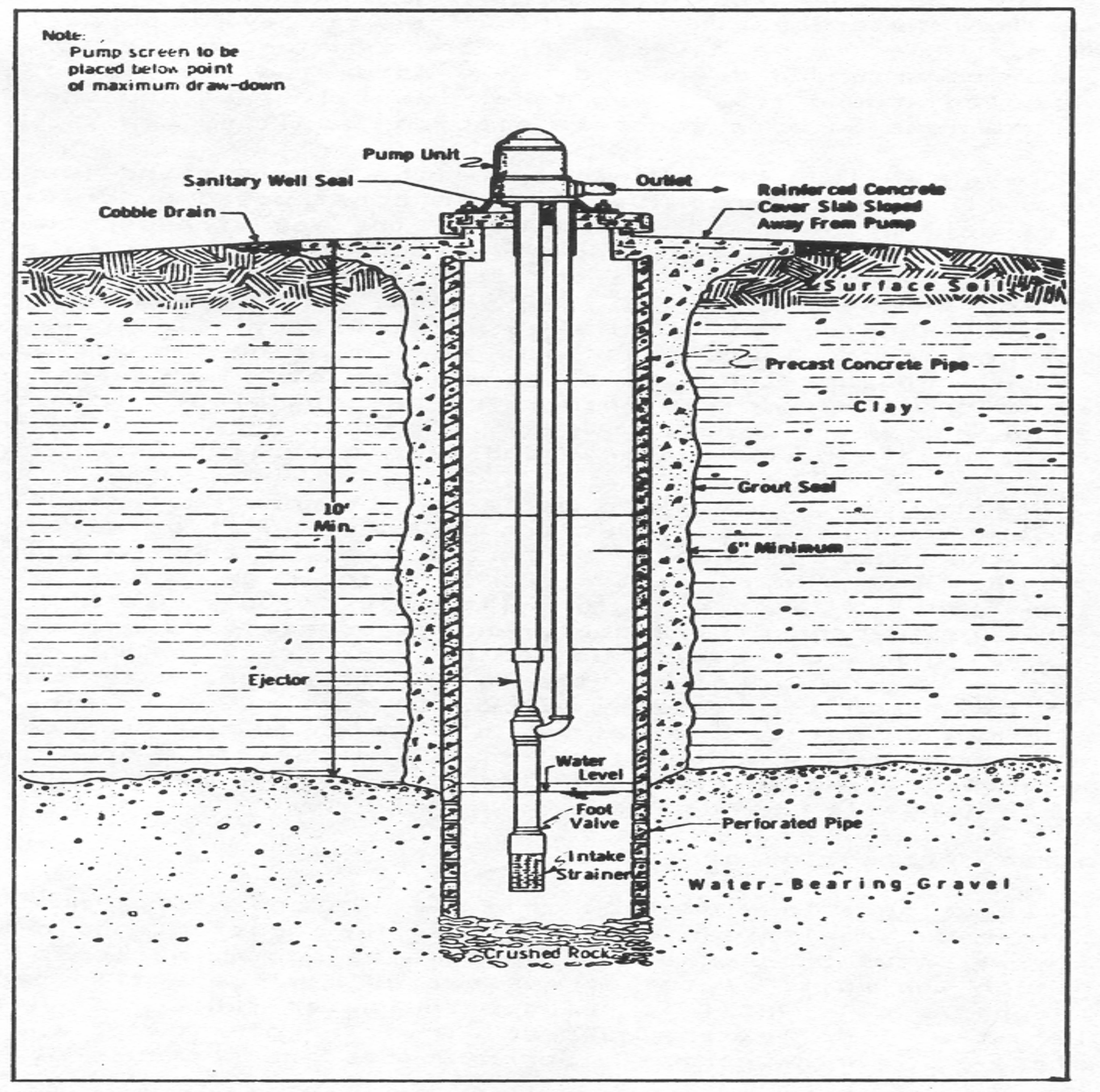


Figure 6-5. Typical dug well.

(2) Bored wells. Bored wells are commonly constructed with earth augers turned by hand or by power equipment. They are considered practical at depths less than 100 feet when the water requirement is low and the earth overlying the aquifer (water-bearing formation) has noncaving properties and few large boulders. Bored wells have roughly the same characteristics as dug wells, but they may be extended deeper into the water table. Like dug wells, they should be grouted around the casing to at least 10 feet and should be protected from contamination by a concrete slab and sanitary seal.

(3) Driven wells. Driven wells are the simplest and least expensive of all well types. The driven well is constructed by driving into the ground a drive well point that is fitted to the end of a series of pipe sections. The pipe sections and drive point are driven by means of a maul, a drive shoe, or a pile driver. The most suitable locations for driven wells are areas containing alluvial deposits (clay, sand, silt, gravel, or similar material deposited by running water) of high permeability. The presence of coarse gravel, stones, or boulders interferes with sinking the well point and may damage the wire mesh jacket covering the well point. For deeper wells, the well points are sometimes driven into water-bearing strata from the bottoms of bored or dug wells (see figure 6-6). The casing should be grouted in the same manner as in (1) above, and provided with a sanitary seal.

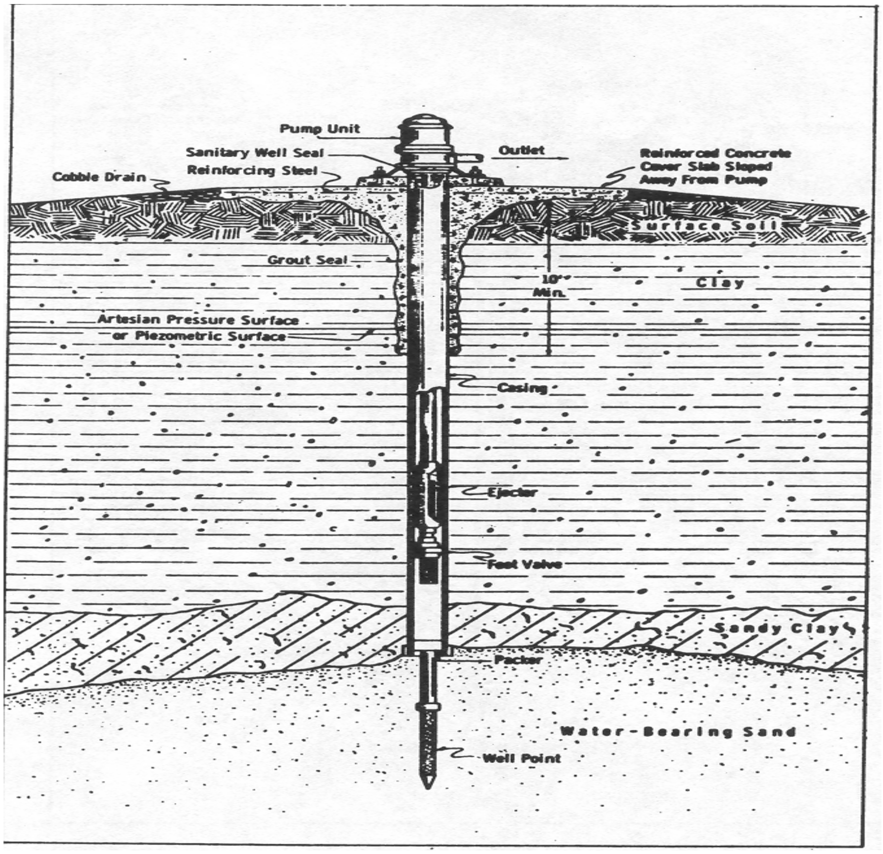


Figure 6-6. Bored well driven well point.

(4) Drilled wells. Drilled wells may be constructed in virtually any type of soil and at depths to 3,000 feet or more. Drilled wells may be drilled either by the rotary method or by percussion. Either method requires a derrick and hoist. The primary difference in techniques is whether the drilling is accomplished by a rotating drilling pipe with a bit at the bottom, or whether the bit is suspended by a cable and alternately raised and dropped in the hole, thus digging by breaking up the soil and rock formations in a pulverizing action. When the depth of the hole reaches the water-bearing strata, a casing is placed. In cases where caving occurs or is likely to occur, the casing may be set as the well is drilled. In addition to the grouting of the annular space around the top of the casing, a grout seal may be pumped through the casing to seal off the aquifer from seepage through other earth layers (see figure 6-7).

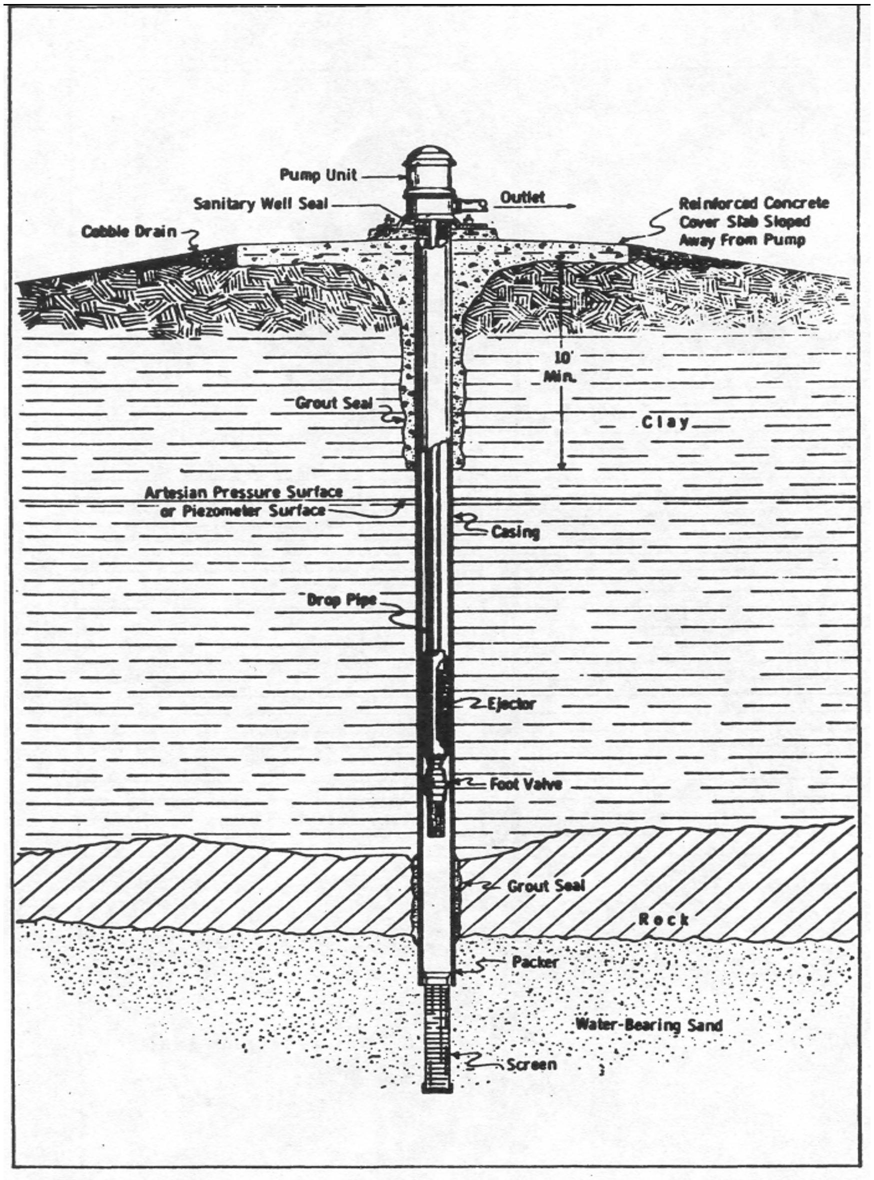


Figure 6-7. Drilled well.

b. **Sanitary Protection of Wells**.

(1) Location. The location of a well is one of the most important considerations in ensuring its sanitary quality. A location should always be selected which will prevent, as nearly as possible, contamination by percolation through the soil. Water or wastewater will generally percolate vertically through the soil until it reaches the water table. When it reaches the water table, it will follow the general direction of flow of the underground water. This flow normally approximates the contours of the earth's surface, but not necessarily. Wherever possible, a well should be located uphill from a possible source of contamination; however, this is not positive assurance that the point at which the well draws water from the water table is not below the level at which contamination may be carried by percolation into the water table. In order to minimize this possibility, wells should be located at least the following distances from sources of pollution.

(a) Building sewer--100 feet.

(b) Septic tank--100 yards.

(c) Sewage disposal field--100 yards.

(d) Seepage pit--100 yards.

(e) Dry well--should be sealed.

(f) Cesspool--100 yards.

**NOTE**: Where there is good reason to believe that the soil is quite permeable, such as a limestone formation, these distances should be increased.

(2) Construction.

(a) The annular space between the well casing and the surrounding soil formation should be filled with watertight cement grout from the surface to a depth of at least 10 feet.

(b) The casing should be surrounded by a 4-inch concrete slab extending at least 2 feet in all directions and sloping away from the casing.

(c) A sanitary well seal should be installed at the top of the well casing to prevent the entrance of contaminated water or other objectionable material.

(d) For artesian aquifers, the casing should be sealed into the overlying impermeable formation so as to retain the artesian pressure.

(e) When a water-bearing formation of poorer quality is penetrated, the formation should be sealed off to prevent the infiltration of water into the well and the aquifer.

(3) Disinfection. All newly constructed wells should be disinfected to neutralize contamination from equipment, material, or surface drainage introduced during construction. To properly disinfect a well, sufficient calcium hypochlorite should be added to provide a concentration of 50 ppm (approximately 1 ounce of dry chemical per 100 gallons of water) (1 ounce of calcium hypochlorite per 100 gallons of water in the well hole) and allowed to remain in the well for 24 hours. Care should be taken to disinfect the sides of a dug well with a brush or broom and to disinfect the interior of a pump by pumping water through it until the odor of chlorine is detected. After 24 hours have elapsed, the pump should be operated until the water is free of chlorine odor.

## 6-4. SPRINGS

a. **Development**. There are two important considerations in the development of a spring: the quantity of water available and the protection of the sanitary quality. Development of a spring inlet includes the following (see figure 5-1):

(1) An open-bottom, watertight basin intercepting the source and extending to bedrock or a system of collection pipes and a storage tank.

(2) A cover that prevents the entrance of surface drainage or debris into the tank.

(3) Provision for the cleanout and emptying of the tank contents.

(4) Provision for overflow.

(5) A connection to the distribution system or auxiliary supply.

b. **Sanitary Protection of Springs**. Springs usually become contaminated when barnyards, sewers, septic tanks, cesspools, or other sources of pollution are located on higher adjacent land. The following precautionary measures will help to maintain developed spring water of a consistently high quality.

(1) Provide for the removal of surface drainage from the site. A surface drainage ditch located at least 50 feet away on the uphill side of the spring will prevent contaminating material from entering the source.

(2) Construct a suitable fence at least 100 feet from the water source to prevent entry of livestock. The drainage ditch should be inside the fence at all points uphill from the source.

(3) Provide for access to the tank for maintenance, but prevent removal of the cover by a suitable locking device.

(4) Monitor the quality of the spring water with periodic checks for contamination. A marked increase in turbidity after a storm is a good indication that surface runoff is reaching the spring.

## Section II. CROSS CONNECTIONS IN WATER DISTRIBUTION SYSTEMS

### 6-5. GENERAL

Public health officials have long been concerned about cross connections and backflow connections in plumbing systems and in public drinking water distribution systems. Such cross connections, which make possible the contamination of potable water, are ever-present dangers. An example of what can happen is the epidemic of amebic dysentery that occurred in Chicago in 1933 when old, defective, and improperly designed plumbing and plumbing fixtures permitted the contamination of drinking water. As a result, 1,409 people contracted amebic dysentery--of which, 98 subsequently died. This epidemic and similar others have made clear the responsibility of all persons involved in public water supplies, distribution, and plumbing for recognizing and eliminating cross connections.

### 6-6. DEFINITIONS

a. **Cross Connection**. A cross connection is any physical connection, whether permanent or temporary, between a potable water system and a nonpotable system or source. Cross connections may be further defined as direct or indirect.

(1) A direct cross connection is a solid pipe connection between a potable and nonpotable system.

(2) An indirect cross connection is one in which there is not a continuous connection at all times, but which can create such a connection when certain conditions exist. An example would be a leaking water line and a leaking sewer line laid in the same trench and in the presence of a pressure differential which would permit wastewater to enter the potable water line.

b. **Backflow**. Backflow is any flow of nonpotable water or other liquid into a potable water system.

c. **Backsiphonage**. Backsiphonage is backflow caused by negative pressure in the potable water system at the point of occurrence.

## 6-7. SIPHON PRINCIPLE

Many of the situations involved in cross connections are based upon the principle of siphonage, as illustrated in figure 6-8. If an inverted "u" tube is filled with water and placed in two open containers at exactly the same level (see figure 6-8 A), a static condition will exist, and the water will not flow in either direction. The atmospheric pressure on the water in the open containers and the vacuum, or negative pressure, caused by the absence of air in the tube will support the column of water in the inverted tube up to a height of 33.9 feet at sea level (other conditions being standard). If, however, we raise one container to a higher level (see figure 6-8 B), we create a pressure differential, or head (H), due " to the weight of the water in the tube. This head causes the water to flow from the higher to the lower container. In this situation, water actually "flows uphill." Figure 6-9 illustrates how this siphon principle can be hazardous in a plumbing system. As long as sufficient pressure is maintained in the supply line, the system remains in equilibrium; however, if the supply line is closed or the pressure is reduced to less than the head at the second floor level (plus atmospheric pressure), water will flow by siphonage from the water closet to the open faucet at the lower level (provided certain other conditions exist, which will be discussed in paragraph 6-9b).

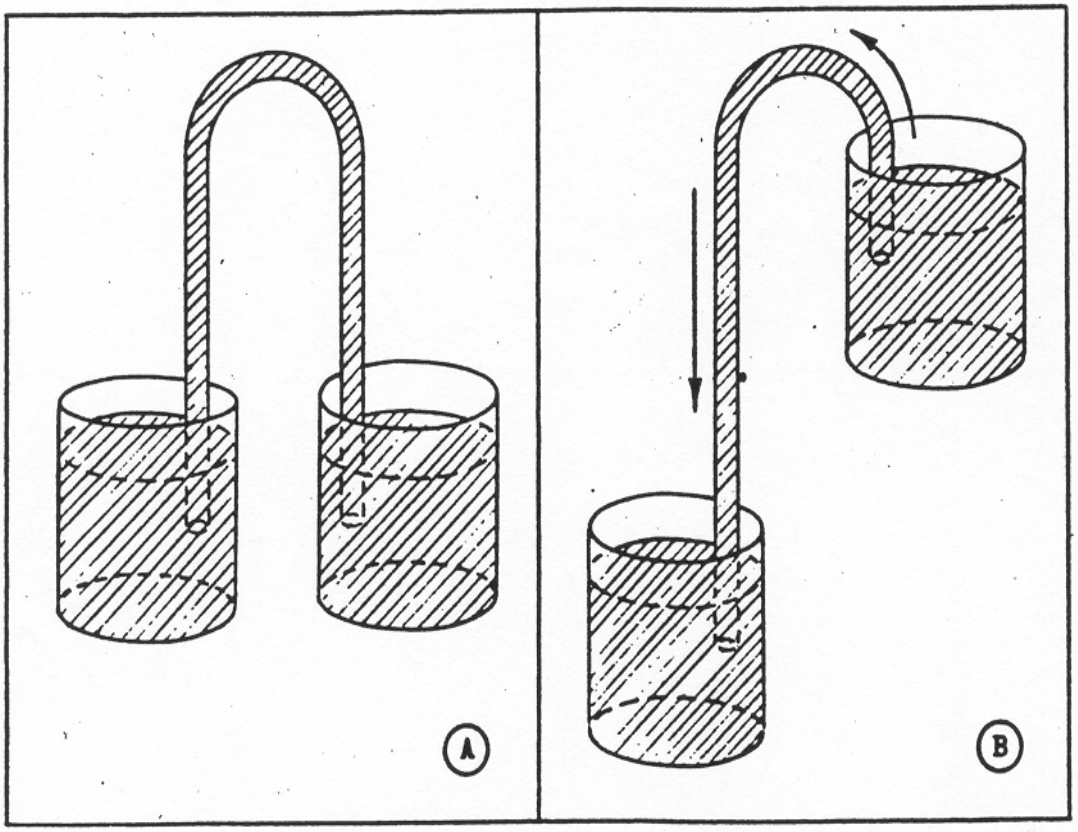


Figure 6-8. Siphon principle.

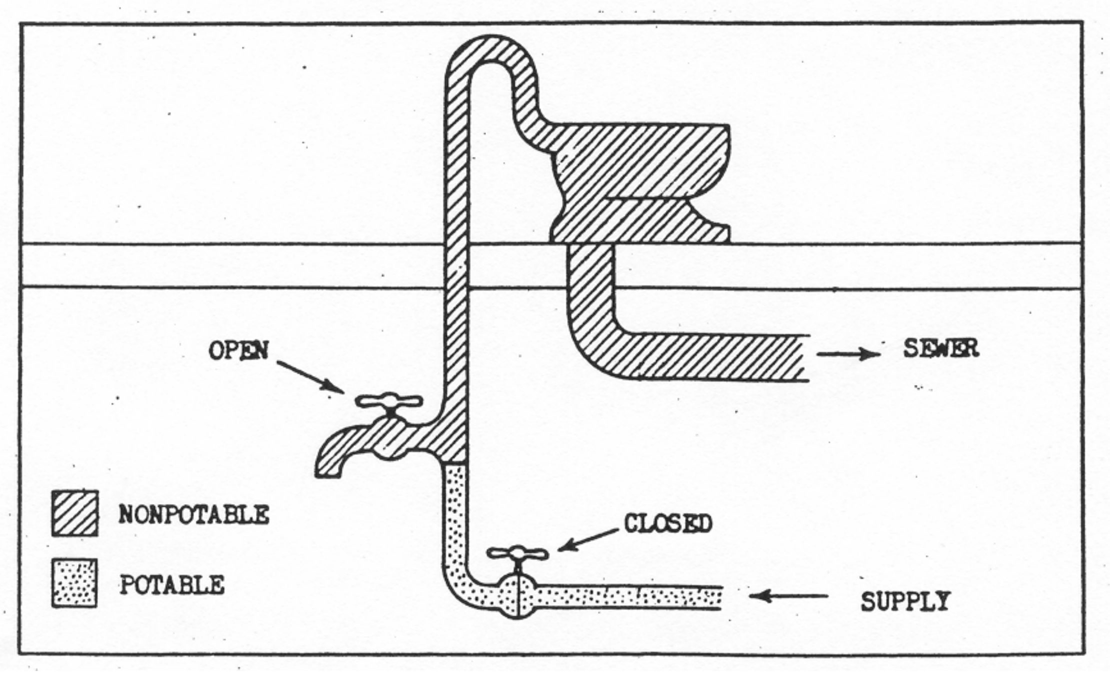


Figure 6-9. Siphon action in plumbing system.

## 6-8. DIRECT CROSS CONNECTIONS

Direct cross connections, when found, are most likely in industrial or commercial buildings where both potable and nonpotable water systems exist. An example would be a small community whose potable water supply is not sufficient for fighting large fires, but which has a readily available source of nonpotable water with which to augment the potable system in an emergency. Such systems could be so designed that the fire hydrants may be supplied with either potable water, nonpotable water, or both. Such an arrangement would always present the hazard of a direct cross connection. Another example of a solid pipe connection is a cooling system whereby potable water is supplied to a cooling jacket and subsequently discharged into a sanitary sewer system. Department of the Army construction criteria prohibit any physical connection between the potable water system and the sewer system, or cross connections with an unsafe supply. Nevertheless, conditions that allow backflow frequently occur because of improper construction, subsequent changes in piping, or carelessness of users.

## 6-9. INDIRECT CROSS CONNECTIONS

Indirect cross connections, because of their very nature, are more difficult, to detect than direct cross connections; however, they are more likely to occur because they are usually the result of an oversight in the installation or use of water supply and plumbing fixtures. The following are a few examples:

a. **Water and Sewer Lines in Close Proximity**. Water and sewer lines are both subject to infiltration, even though joints are properly made and are tight. The infiltration into sewer lines laid below the ground water level may be as much as 10,000 gallons per mile of sewer per day. Sewer lines above the ground water level will have much less infiltration; but, during periods of heavy wastewater flows, seepage into the ground surrounding the sewer pipe will occur since the pressure inside the sewer pipe will be greater than outside except during periods of heavy rainfall when the earth is saturated. Since water lines are normally under pressure, there should be no infiltration into the system; however, small leaks may permit some seepage into the surrounding earth. Under a combination of unusual conditions (such as a leak in a potable water line, a reduction in water pressure caused by such a leak, or by shutting down a portion of the system for repairs, and an unusual amount of water in the soil surrounding the leak), nonpotable water could be drawn into the potable water pipe. If the water in the soil were from a leaky sewer pipe, septic tank, or disposal field, the results could be disastrous. In order to prevent such possibilities, water and sewer pipes should always be separated by as much distance as possible, and never in the same trench if it can possibly be avoided. In any event, the sewer line should always be laid at a lower elevation than the water line. In acid soils or in cinder fill, both the sewer and water pipe should be enclosed in a 3-inch concrete casing to prevent see page and infiltration (see figure 6-10).

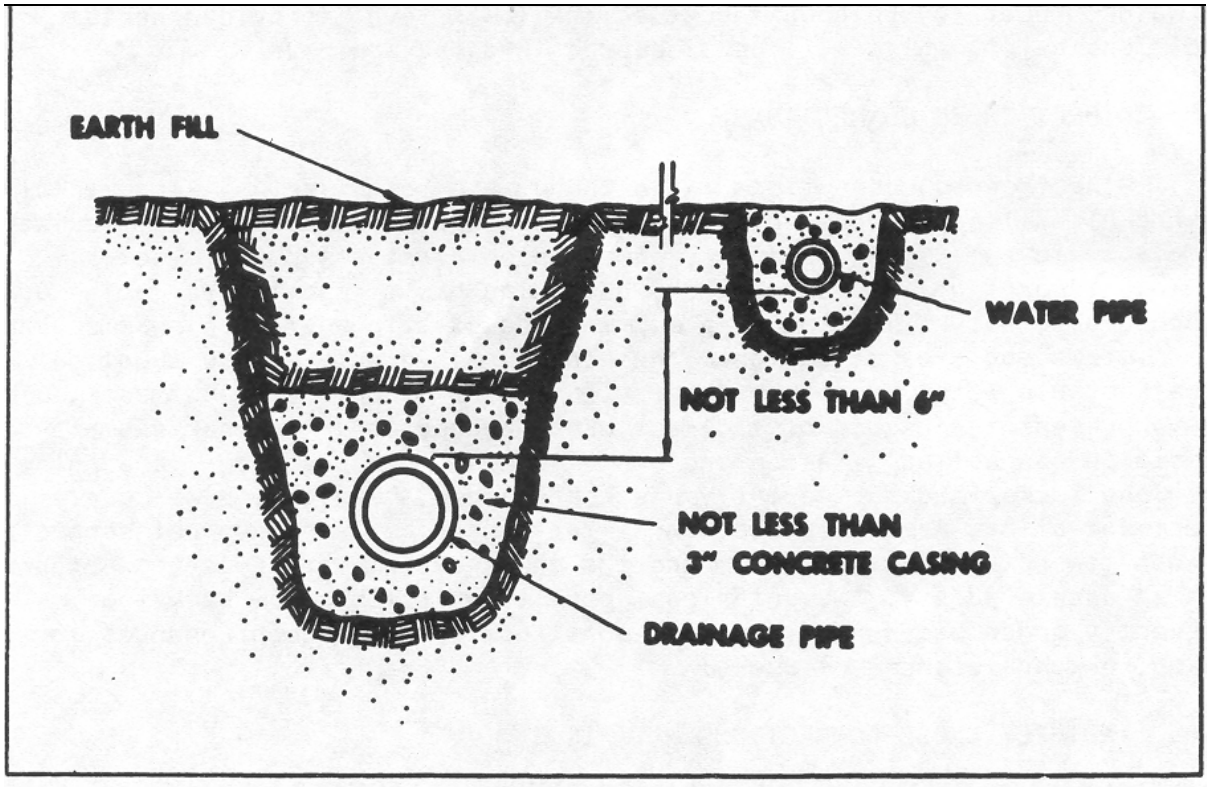


Figure 6-10. Concrete casing in acid soils or cinder fills.

b. **Submerged Inlets**. Submerged inlets are found on many common plumbing fixtures and are sometimes necessary features of the fixtures if they are to function properly. Examples of this type of design are siphon-jet urinals or water closets, flushing rim slop sinks, and dental cuspidors. Old style bathtubs and lavatories had supply inlets below the flood level rims, but modern design has minimized or eliminated this hazard in new fixtures. Some submerged inlets that are difficult to control are those that are not apparent until a significant change in water level occurs or where a supply may be conveniently extended below the liquid surface by means of a hose or auxiliary piping. Any time the means have been established for a continuous flow of water between a potable water supply and a source of contaminated water, a cross connection has been made. This cross connection will convert the intended inlet to a siphon if the pressure in the water supply is reversed. Figure 6-11 illustrates several typical cross connections caused by the submerged inlet principle.

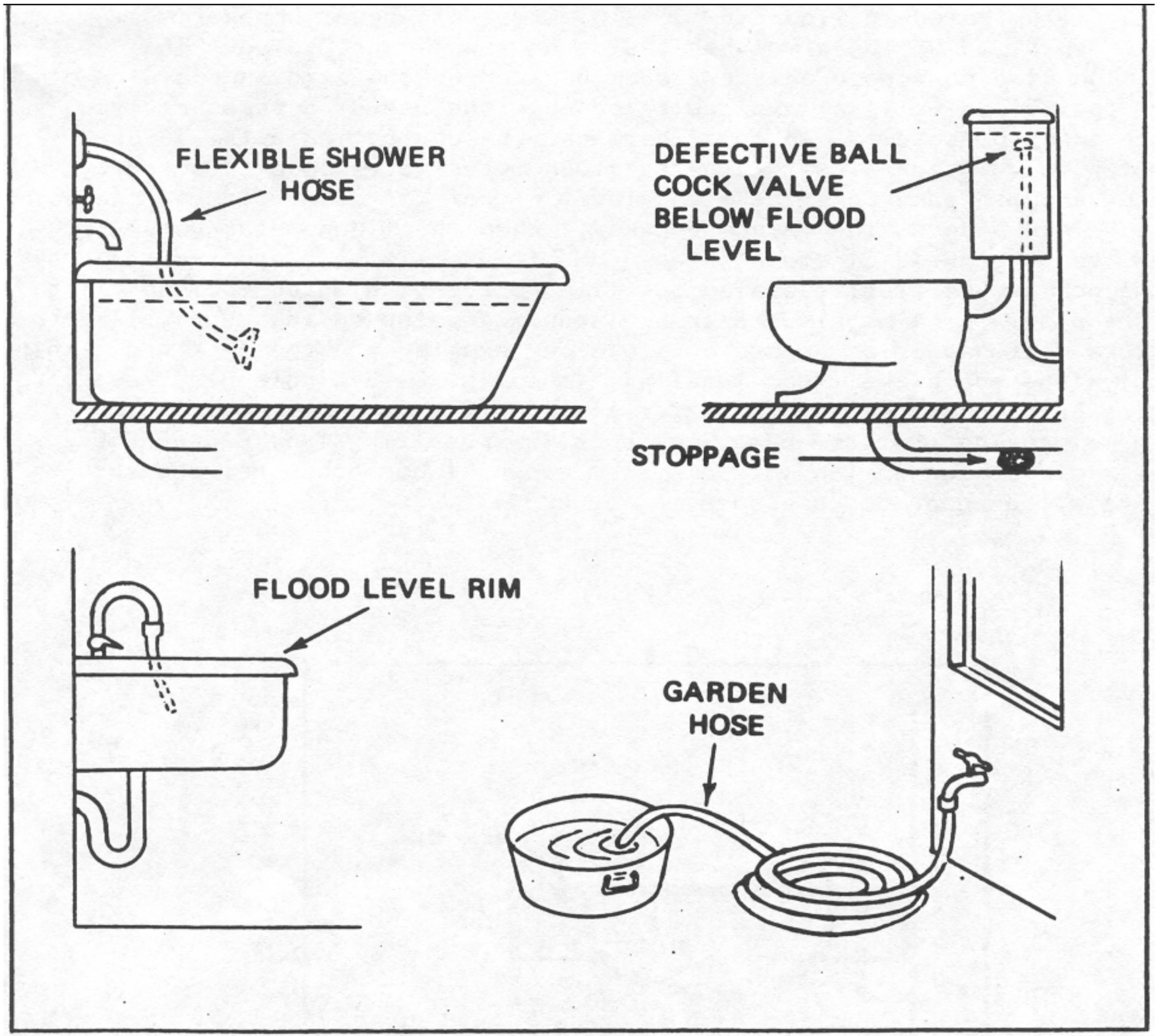


Figure 6-11. Typical submerged inlet type cross connections.

## 6-10. THE AIR GAP

The only absolute means of eliminating the physical link that may result in backsiphonage is with the use of the vertical air gap (see figure 6-12). Air gaps should be used wherever possible and must not be bypassed. The supply inlet to the fixture should be terminated above the flood level rim of the fixture by a distance. equal to at least two times the effective opening of the fixture. There should be no provision for extending the fixture outlet below the flood level rim. If the end of the supply pipe is threaded or serrated to permit the connection of a hose, a properly installed vacuum breaker should also be provided.

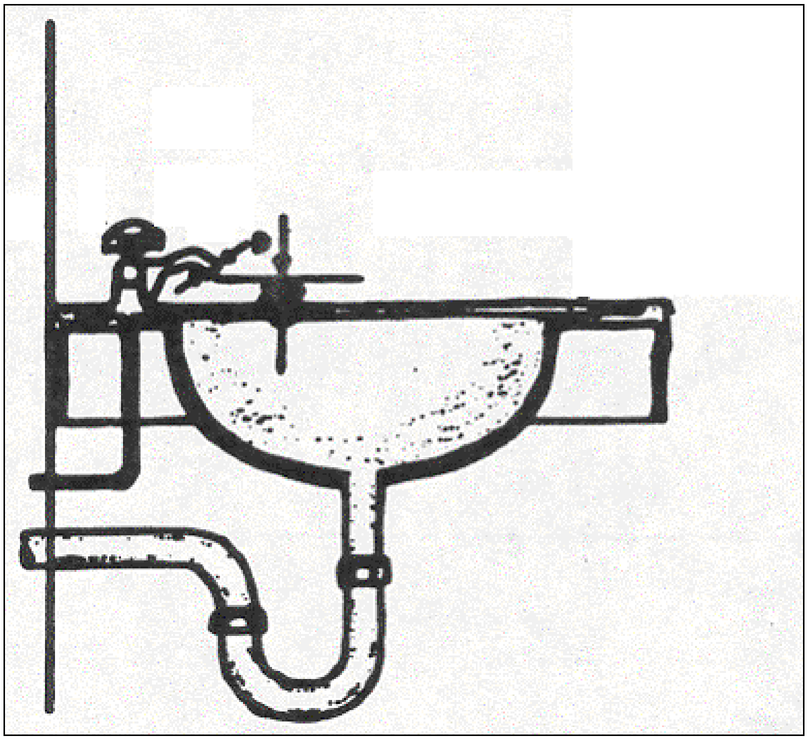


Figure 6-12. Vertical air gap on lavatory

## 6-11. VACUUM BREAKERS

A fundamental factor in backsiphonage, as explained in paragraph 6-6 is vacuum (negative pressure) between the potable water supply and the source of contamination. If atmospheric pressure is admitted to a piping system between the source of pollution and the origin of the vacuum, backsiphonage Will be prevented. This is the function of a vacuum breaker. Because a vacuum may be created at numerous places in a piping system, a vacuum breaker must be located as near as possible to the fixture from which contamination may be expected. The position of a vacuum breaker must be sufficiently above the fixture flood level rim so that flooding or submerging of the vacuum breaker is not possible. There are two types of vacuum breakers:

a. **Nonpressure Type Vacuum Breaker**. The nonpressure type vacuum breaker is illustrated in figure 6-13. This type of vacuum breaker must always be installed on the atmospheric side of the fixture valve. The installation of a nonpressure type vacuum breaker on the atmospheric side of the last control valve is always preferred over the use of a pressure type vacuum breaker (b, below). In this instance, the device is installed on a flushometer valve water closet with the flushometer valve located directly above the vacuum breaker and the flood level rim of the water closet located at least 6 inches below the vacuum breaker. When the flushometer valve is operated (see figure 6-13 A), the flow of water is downward and the disk is in the normal, vertically seated position, preventing water from spilling out of the pipe. If a negative pressure should develop on the supply line to the fixture, atmospheric pressure would be exerted on the disk and within the supply line above the flood level rim (see figure 6-13 B), thus preventing backsiphonage from the water closet. The vacuum breaker IS NOT designed to provide protection against backflow resulting from BACKPRESSURE (such as a direct connection with a system under higher pressure) and should not be installed where backpressure may occur.

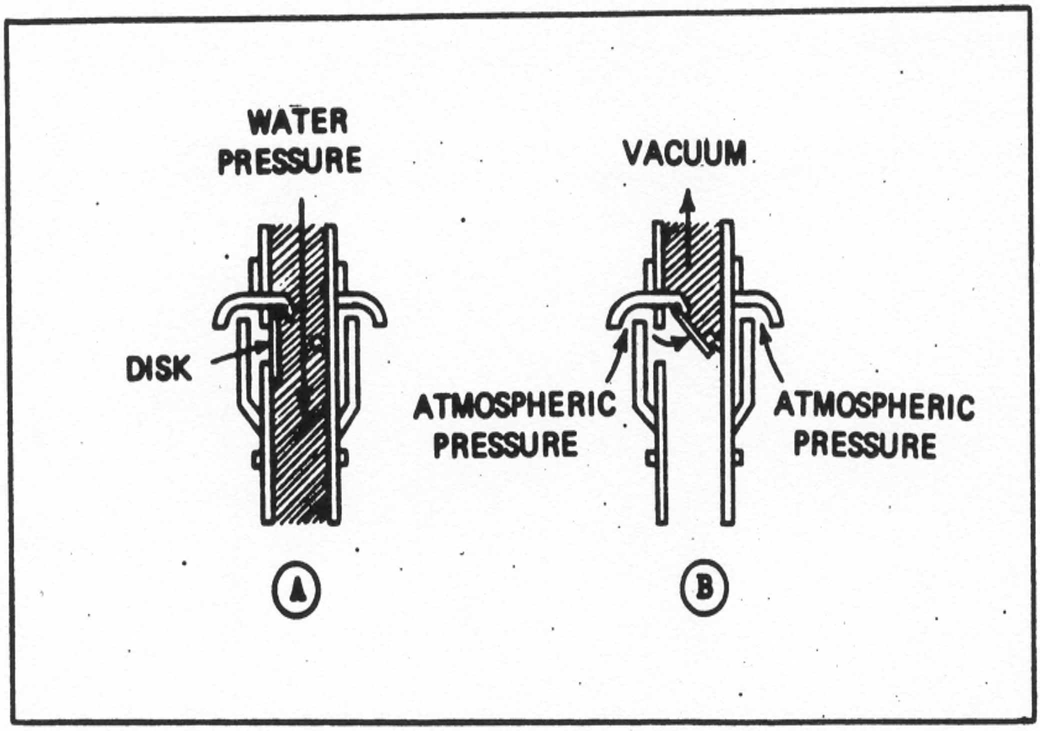


Figure 6-13. Nonpressure type vacuum breaker.

b. **Pressure Type Vacuum Breaker**. The pressure type vacuum breaker is designed to remain operable after having remained under hydrostatic pressure for extended periods of time. This type of vacuum breaker works on the reverse principle of the nonpressure type, in that the moving parts do not complete a full cycle of operation each time the fixture or supply line is used. The principle of operation is shown in figure 6-14. The device is designed to open permitting the admission of air to satisfy the vacuum when a negative head occurs in the supply line. It does not provide protection against backflow resulting from BACKPRESSURE.

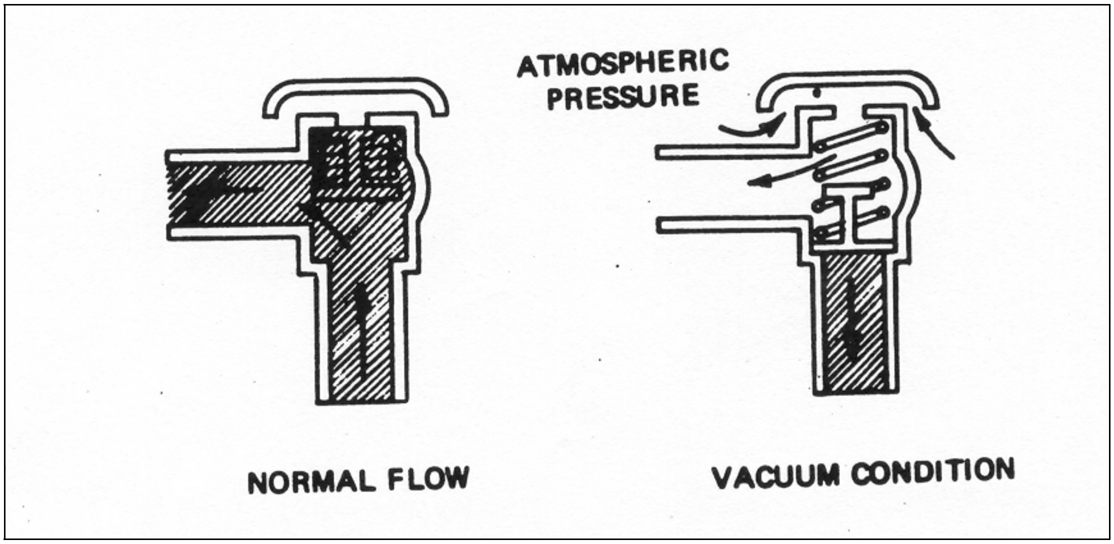


Figure 6-14. Pressure type vacuum breaker.

## 6-12. REDUCED PRESSURE BACKFLOW PREVENTER

The pressure and nonpressure type vacuum breakers are designed to prevent backsiphonage only and cannot be installed where backpressures are likely to occur. In situations where it would be extremely difficult to provide a physical break between two systems and where backpressures can be expected, a reduced pressure backflow preventer can be used. This device consists of two hydraulically or mechanically loaded, pressure-reducing, check valves with a pressure regulated relief valve located between the two check valves as shown by figure 6-15. Flow from the left enters the central chamber through check valve A. The pressure exerted by this check valve lowers the pressure in the central chamber. Check valve B is lightly loaded in the direction of flow. In the event that the pressure increases downstream from the device, causing backpressure, check valve B closes, thus preventing backflow. Because all valves may leak as a result of wear or obstruction, the protection provided by the check valves is not considered sufficient; therefore, a relief valve C is provided in the reduced pressure zone- (central chamber). This relief valve is preset to open at a lower pressure than check valve A. Therefore, if for some reason (an obstruction, wear, and so forth) check valve B should permit a reverse flow to enter the central chamber, the relief valve A will open. This will release the reverse flow to the atmosphere.

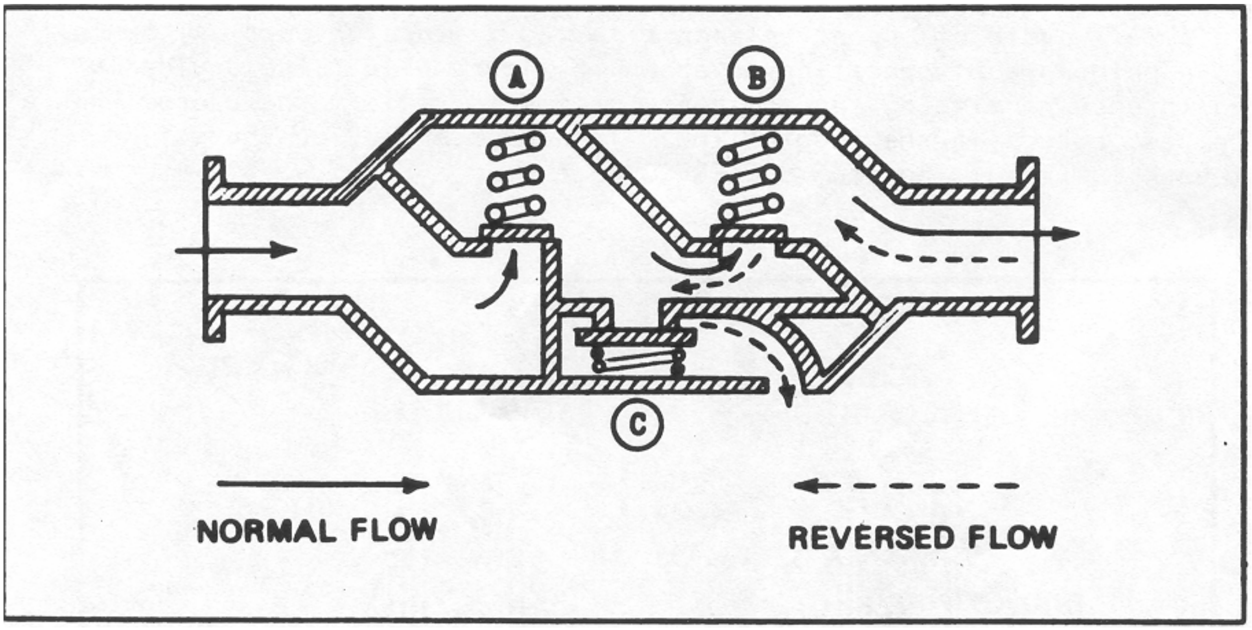


Figure 6-15. Reduced pressure backflow preventer.

## 6-13. SUMMARY

The environmental health specialist is not expected to be a sanitary engineer, nor a plumber. He cannot be expected, therefore, to detect improperly functioning backflow preventive devices. However, he should understand the principles of backsiphonage caused by cross connections. The majority of cross connection hazards are indirect cross connections caused by carelessness or ignorance of the principles of backsiphonage. In conducting inspections of water distribution systems and other facilities, the environmental health specialist should be constantly on the alert for situations in which the principle of the positive air gap has been inadvertently or intentionally defeated. Such situations must be brought to the attention of the responsible individuals. In situations where it is not possible to provide a positive vertical air gap and it appears that no provision has been made for a backflow-preventing device, the fact should be made known to the sanitary engineer or the environmental science officer for further investigation by technically qualified personnel.

## Section III. GENERAL TREATMENT IN THE EVENT OF CONTAMINATION

## 6-14. GENERAL

Primary emphasis in the protection of water supplies must always be placed on prevention of contamination. Nevertheless, because of the numerous hazards involved, contamination of water supplies is a factor with which we must always be prepared to deal. The medical departments of the Army and the Air Force have established a logical set of procedures to be followed when water samples from a potable water system are found to be contaminated. These measures, outlined in paragraphs 6-15 through 6-17 below, are not intended as substitutes for individual initiative and judgment on the part of the responsible surgeon recommending remedial action; however, they provide a systematic point of departure.

## 6-15. REMEDIAL ACTION ACCORDING TO SANITARY CONDITION

There are three sanitary conditions describing local circumstances under which contaminated samples could be obtained from a potable water supply. The following remedial actions are recommended, depending upon the condition, when contaminated water samples are found:

a. **Condition I (Normal)**. No known sanitary defects, health hazards, or incidents of gastrointestinal diseases can be associated with the contaminated samples.

(1) Possible cause. The contaminated samples might indicate a. localized situation within the piping of the building where the sample was collected, or result from a faulty sampling technique.

(2) Recommendations.

(a) Collect repeat samples promptly at the points of previous collection.

(b) Expedite shipment of samples so that a prompt report may be obtained from the laboratory.

(c) Make an immediate investigation to determine if any unusual conditions have occurred, such as repairs to the water mains, faucets, or piping within the building or within the vicinity of the sampling point.

(d) Test for chlorine at various outlets to ensure the proper dosage.

(e) If the foregoing investigation indicates the necessity, flush the portion of the system by opening outlets until a proper chlorine residual is recorded. Carry out localized emergency disinfection if deemed necessary (see para 6-16b).

b. **Condition II (Disaster)**. Contaminated samples are the result of a major disaster, such as the inundation of the source, breakdown in treatment plant units, gross contamination of the system through a cross connection, failure of an underwater crossing, damage from an earthquake, or similar circumstances.

(1) Possible cause. Self evident.

(2) Recommendations.

(a) Immediately reject the water supply system and institute emergency treatment of all drinking water and water used for cui inary purposes (para 6-16a).

(b) After the necessary repairs have been completed, chlorinate and flush the entire system.

(c) Collect samples from representative points throughout the entire system until negative bacteriological results are obtained on at least two consecutive sets of standard samples collected on different days.

(d) Remove restrictions on the use of water.

c. **Condition III (Epidemic)**. Contaminated samples appear to be associated with the occurrence of an outbreak of one of the so-called waterborne diseases.

(1) Possible cause. Contamination of the water system at the source, in reservoirs, in treatment plant facilities, or in the distribution system, and not generally apparent at the onset of the outbreak.

(2) Recommendations.

(a) Carry out recommendations under Condition I (a, above), with special emphasis on investigation of the source, reservoirs, treatment processes, and the distribution system.

(b) Increase the chlorine dosage and residual in the system.

(c) If the conditions contributing to the contamination are found to be serious, such as a direct contamination with wastewater, reject the supply as in Condition II and institute emergency treatment (para 6-16a) until the condition is corrected.

## 6-16. EMERGENCY PROCEDURES

a. **Emergency Treatment**. Emergency treatment, as used in this section, consists of boiling water for at least 1 minute or maintaining a chlorine residual of at least 1 ppm and dispensing the water from tanks, trailers, or Lyster bags.
.

b. **Emergency Disinfection**. Emergency disinfection, as used in this section, consists of the removal of indications of contamination from a water supply system by maintaining a chlorine residual of at least 50 ppm in the affected portion of the system. Calcium hypochlorite, sodium hypochlorite, or liquid chlorine may be used for this purpose. See chapter 4 TB MED 576 for complete instructions.

## 6-17. TYPICAL SANITARY HAZARDS

Contamination may occur due to problems at the location of the source of the water supply, problems in construction, problems in distribution facilities, or problems in the operation of the system. In determining the cause of contamination of a water supply, the investigator may be guided by the following examples of typical sanitary hazards.

a. **Surface Water Supplies**

(1) Location.

(a) Lack of supervision of the water shed area. Unrestricted use for recreational purposes, habitation, and industry.

(b) Water treatment plant and facilities situated in an area subject to flooding.

(c) Sewers, cesspools, latrines, dumps, sanitary fills, or other sources of contamination situated in the vicinity of the various units of the treatment plant.

(d) Improper location of the water intake with respect to the bottom of the body of water, and nearby drainage outlets, natural currents, winds, and tidal action.

(2) Construction.

(a) Common wall (construction) used between treated and raw water units.

(b) Bypass connections for raw and partially treated water whereby such waters may be discharged into distribution system.

(c) Manhole openings into collection reservoir are not provided with raised sill and overlapping covers.

(d) Vents not properly screened or otherwise protected to prevent the entrance of contaminating materials.

(e) Pumping equipment situated in subsurface pumproom subject to flooding.

(3) Operation.

(a) Operator not trained in the fundamental principles of water plant operation.

(b) Operating equipment such as chemical feeders and chlorinators are allowed to become inoperative and are not repaired.

b. **Ground Water Supplies**.

(1) Location.

(a) Source situated in an area where fissured or creviced rock occurs.

. (b) Source situated near sewer lines, garbage fills, latrines, septic tanks, contaminated surface waters, or in low areas subject to flooding.

(c) Top of well casing or lining terminates in a pit or other unfilled space which is subject to flooding.

(2) Construction.

(a) Well not provided with a watertight casing to a sufficient depth to exclude surface water.

(b) Well casing or lining constructed of pervious or improperly joined materials.

(c) Independent drop pipe or pipe not provided for drilled wells. Well casing used as a suction pipe.

(3) Operation.

(a) Well casing allowed to deteriorate and not replaced or repaired.

(b) Sewer lines, drains, or other sources of contamination permitted to be installed in the vicinity of the source. Filter backwash lines connected to the sewer.

c. **Pumping Equipment**.

(1) Location.

(a) Finished water pumping equipment situated in subground level space subject to flooding.

(b) Sewer lines, floor drains, pit latrines, or other sources of contamination in the vicinity of pumping equipment.

(2) Construction.

(a) Annular opening between well casing and education pipe not properly sealed.

(b) Casing vents not properly screened and hooded.

(c) Pumps are not self-priming, and the priming connection is made to unsafe water supplies.

(d) Openings around drawdown gage not properly sealed.

(e) Webbing at base of pump not drilled or slotted to permit drainage of wastewater.

(f) Leakage of contaminated oil I from shaft bearings into water.

(g) Intake or air compressor for airlift system not properly protected by filters or hoods.

(h) Water-receiving tank for airlift system not properly covered.

(3) Operation. Failure to disinfect pumps and piping after opening for repairs.

d. **Distribution System**.

(1) Location.

(a) Water and sewer pipe are laid in the same trench.

(b) Water and sewer pipe crossings not properly installed to prevent contamination of the water.

(c) Underwater crossings not properly protected.

(2) Construction.

(a) Hydrant drains connected to the sanitary sewers.

(b) System constructed of piping of substandard materials.

(c) Sewer flush tanks connected to the water supply.

(d) New piping installed without proper disinfection.

(e) Cooling water returned to the system.

(f) Cross connections to unsafe water supplies.

(g) Improperly designed plumbing fixtures that may permit backsiphonage connected to the system.

(h) Direct connection of potable water piping to treatment units at a wastewater treatment plant or swimming pool.

(3) Operation.

(a) Lack of continuous program to control plumbing installations.

(b) New piping installations not properly disinfected.

e. **Disinfection**. (The following apply to both ground and surface water supplies.)

(1) Equipment not of sufficient capacity to adequately treat the water under all conditions.

(2) Inadequate or limited reserve supply of the disinfecting agent.

(3) Lack of proper testing facilities.

(4) Apparatus in need of repair.

(5) Insufficient contact time between water and disinfecting agent before consumption.

(6) Standby equipment not provided to ensure continuous operation.

f. **Personnel**.

(1) Operating personnel not trained in the fundamental principles of water plant operation.

(2) Personnel inadequately trained for carrying out laboratory control of treatment processes.

## Section IV. TREATMENT FOR NUCLEAR, BIOLOGICAL, OR CHEMICAL CONTAMINATION

### 6-18. GENERAL

In a combat environment, there is always a possibility that nuclear, biological, or chemical (NBC) weapons may be employed. Should such an event occur, the water supply, in all likelihood, would become contaminated. A water source contaminated with an NBC agent can cause incapacitation or death to a consumer. Effective means for determining the presence of NBC agents, followed by proper decontamination procedures, can eliminate or reduce the hazards caused by these agents.

## 6-19. NUCLEAR, BIOLOGICAL, OR CHEMICAL AGENTS

a. **Nuclear Agents**. Radiological contamination in water is caused by fallout from a nuclear weapon. The water itself does not become radioactive, however, the minerals in water form radioactive isotopes when exposed to direct neutron activity from a nuclear weapon. Since this radiation decays to about 1 percent of its original value in about 14 days and because sea water or water with an extremely high mineral content (brackish water) is not normally used as a source of drinking water, direct radiation is not a major concern. The principal concern in radiological contamination is from fallout and from the blow-in or wash-in of radioactive dust and surrounding soil. If the fallout or radioactive particles do not physically enter the water, the water does not become contaminated. Therefore, water in canteens, water cans, trailers, or other sealed containers will not be contaminated by fallout and will be safe for drinking. Likewise, water from springs or deep wells would very likely be safe for drinking with normal treatment processes.

b. **Biological Agents**. Biological agents include any of the microorganisms that are pathogenic to man. Those that would be of major concern in the water supply would be those that are frequently the cause of waterborne diseases, such as typhoid, cholera, hepatitis, bacillary dysentery and amebic dysentery. In many ways, biological agents resemble natural biological contamination that is removed by the usual water treatment processes. However, contamination from the tactical employment of biological warfare agents could result in the presence of unusual microorganisms not normally found in field water, and they could be present in abnormally high numbers.

c. **Chemical Agents**. Chemical agents include the nerve agent (G-series and V-series), blister agents, vomiting agents, and choking agents. The nerve agents, blister agents, and agents containing cyanide are dangerous because they are likely to become poisonous. They are either slow to decompose in solution or remain poisonous after decomposition. Some are soluble in water. Water supplies are likely to become contaminated as an incidental result of widespread chemical attack rather than as a result of direct attack on the water supply.

## 6-20. DETECTION OF NUCLEAR, BIOLOGICAL, OR CHEMICAL AGENTS.

If a NBC agent, or any combination thereof is used, the water supply will invariably be involved. It is impossible to foresee what type of agent will be used, but effective security measures can decrease and counteract the hazards of all three types of agents. Effective security involves prompt and accurate detection. If overt, NBC warfare is initiated, the hazard of contamination will be obvious. In more subtle or surprise employment of NBC agents, detection is more dependent upon the alertness of all concerned.

a. **Nuclerar Agents**. In the event of the employment or accident of nuclear weapons, water supplies must be continuously monitored for radioactivity. Qualitative tests for radioactivity can be performed using the Radiac Set, AN/PDR--27 (see figure 6-16). This instrument measures low-intensity gamma radiation within the range of 0 to 500 milliroentgens per hour.

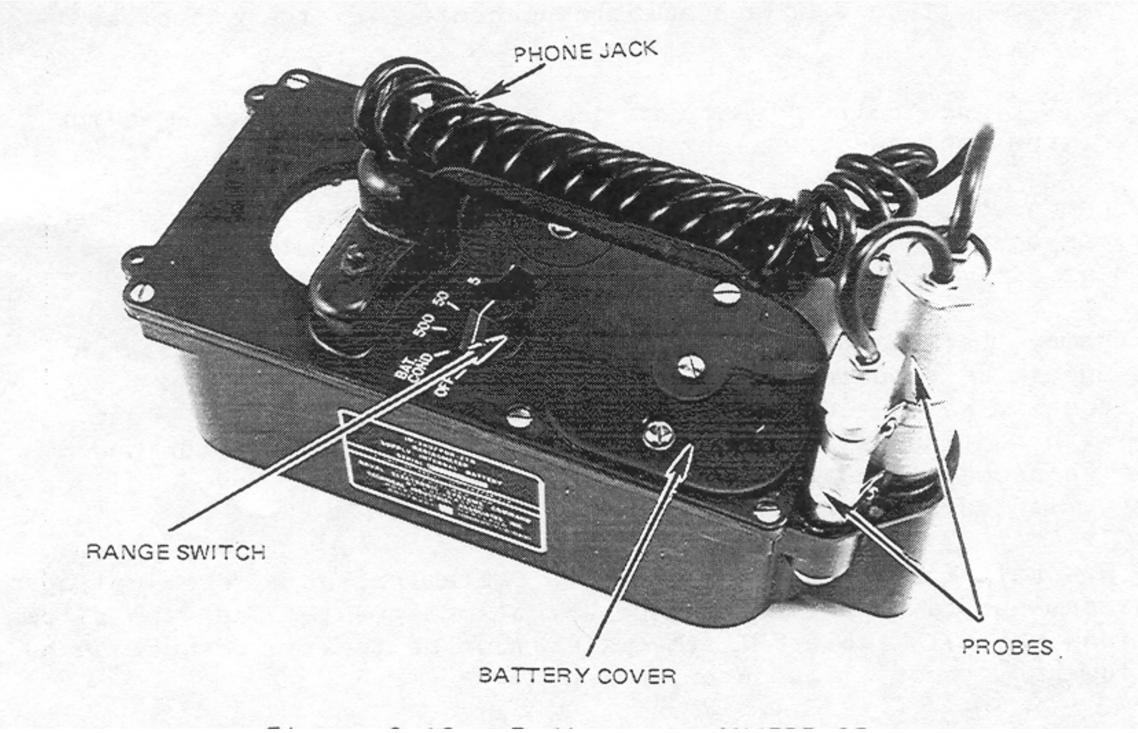


Figure 6-16. Radiac set, AN/PDR-27.

b. **Biological Agents**. The laboratory identification of most microorganisms is difficult and time-consuming; consequently, quick identification of biological agents in the field is not yet feasible. Biological agents may be disseminated by such means as generators, aircraft sprays, missiles, explosives, and insect vectors. When any of these means are employed, the possibility that biological agents are being used must be considered. The results of biological contamination are not so readily evident as are those of chemical contamination; therefore, detection is much more difficult. One sign that may be indicative of biological contamination in water is a sudden and otherwise unexplained increase in the chlorine demand (see paras 2-4b, 5-10b).

c. **Chemical Agents**. Contamination by chemical agents usually, though not always, leaves significant signs that should arouse immediate suspicion. These include a drastic lowering of the pH of the water (less than six), odors, and tastes characteristic of chemical contamination, and dead fish or animals in significant numbers. If chemical contamination is suspected, tests should be initiated immediately to confirm or rule out the contamination. The conduct of chemical tests on water was discussed in Lesson 4.

## 6-21. DECONTAMINATION

When a source of water supply is found to be contaminated, every effort should be made to find an uncontaminated source. When such a source cannot be found, permission must be obtained from a medical officer before treating the contaminated water.

a. **Removal of Nuclear Contamination**.

(1) Nuclear contamination may result from fallout of either fission products (radioactive isotopes) or nonfissioned products (uranium or plutonium), from blow-in or wash-in of radioactive dust. and from induced activity in dissolved materials in water and surrounding soil. Continuous flow equipment, when operated according to standard procedure, is capable of removing a large amount of such contamination. However, sources containing radiological contamination should be avoided if at all possible.

(2) The efficiency of a given process for removal of radioactive materials from water is dependent upon the quantity of the contaminant that is in suspension in the water and the quantity that is dissolved in true solution. Removal of material in suspension is relatively easy since the purification procedure is designed to remove suspended matter and to clarify the water. Available information indicates that most of the radioactivity occurring in fallout and debris from the detonation of a nuclear weapon is insoluble in water. This fact tends to simplify the decontamination problem.

(3) Continuous flow type equipment, with auxiliary processing equipment when necessary, removes radioactive material from water using pretreatment, coagulation, or filtration, or by using a combination of these methods. Coagulation and filtration are normal treatments given to all raw surface waters in operation of field purification units. Removal of suspended radioactive materials by this method is very high. Removal of dissolved radioactivity is frequently possible by using ion exchange equipment. An ion exchange unit operates on the same principle as both commercial and home zeolite water softeners.

(4) Pretreatment is suggested when the degree of radiological contamination indicates a combination of treatment methods or when the more effective ion exchange equipment is not available. Pretreatment consists of batch slurrying the contaminated raw water with a selected material having adsorptive and ion exchange capacity. The material of choice is clay, preferably of the montmorrilionite type, that is high in hydrous aluminum silicate content. Raw water is slurred at 1,000 ppm for 30 minutes and is then coagulated and filtered. This series of steps will remove most of the suspended radioactivity and an appreciable percentage of the dissolved radioactivity.

(5) Figure 6-17 illustrates graphically the methods used for normal water treatment and treatment for removal of NBC contaminants.

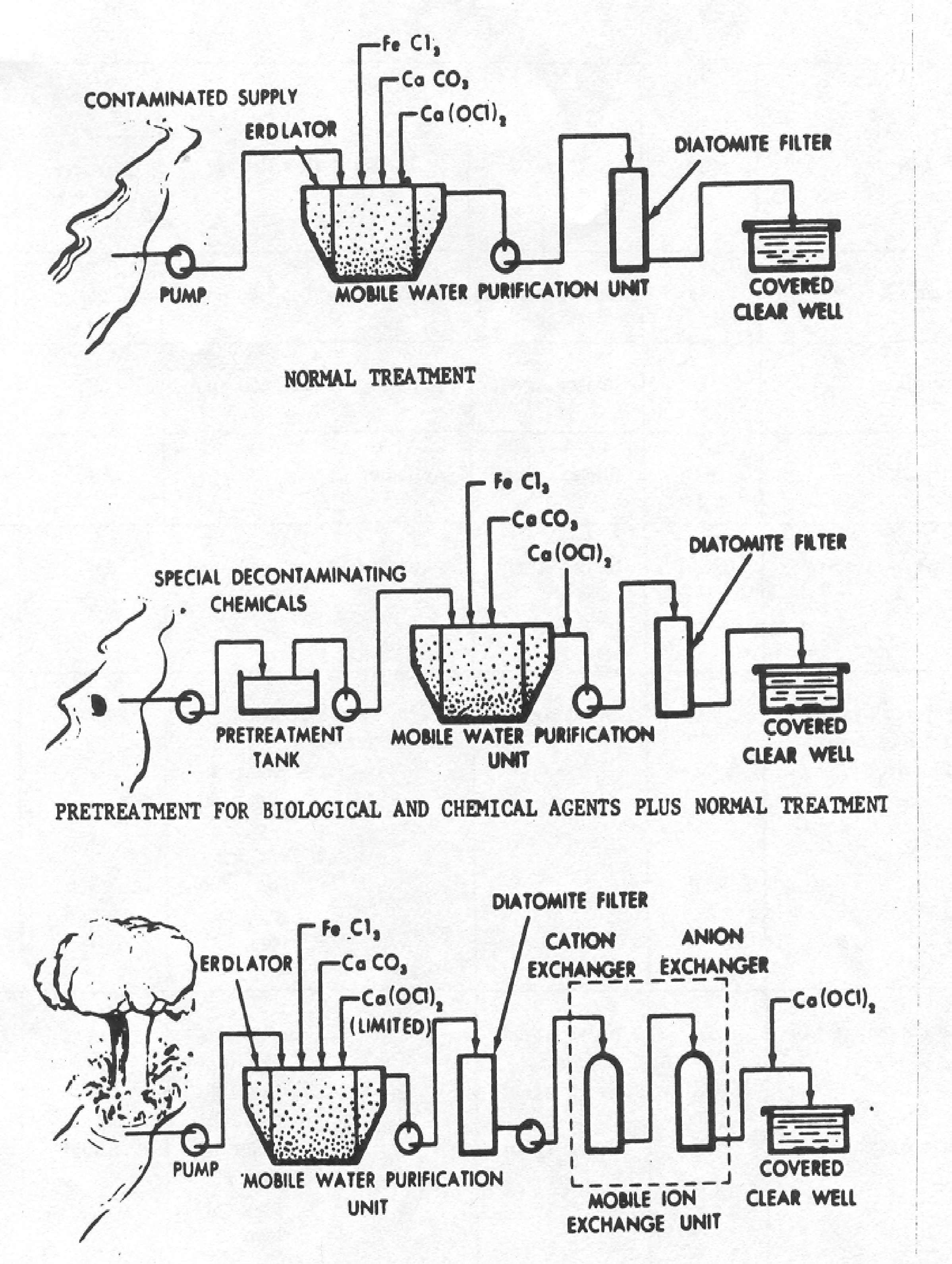
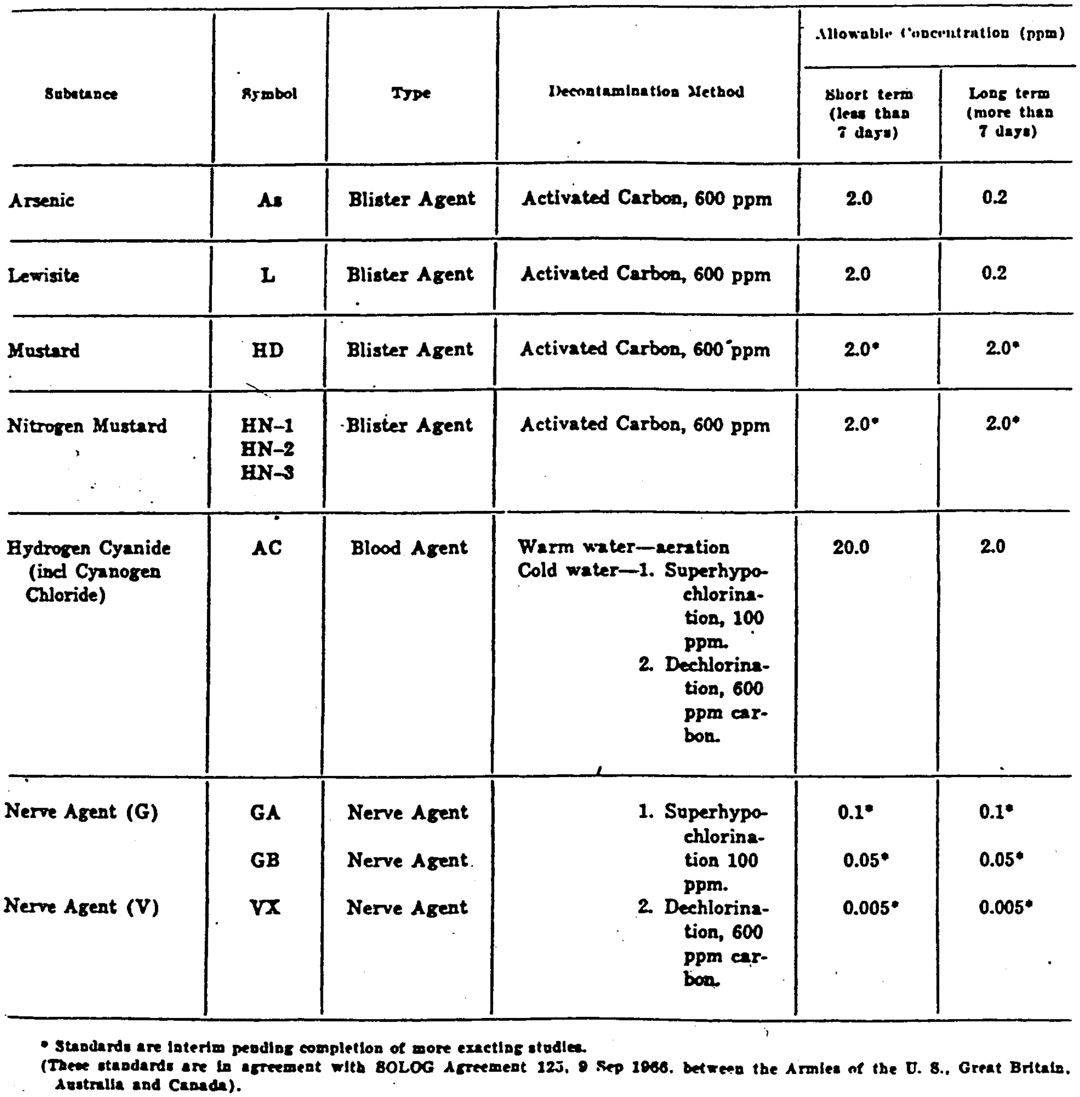


Figure 6-17. Methods used for normal water treatment and treatment for removal of NBC contaminants

**NOTE**: Reverse osmosis units take out most biological, chemical, and nuclear agents, but need two chemical cartridges, with only one being used at a time.

b. **Removal of Biological Agents**. When the presence of resistant biological agents is reported by authorized detection agencies and an alternate uncontaminated source is not available, the prescribed treatment in connection with continuous flow equipment is the super chlorination and dechlorination procedure out lined in a(3) above. A low pH, by acidification if necessary, is desirable.

c. **Removal of Chemical Agents**. When contamination by chemical agents has been determined to be present in concentrations greater than the allowable concentrations shown in Table 6-1, the water must be treated before use by one of the following methods of decontamination:



| Substance | Symbol | Type | Decontamination Method | Allowable Concentration (ppm) | |
|---|---|---|---|---|---|
| | | | | Short term (less than 7 days) | Long term (more than 7 days) |
| Arsenic | As | Blister Agent | Activated Carbon, 600 ppm | 2.0 | 0.2 |
| Lewisite | L | Blister Agent | Activated Carbon, 600 ppm | 2.0 | 0.2 |
| Mustard | HD | Blister Agent | Activated Carbon, 600 ppm | 2.0* | 2.0* |
| Nitrogen Mustard | HN-1<br>HN-2<br>HN-3 | Blister Agent | Activated Carbon, 600 ppm | 2.0* | 2.0* |
| Hydrogen Cyanide (incl Cyanogen Chloride) | AC | Blood Agent | Warm water—aeration<br>Cold water—1. Superhypochlorination, 100 ppm.<br>2. Dechlorination, 600 ppm carbon. | 20.0 | 2.0 |
| Nerve Agent (G) | GA | Nerve Agent | 1. Superhypochlorination 100 ppm.<br>2. Dechlorination, 600 ppm carbon. | 0.1* | 0.1* |
| | GB | Nerve Agent | | 0.05* | 0.05* |
| Nerve Agent (V) | VX | Nerve Agent | | 0.005* | 0.005* |

* Standards are interim pending completion of more exacting studies.

(These standards are in agreement with SOLOG Agreement 123, 9 Sep 1966, between the Armies of the U. S., Great Britain, Australia and Canada).

Table 6-1. Decontamination and minimum potability standards for significant chemical agents.

(1) Activated carbon. This treatment is used when blister agents are present. Activated carbon is a relatively pure, finely powdered form of carbon that adsorbs many substances readily. It is an excellent adsorbing agent because the fineness and porosity of the carbon particles give it an enormous surface area. One cubic inch of activated carbon particles has an internal and external exposure area of about 20,000 square yards. The activated carbon is added to a pretreatment tank set up separately from the coagulator assembly. Raw water is pumped into this pretreatment tank from the source and the activated carbon is added. A concentration of 600 ppm is generally sufficient. The water is al lowed to remain in contact with the carbon for 30 minutes or longer and is then pumped to the purification unit for the usual treatment.

(2) Aeration. When hydrogen cyanide is the contaminant and the water is warm (700F or above), the aeration treatment may be used. Water may be aerated by spraying it into the air, allowing it to flow over cascades, passing it through beds of coke, or passing air under pressure into the water. The spray method can be effectively used with Army purification equipment. Water can be recirculated through storage tanks or reservoirs by pumping the water out of the tank and spraying it back through an elevated strainer or nozzle attached to the discharge end of the hose (see figure 6-18).

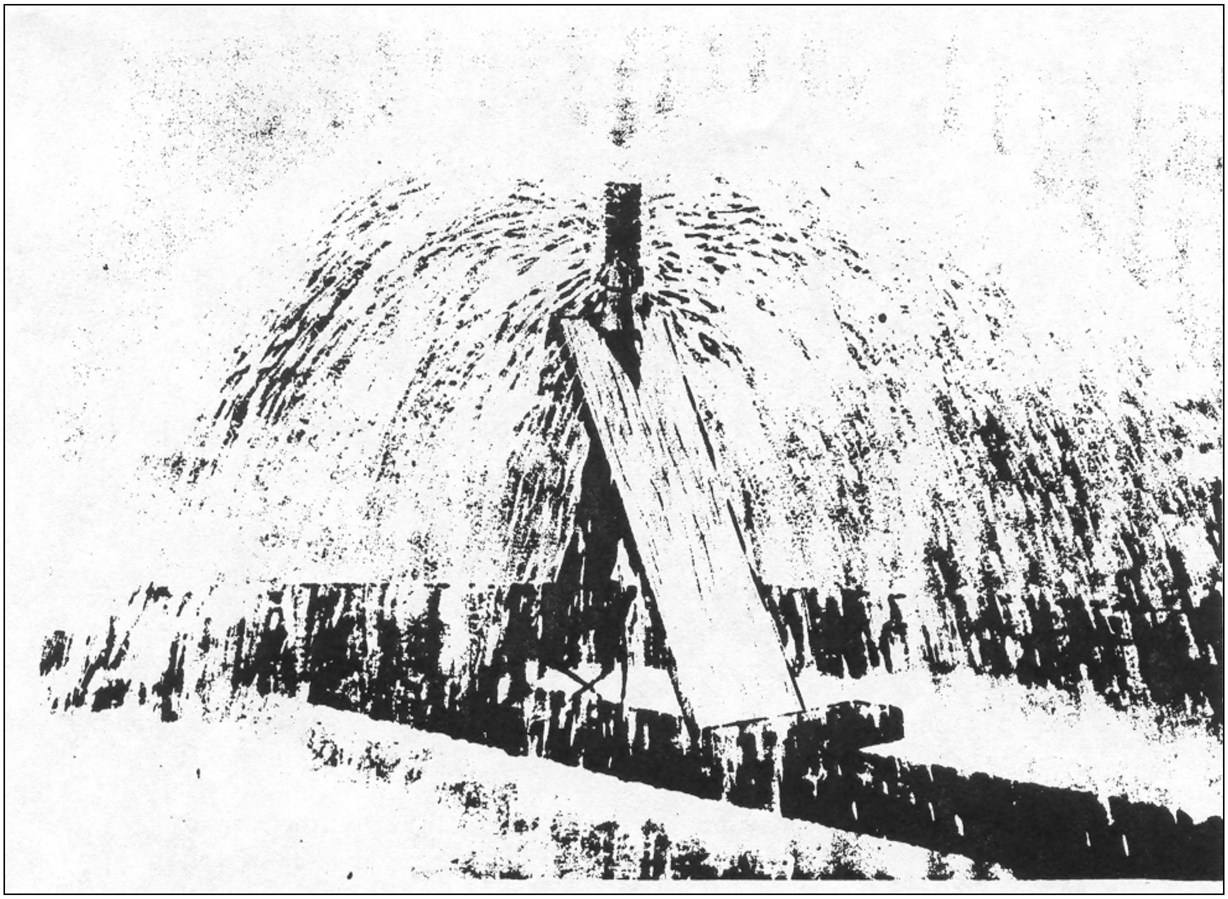


Figure 6-18. Aeration of water

(3) Superchlorination and dechlorination. (See following caution.) When hydrogen cyanide is the contaminant and the water is cold (70°F or below) or when one of the nerve agents is the contaminant, two pretreatment tanks should be used. Raw water is pumped into both tanks and superchlorinated by the addition of 100-ppm available chlorine from high strength calcium hypochlorite. (The calcium hypochlorite is added to the tanks prior to starting to fill them with raw water.) The water is then dechlorinated by the active carbon treatment outlined in (1) above. By the use of two tanks, a continuous quantity of pretreated water can be made available to the coagulator in much the same manner as two or more floc tanks are used in the batch process of normal water treatment. It is important that the residue of activated carbon in the pretreatment tanks be kept in suspension. Pumps should be used for this purpose if necessary. The carbon is removed by coagulation and diatomite filtration. If the residual is inadequate, post-chlorination is necessary.

**CAUTION**: Calcium hypochlorite, a powerful oxidizer, and activated carbon, a reducing agent, will react violently, possibly resulting in fire or explosion, if mixed with one another in slurry form. The following safety precautions should be observed:

(a) Do not store activated carbon and calcium hypochlorite near one another.

(b) Do not use the same pail to prepare slurries of these two substances.

(c) Keep both chemicals dry until actually ready for use.

Continue with Exercises

## EXERCISES, LESSON 6

**INSTRUCTIONS**: Answer the following exercises by marking the lettered response that best answers the exercise, by completing the statement, or by writing the answer in the space provided at the end of the exercise.

After you have completed all the exercises, turn to "Solutions to Exercises" at the end of the lesson and check your answers. For each exercise answered incorrectly, reread the material referenced with the solution.

1. Surface waters are contaminated primarily by:

   a. Surface runoff.

   b. Seepage into artesion aquifers.

   c. Percolation through the soil.

   d. Air pollution adhering to raindrops.

2. If a water source is only 4 inches deep, the intake strainer should be placed:

   a. On the bottom.

   b. On the surface (by means of a float).

   c. In a pit dug in the bottom and lined with sand.

   d. In a pit dug in the bottom and lined with coarse gravel or rocks.

3. Muddy, or turbid water may be improved in quality by the use of:

   a. An intake strainer.

   b. An intake gallery.

   c. A diatomite filter.

   d. A water softener.

4. Which type of well is most difficult to maintain in a sanitary condition?

   a. Dug well.

   b. Bored well.

   c. Driven well.

   d. Drilled well.

5. The annular space between a well casing and the surrounding earth should be filled with cement grout to a depth of at least ___________ feet.

6. In the blank space to the left of each type of well listed below, place the number corresponding to the characteristic in the right-hand column which more nearly describes that type of well than do the other characteristics.

   a. _____ Dug well.

   b. _____ Bored well.

   c. _____ Driven well.

   d. _____ Drilled well.

   (1) Can be constructed in a kind of soil at great depths.

   (2) Used where the water table is not very deep.

   (3) Simplest and easiest where soil is not too hard.

   (4) Can be constructed anywhere with simple tools.

   (5) Practical at depths less than 100 ft where water requirement is low.

7. If an individual wastewater disposal system is to be constructed in the general vicinity of an existing well, what is the least distance that should be maintained between the well and the:

   a. Septic tank. _______ feet.

   b. Laterals (disposal field) _______ feet.

8. Newly constructed wells should be disinfected with ________ ppm calcium. hypochlorite solution.

9. Dug wells should be lined with _____________. ____________, or ___________.

10. Any flow of nonpotable water or other liquid into a potable water system is termed ________________.

11. Backflow caused by negative pressure (partial vacuum) in a water system is termed _________________.

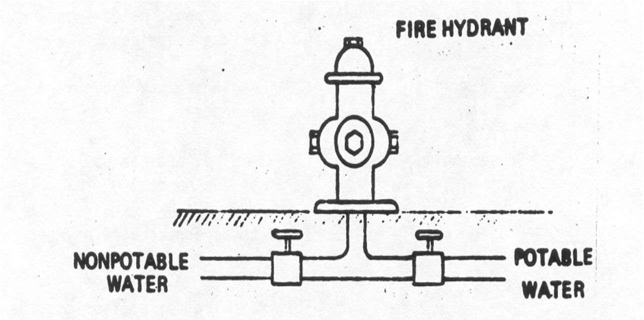
12. The operation of a siphon is based upon three physical factors:

    a. _______________________________________.

    b. _______________________________________.

    c. _______________________________________.

13. Does the illustration below depict a direct or indirect cross connection?



14. The only <u>positive</u> protection against backsiphonage in a plumbing system is a ____________________________.

15. The most common cause of indirect cross connection is the _________________.

16. Vacuum breakers provide protection only against ____________________.

17. When a vacuum breaker must be used, ___________________ the type is preferred. This type must be located on the ____________________ side of the fixture valve.

18. Where backpressures can be expected to occur in a plumbing system, protection against direct cross connections may be increased by the use of a ________________________________.

19. Under Condition 1, what action is taken when a drinking water sample is found to be contaminated?

    a. Rejection of the system.

    b. Increased surveillance and investigation, followed by emergency disinfection if warranted.

    c. Flushing entire system, followed by emergency disinfection.

    d. Increasing chlorine dosage and residual.

20. In the space to the left of each of the components of a water supply system listed below, insert the number of the sanitary defect listed in the right-hand column that is more likely than the others to occur in that type of system.

    a. Surface water source.

    b. Ground water source.

    c. Pumping equipment.

    d. Distribution system.

    (1) Water and sewer lines laid in same trench.

    (2) Livestock watering in stream.

    (3) Improper disinfection after repairs.

    (4) Rain barrels not covered.

    (5) Contamination from privy located nearby.

21. Water may become contaminated as an ______________________ of a widespread chemical attack rather than as a result of a direct attack on the water supply.

22. A drastic lowering of the pH value of water is indicative that a ________________ is present.

23. A sudden increase in the chlorine demand in indicative that an ________________________ agent is present.

24. What is the efficiency of a given process for the removal of radiological contamination dependent upon? ________________________________________________________.

25. Which unit will take out most of the nuclear, biological, and chemical agents from water? ______________________________.

26. What decontamination method would be used to remove nerve agent (V) from the water to make it potable? ______________________________________.

27. Radiological contamination affects __________________ rather than the water itself.

28. Which two types of chlorination help to remove biological agents from the water? ______________________________.

29. What is the symbol of the blister agent mustard and what decontamination method is used to remove it from water? _____________________________________.

30. What is the allowable concentration of cyanogen chloride in water for long term usage? ________________.

***Check Your Answers on Next Page***

## SOLUTIONS TO EXERCISES, LESSON 6

1. a (para 6-2a).

2. d (para 6-2b, figure 6-3).

3. b (para 6-2c, figure 6-4) c and d will also remove turbidity; however, they are not designed for this purpose and operate more efficiently with coagulated water.

4. a (para 6-3b(2).

5. 10 (para 6-3b(2).

6. a(2)
   b(5)
   c(3)
   d(1) (para 6-3a).

7. a-l00
   b-l00 (para 6-3b(1)).

8. 50 (para 6-3b(3)).

9. brick, stone, concrete (para 6-3a(1)).

10. backflow (para 6-6b)

11. backsiphonage (para 6-6c)

12. Atmospheric pressure.
    Vacuum (negative pressure).
    Head (pressure differential) (para 6-7).

13. Direct (paras 6-8. 6-6a).

14. vertical air gap (para 6-10).

15. submerged inlet (para 6-9).

16. backsiphonage (para 6-11).

17. nonpressure, atmospheric (para 6-11a).

18. reduced pressure backflow preventer (para 6-12).

19. b (para 6-15a(2)).

20. a (2) or (5)
    b (5)
    c(3)
    d(1) or (3) (para 6-17).

21. incidental result (para 6-19a).

22. pH value (para 6-20a).

23. increase in chlorine (para 6-20b).

24. Quantities of contaminates suspended and dissolved in water (para 6-21c(2)).

25. Reverse osmosis (para 6-21 NOTE).

26. Dechlorination, 600 ppm carbon (para 6-21a(3)).

27. minerals (para 6-19a).

28. Superchlorination and dechlorination (paras 6-21a(3), b, Table 6-1).

29. HD; Activated carbon, 600 ppm (Table 6-1).

30. 2.0 (Table 6-1).

**End of Lesson 6**