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ABSTRACT

This document, designed to serve as a training manual for technical instructors and as a field resource reference for Peace Corps volunteers, consists of nine units. Unit topics focus on: (1) water supply sources; (2) water treatment; (3) planning water distribution systems; (4) characteristics of an adequate system; (5) construction techniques; (6) operation and maintenance of a distribution and treatment system; (7) scope of disposal system projects in host communities; (8) the privy method of excreta design for a village; and (9) water carried sewage systems construction and maintenance. Each unit includes: an overview (statement summarizing significance of material to follow and points requiring special emphasis); an objective (definition of goal to be achieved); lists of tasks (steps followed to accomplish objectives), functional skills (knowledge skills needed to perform tasks), terminal performance tests; content information describing the knowledge and skills needed to perform tasks correctly; and lesson plans. (JN)

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Peace Corps

# WATER PURIFICATION, DISTRIBUTION AND SEWAGE DISPOSAL

FOR

PEACE CORPS VOLUNTEERS

Prepared by

Volunteers for International Technical Assistance, Inc.

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# PREFACE

WATER PURIFICATION, DISTRIBUTION, AND SEWAGE DISPOSAL is designed to aid both the technical instructor as a training manual and the Peace Corps Volunteer as a field resource reference. We hope that the manual will help to turn out Volunteers who can perform effectively in the field.

Each logical unit of instruction is sub-divided into the following categories:

| | |
|---|---|
| OVERVIEW | A statement summarizing the general significance of the material to follow, and points requiring special emphasis. |
| OBJECTIVE | A definition of the goal to be achieved by the trainee for that unit of instruction. |
| TASKS | The steps to be followed to accomplish the objective. |
| FUNCTIONAL SKILLS | The knowledge and skills needed to be able to perform the tasks. |
| TERMINAL PERFORMANCE TESTS | The means of evaluating the ability of the trainee to perform the skills needed to complete the tasks in order to accomplish the objective. |
| RELATED INFORMATION | Content information describing the knowledge and skills needed to perform the tasks correctly. |
| LESSON PLANS | Suggested guidelines for providing instructional time for the essential areas of each unit. |

Although we have followed a typical pattern of presentation, offering logical units of information, it is important to keep in mind that the manual is to be used in preparing Volunteers for a program and that no single unit can possibly stand alone. All are interrelated and need to be included in a systematic presentation. Its value as a reference tool will come after the skills have been learned and the Volunteer is overseas. Once in the field, the objectives and tasks can be used by the Volunteer as an outline description of how the project should proceed.

During the early stages of the project, valuable suggestions and opinions were offered by VITA Volunteers, Robert Fortman, James Patterson, Morton Hilbert and Ramesh Patel.

To Union College students Robert Okello and Richard Sack who collected, summarized, and organized the material into the manual's present format, a most sincere vote of thanks. Without their efforts, we would still be in first draft stages.

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Finally, errors and oversights must be credited to...

Michael J. Glowacki

Project Coordinator

Schenectady, New York
April 18, 1969

# SECTION 1

## WATER SUPPLY SOURCES

OVERVIEW:

The purpose of a water supply system is to distribute water to the locations where it is needed. A source of water must be found which is adequate in quantity and quality. An understanding of the geological properties of the earth is necessary to recognize and evaluate the potential sources of water for this system.

This section is planned to familiarize the student with these basic geological properties. Also included is information on making topographic maps to aid in this evaluation. This background knowledge is then used to describe water sources and how they can be developed to provide potable and palatable water for distribution by the water supply system.

The learning activities in this section are primarily field exercises. The trainees will be in the field seeing actual examples of water sources. They will examine samples of the various rock types. The emphasis should be on individual participation. It is only through this experience that a trainee will be able to again recognize suitable sources when he is overseas.

# WATER PURIFICATION, DISTRIBUTION, AND SEWAGE DISPOSAL

## WATER SUPPLY SOURCES AND TREATMENT

### SECTION 1: WATER SUPPLY SOURCES

OBJECTIVE: Locate and identify water supply sources and determine potential feasibility as village or rural water supply sources.

TASKS:

1. Procure existing topographic maps and sketches of the area and consult people with a knowledge of the same information onthe types and locations of the sources.
2. Determine the location of any lakes or ponds, cisterns, springs, rivers, or wells with respect to the community.
3. Identify any lakes, ponds, rivers, springs, wells, or cisterns.
4. Roughly sketch the topography between the sources and the community.
5. Plot the location of any houses, livestock grazing areas, privies, etc. on an existing map or a simple sketch map.
6. Estimate by means of field determinations and past records the amount and the variation in the amount of water available from each source.
7. Identify the nature and quantity of any physical, bacteriological, and chemical pollutants of each source.
8. Identify the extent to which any developments would improve the quality or quantity of the various potentially productive sources.
9. Determine the cost of developments for each potential source.

FUNCTIONAL SKILLS:

1. Interpret and make simple topographic maps.
2. Use a compass.
3. Identify the various types of water supply sources.

WATER SUPPLY SOURCES (cont.)

4. Identify the basic rock and soil types and know the hydrological properties of each.

5. Know what factors influence the quantity of a given water supply source.

6. Know what factors influence the quality of a given water supply source.

7. Identify physical pollutants (the extent of chemical and bacteriological pollution will be determined by laboratory analysis).

8. Identify what developments can significantly reduce pollution or improve the yield of the various water supply sources.

9. List the relative costs of various types of source developments.

TERMINAL PERFORMANCE TESTS:

1. Given a compass, draw a simple topographic map of any prominent topographic features such as a hill.

2. In a field exercise, correctly identify the various types of water supply sources.

3. Correctly identify the basic rock and soil types.

4. Correctly list the factors which influence the quality and quantity of a given water supply source, and the extent that each factor influences that source as a water supply consideration.

5. Given a number of water samples, correctly identify all physical pollutants present in each sample.

6. Opposite each type of water supply source, correctly list the developments that may improve its quality or quantity.

7. On a written examination list the relative cost of given types of source developments.

# WATER SUPPLY SOURCES AND TREATMENT

## WATER SUPPLY SOURCES

## BACKGROUND INFORMATION

### TOPOGRAPHIC MAPPING

In planning a water distribution or sewage disposal system, the layout of the community with respect to any water supply sources must be mapped. When no maps of an area are available, crude sketch maps are sufficient. Such maps should indicate the approximate placement of any man-made structures, livestock grazing areas, water supply sources, and disposal systems.

#### Topographic Contouring

A topographic map is a means of illustrating, through the use of contour lines, the shape of the ground surface. This exercise involves the determination of ground relief (topography) from points whose elevations above sea level are known.

The method is called "contouring from spot elevations". The data might have been obtained by surveying with a plane table and alidade, although modern topographic maps are made much more easily and accurately by the stereoscopic plotting of airphoto information.

Rules and hints in topographic contouring.

1. All points lying on a contour are of the same elevation above (or below) a reference point. However, one contour need not satisfy all the points of equal elevation; eg. adjacent hilltops of similar relief might require separate, closed contours each showing comparable levels. Some contours may be cut by the edges of the map and appear to be discontinuous but if the map be made large enough every contour eventually closes on itself, becoming continuous.

2. With rare exceptions, the contour interval is constant for the map area and is defined as the vertical distance between successive contours. The contour interval is stated as part of the scale of the map so that the vertical dimension of the contoured surface has identity. Ten-foot, twenty-foot, fifty-foot and 100-foot intervals are common. The interval is selected to best show the shape of the surface at the desired horizontal scale without requiring an unnecessary, unreadable number of lines. The relief of the area to be mapped also influences the choice of the contour interval.

3. Contours do not cross. Such a situation would illustrate an impossible ground surface shape. Contours are closely spaced on steep slopes, and distantly spaced on gentle slopes.

4. Closed depression contours are hachured on the lower side. They are used when all points within the line are below the level of the line. Obviously they are only required to show depressions which are completely surrounded by high ground. Gullies and river valleys are not usually closed on the downstream side and therefore are not illustrated by depression contours. A depression contour takes its value from that of the lowest, topographically adjacent regular contour.

5. In contouring gullies and valleys, the contours vee in the upstream direction. Be careful to confine the stream to the lowest part of its valley by passing the stream through the notch of the vee.

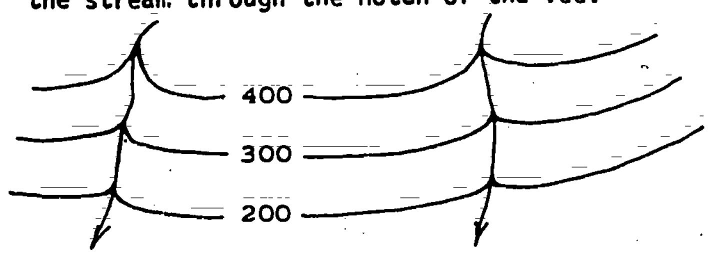



Fig. 1 Contour Lines

Contours are broken where numbering is necessary, to improve readability.

6. The use of some degree of "artistic license" is recommended in contouring. Do not attempt to just satisfy the point data. Try to make the trend of a contour reflect the trend of its neighboring contours.

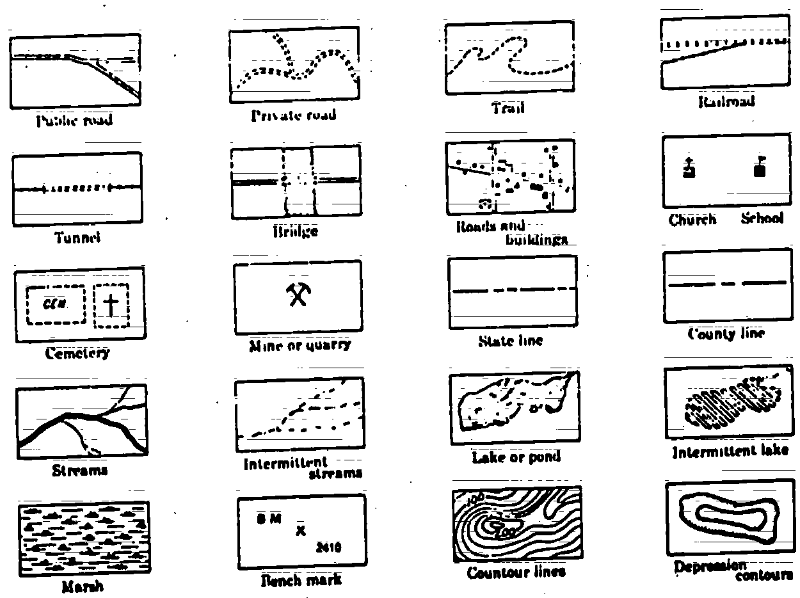
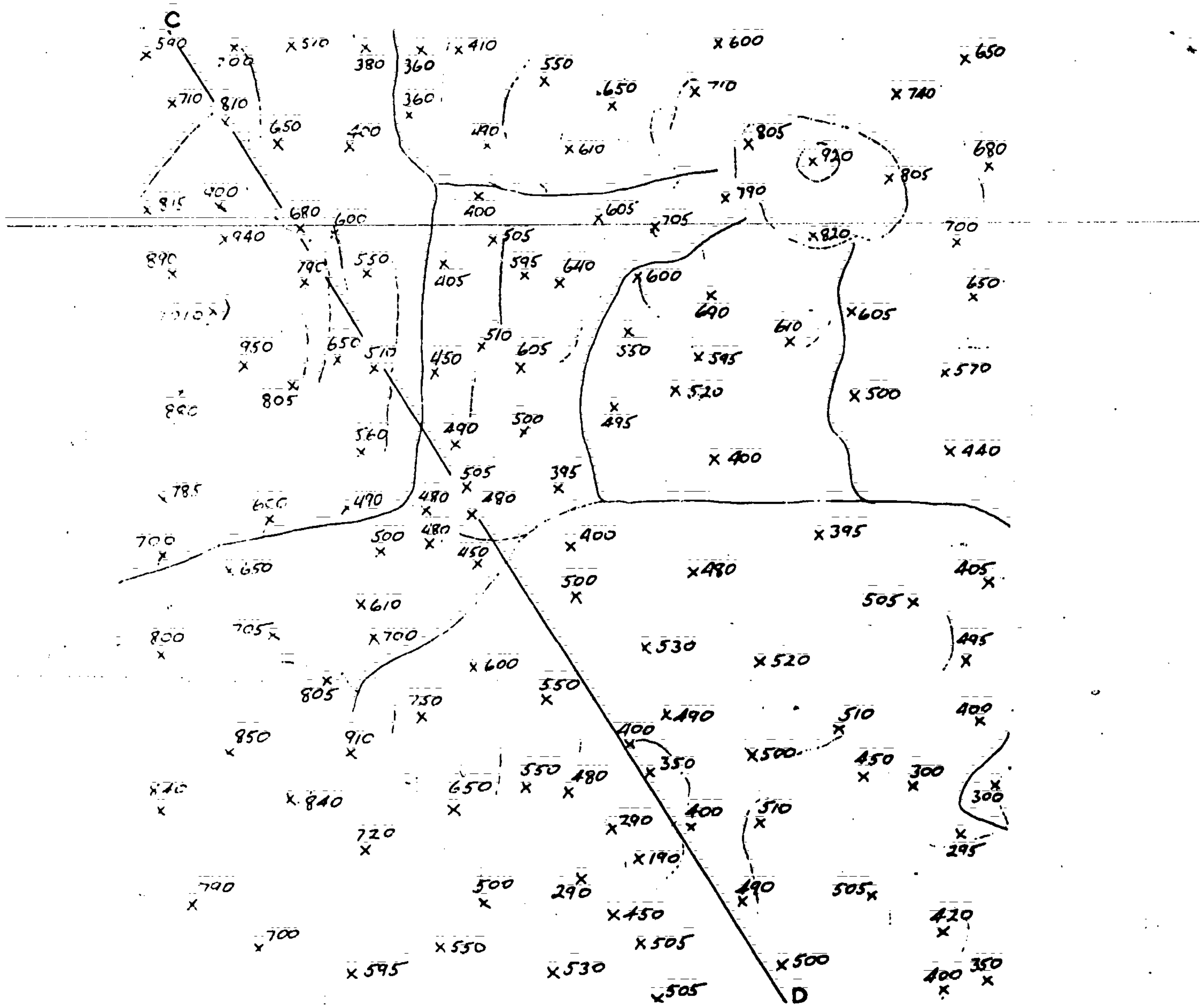



Fig. 2 Symbols for Topographical Maps

Fig. 3 CONTOURING FROM SPOT ELEVATIONS




1. Draw and label the contours every 100' (300', 400', 500', etc.)
2. Indicate with dashed line a divide; with dotted line an area of future stream capture. Label the highest point A, the lowest point B.
3. Distinguish areas of high and low stream gradient, indicate direction of flow of streams.

General

In making a crude topographic sketch very little attention should be paid to detail. Scale can be determined by pace, and direction by a compass. Periodic sighting of a distant object in a path and determination of its position relative to a present mark will serve for proper orientation.

Determining Pace

Lay out a one hundred foot interval on level ground, an uphill, and a downhill slope. If only a foot ruler is available, this may be used to mark out three or four feet on a stick, and this stick in turn used to measure the 100 feet. Being careful to work normally, the map maker then determines the number of paces over the 100 foot interval for each slope. By division, it is then possible to find a number of feet in an average pace for uphill, level, and downhill slopes.

Taking Bearings with the Compass

A bearing is the compass direction from one point to another. A bearing is always in a unidirectional sense; for example, if the bearing from A to B is N30W, the bearing from B to A can only be S30E. To read accurate bearings, three things must be done; (1) the compass must be leveled, (2) the point sighted must be centered exactly in the sights, and (3) the needle must be brought to rest.

In a sketch map, contours are used only to show the relative differences in elevation and the nature of the topography. It is unnecessary to know the elevation of a given contour or to connect all of them. Contours can be drawn arbitrarily to indicate that a hill is steep, a stream runs in a given direction, the community is uphill from a water source, etc. A realistic sketch map can be drawn by estimating the relief of an area around a point and then proceeding to a point on the periphery of this area. Plane table mapping may prove more adequate when more detailed maps are required.

Map Making Using a Plane Table

A description is given for the construction of serviceable maps using a plane table. Such maps are valuable for irrigation, drainage and village layout plans.

Tools and materials needed are:

Plane Table
Paper
Pencil
Ruler
Pins
Tape measure (optional)
Spirit level (optional)

The first step is to decide on a scale for the map. This is determined by judging the longest distance to be mapped and the size of the map desired. It should be noted that the map does not have to be made on a single sheet of paper but can be spliced together when completed. As an example, if one wanted a map 2 1/2 feet long to portray an area whose major distance is 1/2 mile, 2640 feet, then a scale of 100 feet to the inch would be convenient.

Paper should be placed on the plane table and the plane table oriented on or near some principal feature of the map, that is, a path, road, creek street, etc. A pin should then be placed vertically in the spot on the finished map where this location is desired. The plane table should be made level - by use of a spirit level, if available. The table should be rotated to a proper orientation, that is, so that the direction will appear on the finished map in the desired way. Now sight along the first pin to another principal feature which is visible from the table location (a bend in the road, a hill or any feature that will tie the map together), moving the second pin into the line of sight. A ruler may be used for this purpose if it has a sighting edge or even a couple of pins stuck into it. Now draw a line in the direction defined by the two pins. Measure the distance to the feature observed either by pacing or with a tape. Scale this distance along the line drawn, starting at the initial pin. Repeat this process for other principal features which may be seen from this location. When this has been done, move the table to one of the points just plotted, selecting one which will enable you to move over the territory in a convenient fashion. For example, follow a lane or creek or some feature which ties things together. Set up the plane table over this point and reorient the table. Do this by putting pins into the map at the present and previous locations. Next rotate the table so that the pins line up with the previous location. This procedure in fact locates the line joining the two locations on the map in the same direction as the line exists in nature. Again from this new location map in the desired features which can be conveniently sighted.

In this way the entire region to be mapped may be covered in a systematic way. If gaps appear or if more detail is needed, you may go back and set up over some mapped feature, reorient the map by sighting on a second feature, and proceed to map in the detail.

An alternate procedure may be used in mapping features which are not going to be used as plane table locations in the mapping process. This involves drawing a line in the direction of each feature from two plane table locations. The intersection of these two lines corresponding to a single feature locates the feature on the map. As a result this avoids the necessity for measuring distances. Note, however, that it is impossible to avoid measuring the distances between plane table locations.

If a spirit level is available, it is possible to level the plane table accurately, and using a ruler or other sighting device, relative elevations may be plotted on the map. A stick about six or eight feet long should be marked off in inches, and the person holding the stick vertically can, by moving his finger, identify to the person sighting, the distance up from the ground through which the line of sight passes.

## ROCK FORMATIONS AND THEIR WATER-BEARING PROPERTIES

The rocks that form the crust of the earth are divided into three classes:

Igneous--rocks which are derived from the hot magma deep in the earth. They include granite and other coarsely crystalline rocks, dense igneous rocks such as occur in dikes and sills, basalt, and other lava rocks, cinders, tuff, and other fragmental volcanic materials.

Sedimentary--rocks which consist of chemical precipitates and of rock fragments deposited by water, ice, or wind. They include deposits of gravel, sand, silt, clay, and the hardened equivalents of these--conglomerate, sandstone, siltstone, shale, limestone, and deposits of gypsum and salt.

Metamorphic--rocks which are derived from both igneous and sedimentary rocks through considerable alteration by heat and pressure at great depths. They include gneiss, schist, quartzite, slate, and marble.

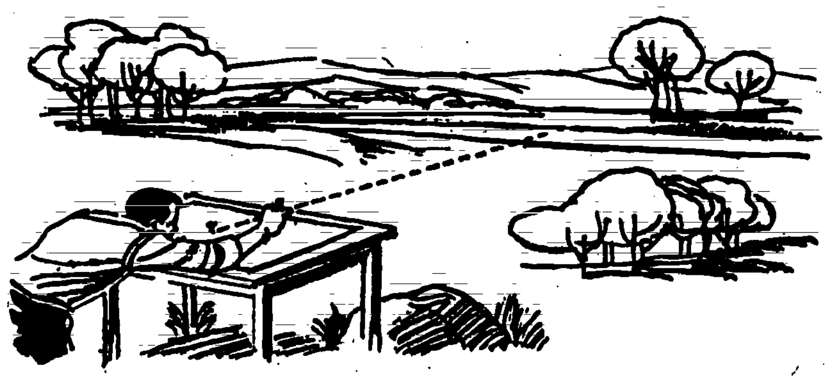


Fig. 4 PLANE TABLE MAPPING

The pores, joints, and crevices of the rocks in the zone of saturation are generally filled with water. Although the openings in these rocks are usually small, the total amount of water that can be stored in the subsurface reservoirs of the rock formations is large. The most productive aquifers* are deposits of clean, coarse sand and gravel: coarse porous sandstones; cavernous limestones; and broken lava rock. Some limestones, however, are very dense and unproductive. Most of the igneous and metamorphic rocks are hard, dense, and of low permeability. They generally yield small quantities of water. Among the most unproductive formations are the silts and clays. The openings in these materials are too small to yield water, and the formations are structurally too incoherent to maintain large openings under pressure. Compact materials near the surface, with open joints similar to crevices in rock, may yield small amounts of water.

EXAMPLES OF MIXED ROCK

| | | |
|---|---|---|
| Medium sand with fine gravel, gray | Fine gravel | 20% |
| | Coarse sand, gray | 30% |
| | Medium sand, gray | 40% |
| | Fine sand, gray | 10% |
| Medium gravel with coarse sand, brown | Coarse Gravel, brown | 20% |
| | Medium gravel, brown | 30% |
| | Fine gravel, brown | 20% |
| | Coarse sand, brown | 20% |
| | Medium sand, brown | 10% |
| Clay with sand and fine gravel, blue | Fine gravel, gray | 5% |
| | Coarse sand, gray | 5% |
| | Medium sand, gray | 10% |
| | Fine sand, blue | 20% |
| | Clay, blue | 60% |

The nomenclature used in consolidated sedimentary rocks is very similar to that used for the unconsolidated rocks. The following names should be applied to the consolidated equivalent of the eight classes of unconsolidated rocks.

| Name of unconsolidated rock | Name of consolidated equivalent |
|---|---|
| 1. Boulders | Boulder conglomerate |
| 2. Coarse gravel | Coarse conglomerate |
| 3. Medium gravel | Medium conglomerate |
| 4. Fine gravel | Fine conglomerate |
| 5. Coarse sand | Coarse sandstone |
| 6. Medium sand | Medium sandstone |
| 7. Fine sand | Fine sandstone |
| 8. Clay | Claystone |

* A formation, group of formations, or part of a formation that is water bearing.

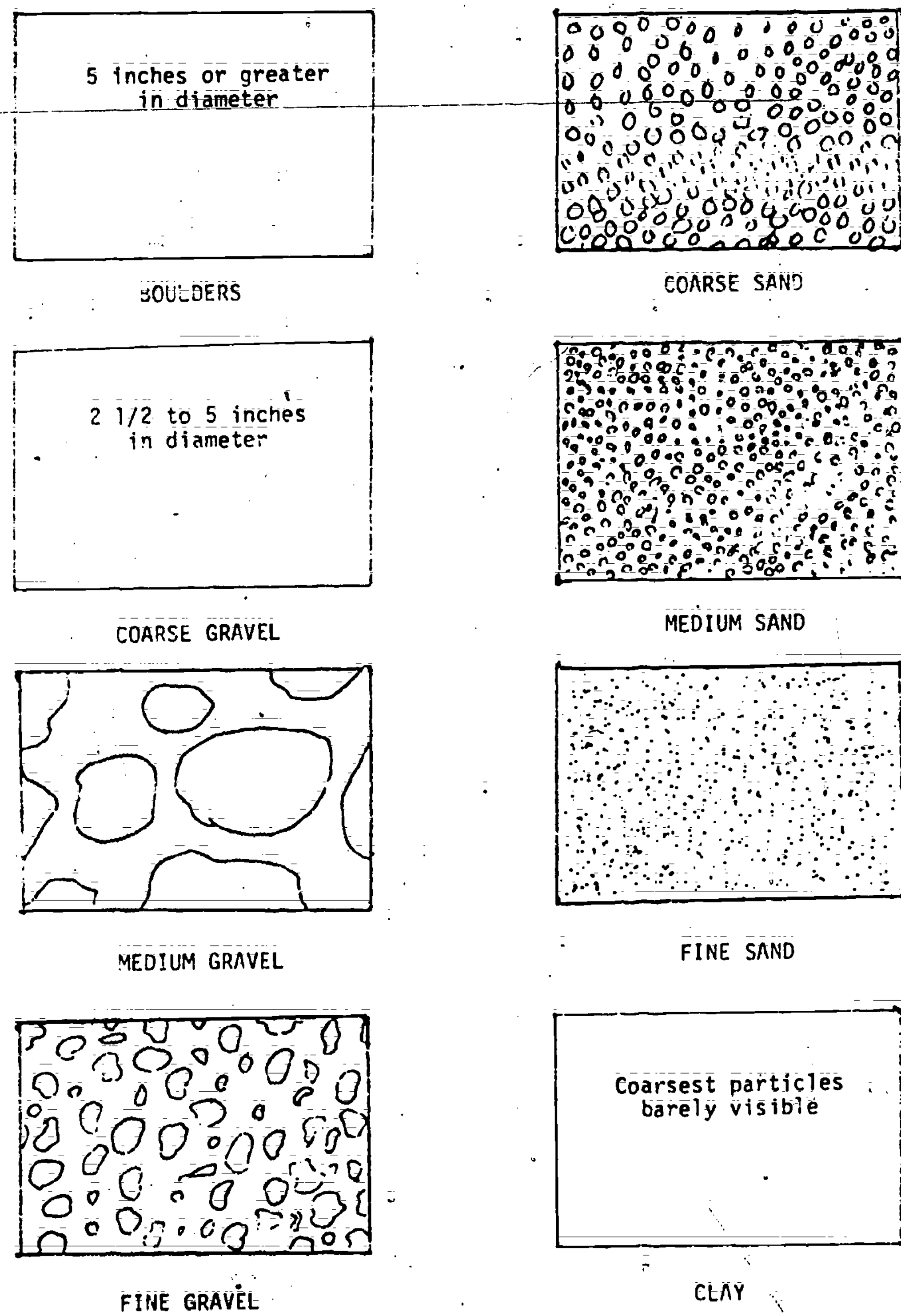
TABLE 1

CLASSIFICATION OF UNCONSOLIDATED MATERIALS

| Classification | Grade Name | Particle Dimensions** (mm) | Particle Dimensions** (in.) | Name to be Applied in Logging Water Wells |
|---|---|---|---|---|
| GRAVEL | Very large boulders | 2048 to 4096 | 80 to 160 | Boulders |
| | Large boulders | 1024 to 2048 | 40 to 80 | |
| | Medium boulders | 512 to 1024 | 20 to 40 | |
| | Small boulders | 256 to 512 | 10 to 20 | |
| | Large cobbles | 128 to 256 | 5 to 10 | |
| | Small cobbles | 64 to 128 | 2.5 to 5 | Coarse Gravel |
| | Very coarse pebbles | 32 to 64 | 1.3 to 2.5 | |
| | Coarse pebbles | 16 to 32 | .6 to 1.3 | Medium Gravel |
| | Medium pebbles | 8 to 16 | .3 to .6 | |
| | Fine pebbles | 4 to 8 | .16 to .3 | Fine Gravel |
| | Very fine pebbles | 2 to 4 | .08 to .16 | |
| SAND | Very coarse sand | 1 to 2 | | Coarse Sand |
| | Coarse sand | .5 to 1 | | |
| | Medium sand | .25 to .5 | | Medium sand |
| | Fine sand | .125 to .25 | | Fine sand |
| | Very fine sand | .062 to .125 | | |
| CLAY AND SILT | Coarse silt | .031 to .062 | | |
| | Medium silt | .016 to .031 | | Clay |
| | Fine silt | .008 to .016 | | |
| | Very fine silt | .004 to .008 | | |
| | Coarse clay | .002 to .004 | | |
| | Medium clay | .001 to .002 | | |
| | Fine clay | .0005 to .001 | | |
| | Very fine clay | 00024 to .0005 | | |

** American Geological Institute Data Sheet No. 7

Fig. 5 NOMENCLATURE OF UNCONSOLIDATED ROCKS



Sedimentary rocks and volcanic rocks are sometimes interbedded with strata of volcanic ejecta. Some of these strata have been deposited by water and others by direct air fall. The terms "pumice" and "cinders" should be used to describe these materials.

| | |
|---|---|
| Pumice | A very light, excessively cellular volcanic glass. Its color is generally light gray or white and is often so light that it will float on water. |
| Cinders | Uncemented glassy and vesicular ejecta from a volcanic cone. Generally black or red in color. In logging a well penetrating into strata of cinders, the cinders should be also described by color and degrees of coarseness. |

MISCELLANEOUS TERMS RELATED TO SEDIMENTARY ROCKS:

| | |
|---|---|
| Caliche | A hard lime deposit generally found in the soil zone in arid regions. It is usually found in layers ranging from a few inches to a few feet in thickness. |
| Chalk | A soft, white to gray, fine-grained limestone. Often incorrectly used on well logs to describe diatomite. |
| Diatomite | A soft white to gray, fine-grained rock composed of the siliceous shells of diatoms. |
| Dirt | A term used by many well drillers to describe the soil zone. The term "soil" with a descriptive adjective as "gravelly soil" or "sandy soil" is recommended for use on well logs. |
| Gumbo | A term applied by some well drillers to a soft sticky clay. The term "soft sticky clay" is preferred for use on well logs. |
| Hardpan | A term that has been applied to many hard impermeable rocks including glacial sill, caliche, conglomerate, claystone, and sandstone. The term should never be used on a well log. |
| Loess | Wind deposited material composed chiefly of silt but may contain subordinate amounts of very fine sand and clay. Loess should generally be reported as clay on a well log. |
| Mud | A term used by many well drillers to describe soft clay or silt. The term "soft clay" is preferred for use on well logs. |
| Quicksand | A term often applied to "running" or "heaving" sand. The terms "finesand, waterbearing" or medium sand, waterbearing" is preferred for use on well logs. |

| | |
|---|---|
| Shale | A laminated claystone. As laminations are not generally discernible in drill cuttings, the term "claystone" is preferred for use on well logs. |
| Slate | A metamorphic rock possessing a very well developed platy cleavage. The term has been used by many well drillers to describe a "hard claystone". It is recommended that this term not be used to describe sedimentary rocks but restricted to true slates. |

POROSITY AND PERMEABILITY

Porosity is essentially the capacity of a rock or sediment to contain water. It can be measured as the total volume of a material that is void space. Permeability is the capacity of a rock or sediment to transmit water. Permeability is measurable as the quantity of water flowing through a given cross-sectional area per unit time. Permeability is directly proportional to grain size. Thus clay, which has a high porosity, has a very low permeability because it is fine grained.

The following figures indicate the porostiy of common soils and rocks:

| | |
|---|---|
| Sand and gravels of fairly uniform size and moderately compacted | 35% - 40% |
| Well-graded and compacted sands and gravels | 25% - 30% |
| Sandstone | 4% - 30% |
| Chalk | 14% - 45% |
| Granite, schist, and gneiss | 0.02% - 2% |
| Slate and shale | 0.5 % - 8% |
| Limestone | 0.5 % - 17% |
| Clay | 44% - 47% |
| Topsoils | 37% - 65% |

Silts may be as high as 80% porosity In general, soils with fine, separate particles, such as clay, topsoil, and silt, have a very high porosity. In other words, they have a big volume in which water can be stored.

EVALUATION OF SOURCES

THE QUALITY OF WATER

Absolutely pure water is never found in nature. The impurities in water vary from dissolved gases and chemical compounds to suspended matter such as disease organisms and dirt. While some of these impurities can be seen by the naked eye and others can be detected by taste or odor, most can be detected only by laboratory test.

Water takes on various characteristics and properties as it passes over and through the earth. These characteristics and properties vary, and are dependent on the materials encountered. They may be classified according to means of detection as physical (detected by one or more of the five senses) and chemical (detected by chemical analysis). The most important physical characteristics are turbidity, color, odor, taste and temperature. The most important chemical characteristics are acidity, alkalinity, hardness, and corrosiveness. Sometimes these two types of characteristics overlap; for example, iron in water is a dissolved mineral detectable by chemical analysis, yet its color and taste are also physical. This section discusses these characteristics and their causes.

BACTERIOLOGICAL QUALITY

The selection of a source of supply may be restricted because of economic or technical limitations involved in the use of normal water-treatment processes for making the water from this source safe for human consumption.

The effectiveness of a water-treatment process can not be established in specific, quantitative values. For instance, the bacteriological quality of filtered, chlorinated water is dependent upon the bacterial content of the raw water; its chlorine demand; the coagulating, settling and filtering characteristics of the treatment plant; the degree of uniformity of the raw water; and, not least, the integrity and ability of the treatment plant operator. Furthermore, the public health significance of the degree of bacterial pollution of raw water, and hence of any bacteria remaining in the treated water produced, depends upon the probable source of contamination of the raw water with coliform organisms, which serve as an indicator of pollution. These organisms may have originated largely from surface drainage, a situation likely to be most noticeable when manured fields are found within the watershed involved. On the other hand, sewage pollution may be the chief source of such organisms, in which case the indidence of intestinal diseases among the population contributing the sewage would have ammarked impact on the water. In this case the probable ratio between the numbers of pathogenic organisms and of coliform bacteria in the polluted water will be considerably increased. Such conditions are often encountered in rural as well as semi-urban areas where intestinal diseases constitute a serious public health problem, the treatment of the sewage is not practicable, and effective water-treatment is beyond the economic and technical resources available.

For these reasons, any bacteriological standards of quality adopted for drinking-water on a country-wide basis generally appear to be too rigid for large areas where, because of economic and social conditions, they are most difficult to apply and enforce. However, it must be reckoned that the adoption under these circumstances of more lenient standards, because they appear to be more realistic, only confuse the issue by lowering the goal of safety and potability without providing a meaningful substitute. Instead, it is preferable to keep the public health objectives of the water supply constantly in mind, but to appraise local situations and review pertinent information in the light of qualified professional judgement. In many cases, therefore, it is best for you to rule out the use of many surface waters which might appear to be suitable and convenient sources of potable water supply, and to throw considerable emphasis upon the use of ground waters whenever feasible.

The above statement should not be interpreted to mean that surface waters, because of bacteriological considerations, are unsuitable sources of supply for rural communities. This would be far from the truth. In fact, the use of surface waters often makes it possible to provide consumers with ample quantities of water in their own homes, thus fulfilling most of the major health objectives of the systems. In some instances this is achieved by passing surface water through a simple and economical treatment plant. In most rural situations such a system may be considered as a step in the right direction, and is to be preferred to the appalling conditions under which the villagers are forced to carry, or even to purchase, small amounts of raw and polluted water. As time goes on, public pressure, technological advances, and the development through training of local skills, will gradually bring about the improvement of plant efficiency, operation and technical supervision to a point where the enforcement of existing standards of water quality may be possible.

It is necessary and desirable to establish some form of control over rural water-supplies. However, in most countries of the world, routine bacteriological control, which is obligatory in urban communities, would be unrealistic under rural situations, as indicated by the above discussion. In the latter, the attention of the local health administration should be concentrated primarily on those major elements of location and design of the supplies which will afford natural protection later against outside contamination, and on routine sanitary inspections by qualified sanitarians, to educate the rural population in the application and enforcement of rural sanitation regulations. Periodically tests for physical, chemical, and bacteriological quality should be made for the purpose of detecting major health hazards.

Bacteriological Standards for Drinking Water Recommended by the WHO Study Group

Some public drinking-water supplies are chlorinated or otherwise disinfected before being distributed; others are not. Effective chlorination yields a water which is virtually free from coliform organisms i.e. these organisms are absent in 100-ml portions; if communal supplies which are distributed without treatment or disinfection cannot be maintained to the bacteriological standard established for treated and disinfected water, steps should be taken to institute chlorination or disinfection, or other treatment, of these supplies.

A standard demanding that coliform organisms be absent from each 100-ml sample of water entering the distribution system--whether the water be disinfected or naturally pure--and from at least 90% of the samples taken from the distribution system can be applied in many parts of the world. Although there is no doubt that this is a standard that should be aimed at everywhere, there are many areas in which the attainment of such a standard is not economically or technically practicable.

In these circumstances there would appear to be economic and technical reasons for establishing different bacteriological standards for public water-supplies which are treated or disinfected and for those which are not treated. The following bacteriological standards are recommended for treated and untreated supplies of present use throughout the world, with the hope that improvements in economic and technical resources will permit stricter standards to be adopted in the future.

The standards described below are based on the assumption that frequent samples of water will be taken...For each individual sample, coliform density is estimated in terms of the "most probable number (MPN)" in 100-ml of water, or "MPN" index... The use of the MPN index is recommended as the basis of quantitative estimation of coliform density after full recognition of its limitations. However, the value of the index is sufficiently enhanced by the use of data from a series of samples to warrant its use in the recommended standards.

Treated Water

In 90% of the samples examined throughout any year, coliform bacteria shall not be detected or the MPN index of coliform microorganisms shall be less than 1.0. None of the samples shall have an MPN index of coliform bacteria in excess of 10.

An MPN index of 8-10 should not occur in consecutive samples. With the examination of five 10-ml portions of a sample this would preclude three of the five 10-ml portions (an MPN index of 9.2) being positive in consecutive samples.

In any instance in which two consecutive samples show an MPN index of coliform bacteria in excess of 8, an additional sample or samples from the same sampling point should be examined without delay. This is the minimum action that should be taken. It may also be desirable to examine samples from several points in the distribution system and to supplement these with samples collected from sources, reservoirs, pumping stations and treatment points. In addition, the operation of all treatment processes should be investigated immediately.

Untreated Water

In 90% of the samples examined throughout any year, the MPN index of coliform micro-organisms should be less than 10. None of the samples should show an MPN index greater than 20.

An MPN index of 15 or more should not be permitted in consecutive samples. With the examination of five 10-ml portions of a sample, this would preclude four of the five 10-ml portions (an MPN index of 16) being positive in consecutive samples. If the MPN index is consistently 20 or greater, application of treatment to the water-supply should be considered.

In any instance in which two consecutive samples show an MPN index of coliform organisms greater than 10, an additional sample or samples from the same sampling point should be examined immediately. It may also be desirable to examine samples from several points in the distribution system and to supplement these with samples collected from sources, reservoirs and pumping stations.

When accurate and complete data concerning the sanitary conditions at the sources of an untreated water-supply, covering all possible points of pollution, are available and indicate that indices higher than the established maximum may bear little relation to potential health hazards, the local health and water-supply authorities should be responsible for ruling that such higher indices do not constitute need for treatment of the water.

CHEMICAL AND PHYSICAL QUALITY

Water of good chemical and physical quality is necessary from the points of view of its acceptability by the people, the protection of the health of the consumer, and the conservation of the water system. Anyone who has drank water from different sources encountered situations in which offending chemical substances have made a water source unacceptable even though its bacteriological quality was excellent.

Palatability of water is a term which describes the characteristic of being pleasing to the sense of taste. Drinking water should be free from color, turbidity, taste, and odor, and should be cool and aerated. At least four human perceptions can be used in judging these qualities. They are the senses of sight (color and turbidity), taste, smell (odor), and touch (temperature). However, palatable water is not always safe to drink or potable.

Turbidity and color are important in rural water-supplies. Depending upon the character of the watershed, turbidity may vary considerably from one season to another because of rainfall. A sudden increase in turbidity may do serious damage, or at least stop the operation, of small water-treatment plants if adequate precautions are not taken in advance in order to allow for rejection of the incoming supplies at such times. Water from slow-moving streams and small lakes is likely to be colored, at least during certain seasons of the year. Both turbidity and color will cause discoloration of clothes and may be responsible for rejection of the supply if removal by simple and economical processes cannot be achieved.

CORROSION AND SCALE

Hydrogen sulfide, dissolved oxygen, and carbon dioxide in water cause acidity and are responsible for corrosion of iron pipes. Hydrogen sulfide, which is sometimes found in deep-well water, is a product of decomposition of organic matter. It attacks cement and concrete and destroys storage tanks built of these materials. Dissolved oxygen combines with ferrous iron, which is sometimes found in solution in well water, and produces ferric hydroxide, which is insoluble and gives the water a rusty color. It may also cause serious corrosion of distribution pipes and house plumbing pipes.

Perhaps the most important and troublesome of the three products mentioned here is carbon dioxide, which is often found in well water and in surface water drawn from heavily wooded watersheds or from the lower layers of deep ponds. Carbon dioxide in water is responsible for heavy and rapid corrosion of unprotected pipes, thus creating increasing difficulties with maintenance and operation of a water system. Various materials, mostly bituminous compounds and cement are used by manufacturers for lining the interior surfaces of pipes against corrosion. These materials are also used to protect outside pipe surfaces against corrosion caused by the contact of pipes with certain soils and, under certain circumstances, by electrolysis.

Natural water containing carbon dioxide will dissolve carbonates from rocks in the ground, thus producing soluble bicarbonates. Depending upon the relationships between the bicarbonate alkalinity and the pH of the water on the one hand, and between the free carbon dioxide and the alkalinity on the other, the water will either be corrosive or, on the contrary, will deposit a film of carbonate on the inner surface of pipes. This film may somtimes develop sufficiently to become a thick scale which obstructs small distribution and service pipes, water meters, etc. The prevention of corrosion and scale rests upon the chemical control and maintenance of the proper equilibrium between the three factors mentioned, i.e., by reducing the content of carbon dioxide or increasing the alkalinity as determined by special tests. Except in rare instances, this type of chemical control is beyond the technical resources of small rural water-supply systems and, therefore, will not be discussed here in greater detail.

## TURBIDITY

Turbidity is a muddy or unclear condition of water, caused by particles of sand, silt, clay, or organic matter being held in suspension. The faster water flows, the more material it picks up and the larger the size of the pieces carried along. As water shows down, the larger particles settle out. Clay and silt remain suspended in water longest, because of their particle size and specific gravities.

## COLOR

Color in water is due to the presence of colored substances in solution such as vegetable matter dissolved from roots and leaves, and to humus and iron and manganese salts. True color is due to substances in true solution; apparent color includes true color and also that due to substances in suspension. Water taken from swamps, weedy lakes, and streams containing vegetation is most likely to be colored. Color may also be caused by industrial wastes and turbidity. The latter is responsible for an apparent color, rather than the true color, and is caused by materials of vegetable origin. Color as such is harmless, but objectionable due to its appearance and to the taste and odors sometimes associated with it.

ODORS AND TASTE

Taste and odors found in water are most commonly caused by alga (minute water plants), decomposing organic matter, dissolved gases, or industrial waste. Mineral substances may also be a cause. Potability is not normally affected by the presence of odors and tastes. On the other hand, palatability is frequently affected, particularly when a substance such as bone or fish oil is present. Water containing one of these substances in noticeable quantities is unpalatable. Tastes and odors which make water unpalatable must be removed. Use of free available chlorine and activated carbon will do much to prevent odorous combinations of chlorine with organic impurities in water.

TEMPERATURE

Warm water tastes flat. Lowering the temperature of water suppresses odors and tastes and, therefore, increases its palatability. In the summer the temperature of deep lakes and reservoirs decreases sharply from top to bottom. By shifting the depth of intake, it may be possible to draw relatively cool water even during hot weather. Water should be drawn from the lower depths when possible. Cool water is more viscous than warm water and thus is more difficult to coagulate and effectively chlorinate than warm water due to slower reactions. Water treatment times should be increased when water temperatures are less than 45°F.

ACIDITY AND ALKALINITY

Some of the physical impurities mentioned cause water to behave as either an acid or as a base. The degree of acid behavior is called acidity. The degree of basic behavior is called alkalinity. Since either condition has an important bearing on water treatment, the degree of acidity or of alkalinity must be determined.

The pH value is a measure of the acidic or alkaline nature of the water. The pH value ranges from 0 - 14. A value of 7 is neutral. A high pH value indicates a very strong alkaline solution.

The pH influences the corrosiveness of the water, the amount of chemical dosages necessary for proper disinfection, and the ability of an analyst to detect contaminants.

HARDNESS AND OTHER CHARACTERISTICS DUE TO DISSOLVED MINERALS

Hardness is caused by the soluble salts of calcium, magnesium, iron, manganese, sodium, sulfates, chlorides, and nitrates. The degree of hardness depends on the type and on the amount of impurities present in the water. Hardness also depends on the amount of carbon dioxide influences the solubility of the impurities that cause hardness.

The hardness caused by carbonates and bicarbonates is called carbonate hardness. The hardness caused by all others (chlorides, sulfates, nitrates) is called non-carbonate hardness. Alkalinity is usually equivalent to the carbonate hardness. Sodium, however, also causes alkalinity. In natural waters, sodium is not normally present in appreciable amounts. Therefore, in natural waters, the alkalinity is equal to the carbonate hardness. After a water has been softened, however, a large amount of sodium remains in the treated water. In softened water, the total alkalinity is the sum of the carbonate alkalinity plus the sodium alkalinity.

Hardness is undesirable in that it consumes soap, makes water less satisfactory for cooking, and produces scale in boilers and distillation units.

The following minerals cause hardness in ground and surface waters:

Calcium carbonate. Alkaline and only slightly soluble; causes carbonate hardness and alkalinity in water.

Calcium bicarbonate. Contributes to the alkalinity and carbonate hardness of water. Calcium bicarbonate when heated produces carbon dioxide and calcium carbonate. This calcium carbonate precipitates as scale in boilers and distillation units.

Calcium sulfate or gypsum. Causes noncarbonate hardness in water. Being more soluble in cold water than in hot, it separates from the water in boilers and forms scale on the boiler tubes.

Calcium chloride. Causes noncarbonate hardness in water. In steam boilers and distillation units, the presence of calcium chloride can cause chemical reactions which result in pitting of the boiler tubes.

## FACTORS INFLUENCING THE QUALITY OF WATER

As water goes through its hydrologic cycle, it gathers numerous impurities. Dust, smoke, and gases fill the air and tend to contaminate rain, snow, hail, and sleet. As runoff, water picks up silt, chemicals, and disease organisms. As it enters the earth through seepage and infiltration, some of the suspended impurities may be filtered out, but at the same time, other minerals and chemicals are dissolved and carried along. It is now ground water in an underground deposit and, although it may now become less contaminated or polluted, it is not necessarily pure, and may contain disease organisms as well as harmful chemicals.

In addition to the impurities in water resulting from infiltration, many are contributed by an industrialized society. Garbage, sewage, industrial waste, insect sprays, and chemical, biological, and radiological agents are examples of these.

Impurities in water are either suspended or dissolved. The suspended impurities are usually more dangerous to health. They include mineral matter, disease organisms, silt, bacteria, and algae, and must be destroyed or removed from water that is to be consumed.

1) The main factors influencing the quality of a given water supply source are:

   A) Nature of the surface geology; character of soils and rocks.

   B) Character of vegetation; forests; cultivated and irrigated lands, including salinity, effect on irrigation water, etc.

   C) Methods of sewage disposal whether by diversion from watershed or by treatment.

   D) Character and efficiency of sewage-treatment works on watershed.

   E) Proximity of sources of faecal pollution to intake of water supply.

TURBIDITY TEST

The turbidity test is used to show the amount of suspended matter present in raw water, and also to determine the amount removed from treated water. The test may be made with the white porcelain cup with its black enameled dot, or by employing the turbidimeter and standard turbidity solution. Rapid approximate readings only can be made by using the cup.

Turbidity Determination by Use of Measuring Cup:

The measuring cup can be used to determine whether raw water has more or less than 100 turbidity units. If the black spot cannot be seen when the cup is filled to the top with the water sample, the turbidity is 100 units or over. The turbidity is less than 100 units if the outline of the black spot is visible.

DOT CLEAR — LESS THAN 5 ppm

DOT HAZY — BETWEEN 5 ppm AND 100 ppm

DOT OBSCURED — MORE THAN 100 ppm

Fig. 6 Turbidity Test

Waters having low turbidities, such as effluent from a purification unit, may be checked by adding about 1/2 inch of water to the cup and looking at the black spot, it appears as black as it was originally, the turbidity is less than 5 units. Turbidities over 5 units produce a graying or milky hue in the black spot.

## THE QUANTITY OF WATER

Surface water originates mostly from rainfall and is a mixture of surface run-off and ground water. It includes large rivers, ponds and lakes, and the small upland streams which may originate from springs and collect the run-off from the watersheds. The quantity of run-off depends upon a large number of factors, the most important of which are the amount and intensity of rainfall, the climate and vegetation and, also, the geological, geographical, and topographical features of the area under consideration. It varies widely, from about 20% in arid and sandy areas where the rainfall is heavy. Of the remaining portion of the rainfall, some of the water percolates into the ground, and the rest is lost by evaporation, transpiration and absorption.

### FACTORS INFLUENCING THE QUANTITY OF WATER

A) Total annual precipitation.

B) Seasonal distribution of precipitation. Both the total annual precipitation and the seasonal distribution of precipitation are best determined by past record.

C) Soil porosity and permeability.

D) Annual and monthly evaporation and transpiration.

One of the first steps in the selection of a suitable water supply source is determining the demand which will be placed on it. The essential elements of water demand include the average daily water consumption and the peak rate of demand. The average daily water consumption must be estimated:

1. To determine the ability of the water source to meet continuing demands over critical periods, when surface flows are low, and ground-water tables are at minimum elevations.

2. For purposes of estimating quantities of stored water which would sustain demands during these critical periods.

The peak demand rates must be estimated in order to determine plumbing and pipe sizing, pressure losses, and storage requirements necessary to supply sufficient water during periods of peak water demand.

## TYPES OF SOURCES

### SURFACE WATERS

Surface water sources are lakes and ponds, rivers, streams, and controlled catchments (cisterns).

#### Lakes and Ponds

A lake or pond is any standing body of inland water.

Quantity: Advantageous in that it is usually able to store water in wet periods for use in dry periods.

Quality: Generally poor. Normally turbidity and bacteria are the major pollutants. Use only when ground water sources and controlled catchments are not available or are insufficient or inadequate.

Development requirements: The ideal situation is that the watershed permits water of the highest quality to enter the pond. To approach this goal, the watershed should be clean, free from septic tanks, barns, privies, etc., protected against erosion and drainage from livestock areas, and livestock should be excluded (fencing if necessary).

Treatment requirements: No lake or pond water can be considered safe until it has been disinfected. Generally it is also necessary to remove turbidity.

Treatment processes:

1) Sedimentation plant - (w/o alum for coagulation) allows large particles of turbidity to settle out.

2) Filtration to remove turbidity and reduce bacterial content.

3) Disinfection

Warning: Lake and pond waters usually require extensive treatment and a floating intake structure. In many cases the filtration unit becomes clogged and must be cleaned. It is advisable to look elsewhere for a source of water.

#### Rivers and Streams

General: A stream or river is a body of running water on the surface of the earth, from higher to lower ground.

Quantity: Yield controlled by rate of minimum flow per day and year. Streams generally exhibit marked seasonal variation in flow.

Quality: Generally poor. Chemical nature partially dependent on bedrock. Physical and bacteriological quality highly variable. Easily contaminated. Impossible to exert sanitary control over watershed.

Development requirements: Requires a submerged intake structure and in the case of small streams requires the construction of small diversion dams.

Treatment requirements: Same as lakes and ponds. Likely to be more turbid and have a greater quantity of chemical pollutants.

Treatment Processes: Same as the lakes and ponds.

Warning: Rivers and streams should be considered last as a potential source of water unless, of course, adequate treatment facilities already exist.

Springs

General: The outflow of water that has previously run or percolated through the pores of rocks. Two types:

1. Gravity-ground water flows over impervious stratum onto ground surface.

2. Artesian-water rise to surface after confinement between two impervious beds.

Quantity: (1) Yield of gravity springs fluctuates with rainfall Characteristically have low discharge. (2) Artesian springs tend to have a nearly constant yield.

Quality: Are subject to contamination near points of emergence. Poor to good. Usually contain dissolved minerals (especially calcium carbonate). Caution*- springs emerging from limestone channels allow for very little natural filtration. May become highly turbid and polluted after heavy rains. Careful investigation recommended.

Development requirements: Elimination of all sources of contamination near point of emergence. If gravity type, further development not recommended.
Requirements---(1) filtration-sometimes not necessary
(2) disinfection

Processes: (1) slow-sand filter (2) chlorination

* Gravity springs have the advantage in that they provide a gravity type distribution system. A filtration and storage unit can be constructed before point of emergence. Such a development is not feasible unless the spring has a substantial yield.

Catch Basins (Cisterns)

General: A sloping surface area for collection of rainfall run-off leading to a covered tank (cistern). Roofs are the most common collection areas.

Quantity: Dependent on amount and variation of rainfall, evaporation, infiltration, and replacement of the soil deficit. For covered surfaces, losses are less than fifteen percent.

Quality: Wholly dependent on the character of the surface of the area of collection.

Development requirements: Construction of a watertight, manholed covered, tank with outlet.

Treatment requirements: Tank must be periodically disinfected. With fenced catch areas of clay surface, filtration advisable before intake. With roofs, cement or other hard surfaces it is advisable to have some screen to catch leaves, etc. Hard surfaces should be cleaned periodically.

Treatment processes: Disinfection is the only necessary treatment.

GROUND WATER

Ground water serves the great majority of people who live in rural areas and have a water-supply system of one type or another. The reason is that, among the various sources of supply, ground-water is by far the most practical and safe in nature. Even in a highly industrialized country such as the USA, municipal ground-water installations far outnumber surface-water supplies. It is very probable that, for a long time to come, ground water will be the most important source of supply for most rural communities of the world.

The advantages of ground water are:

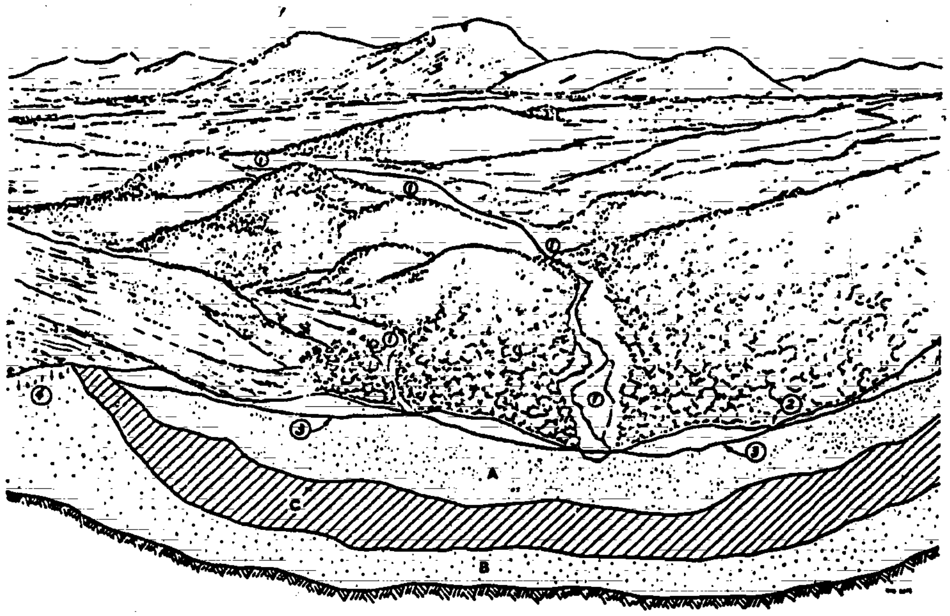
1. It is likely to be free of pathogenic bacteria;
2. Generally, it may be used without further treatment;
3. In many instances it can be found in the close vicinity of rural communities;
4. It is often most practical and economical to obtain and distribute;
5. The water-bearing stratum from which it is drawn usually provides a natural storage at the point of intake.

The disadvantages are:

1. Ground water is often high in mineral content;
2. It usually requires pumping.

In ground-water supply investigations and design, the engineer is concerned with the following steps:

1. to find it in the required quantity and quality as near as possible to the center of consumption, in order to reduce transport costs;
2. to extract it by means of a system which produces the quantity required, safeguards the quality, and, at the same time, involves the least capital outlay;
3. to transport the water to the consumer in a way which requires the least amount of operational and maintenance skill and cost.

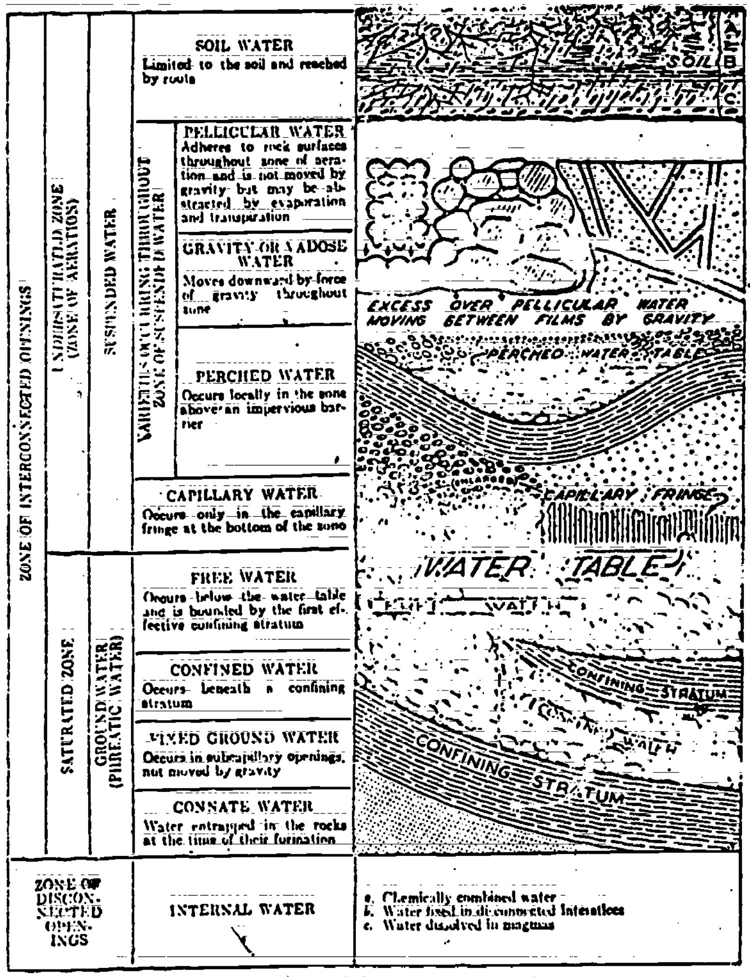


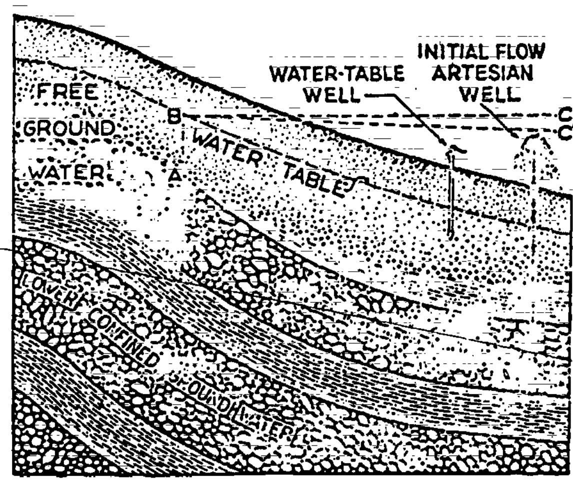
1 — Areas where there are good possibilities of obtaining water from infiltration galleries, well-point systems
2 — Ground water is outcropping at this point, so that a flowing spring is formed. At the foot of river banks and hills other springs may possibly be found.
3 — Top of ground-water table
4 — Area of infiltration to supply-formation B
A — Non-confined (non-artesian), water-bearing formation covered with top soil
B — Confined (artesian), water-bearing formation
C — Impervious rock, or hard-pan formation

Fig. 7 Geological Formations

Ground water is that portion of the atmospheric precipitation, mostly rainfall, which has percolated into the earth to form underground deposits called aquifers (water-bearing formations) (See Fig. 8). These can be tapped by various means, to be discussed later; and, in the great majority of cases, they can be used without further treatment for individual and community water-supplies in rural areas. Fig. shows the occurrence and distribution of subsurface water.

Fig. 8 OCCURRENCE AND DISTRIBUTION OF SUB-SURFACE WATER




BC = theoretical static level of confined water body
BC' = pressure gradient; indicates actual static level in wells piercing the conduit

Reproduced from Tolman, C. F. (1937) *Ground water*, p. 35, by kind permission of McGraw-Hill Book Co. Inc., New York

The great majority of wells for rural water-supplies take water from the "free-water zone". (Figs. 9, 10). These will usually be jetted, dug, driven, or bored wells. Infiltration galleries also take water from this zone. Drilled wells often penetrate the confined water aquifer. It is from this stratum that flowing wells are developed.

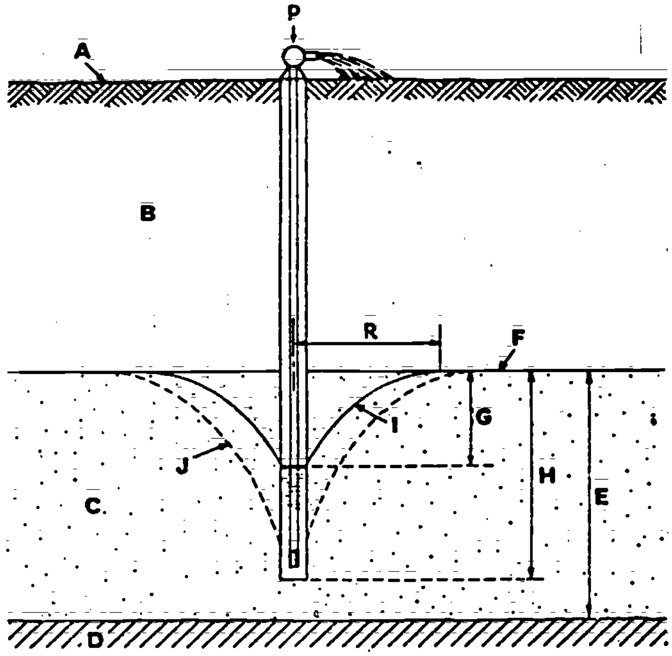
The aquifer must be supplied with an ample quantity of water if it is to serve as a source. It is simply a reservoir and can be depleted in the same manner as a surface reservoir if its supply is inferior to the demand placed on it. In rural areas this is very seldom a concern as the aquifer will usually be replenished sufficiently to supply the relatively small demands of rural communities. An element of greater significance for the engineer searching for ground water pertains to the characteristics of the soil formation of the aquifer, i.e., to the ability of the aquifer to give up water and, therefore, to serve as a reliable source of supply.

The quantity of water that can be extracted from an aquifer will depend on (1) its porosity and permeability, and (2) the draw-down in the well. The porosity and the permeability, of a formation are limited by nature; and while conditions may be altered somewhat in the immediate vicinity of a well intake, the general nature of the aquifer is fixed and cannot be modified. The draw-down in a well, however, can be varied within the limits of the thickness of the aquifer, the penetration of the well into the aquifer, and the capacity of the pump used (Fig. 9,10).

Ground formations, however, have a certain tendency to hold the water and to give up only a part of it. This characteristic of a soil formation is called permeability; it is the quality of a formation which controls the passage of water through it. From a knowledge of hydraulics, it is obvious that water will pass through large openings more easily than it does through small ones.

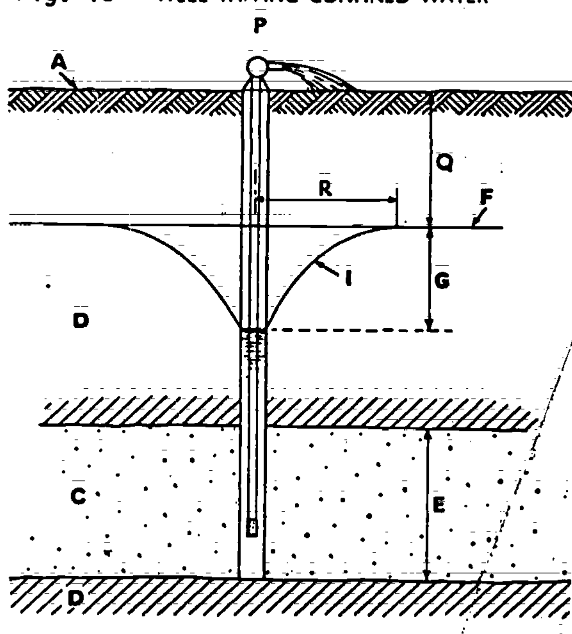
Clays and topsoils have high porosity (large volume of voids) but low permeability (very small opening between particles), so that water passes through them with great difficulty. Gravels and sands, on the other hand, are permeable and therefore allow ground water to pass with relative ease. This type of formation is also porous, as can be seen above, so that it can store large quantities of water. These, then, are the water-bearing formations most amenable to the development of wells and most important to the engineer in searching for a rural community water-supply. Sandstone is both porous and pervious and therefore an excellent aquifer which can be tapped to produce large quantities of water, especially if it is confined as shown in Fig. 9 (formation B) and Fig.10 . Where it is known, for example, that sandstone underlies an area, and where no other readily available source is found, a test hole into this stratum would be a good risk. Chalk formations in the British Isles and in Haiti are known to produce reasonable quantities of water.

Fig. 9 SHALLOW WELL IN FREE-WATER ZONE




A = Ground surface
B = Top layers of soil
C = Water-bearing stratum
D = Impervious stratum
E = Thickness of water-bearing stratum
F = Water table
G = Draw-down
H = Depth of penetration of well into aquifer
I = Draw-down cone
J = Curve of maximum draw-down
P = Pump
R = Radius of circle of influence

Fig. 10 WELL TAPPING CONFINED WATER




A = Ground surface
C = Water-bearing stratum
D = Impervious stratum
E = Thickness of water-bearing stratum
F = Water table
G = Draw-down
I = Draw-down cone
P = Pump
Q = Depth of water in well
R = Radius of circle of influence

Except for unusual geological features or underground dams, it can be said that, in any drainage basin, ground-water always flows towards the principal streams (Fig. 7 ). While there are exceptions to this rule, the best place to look for shallow ground-water is at the bottom of draws and valleys. It is in this area that pockets of sand and gravel may have been deposited. If these are close to the present stream or in an old course, they will probably be well supplied. Underground sampling by boring or jetting in these areas will usually be profitable. In this way, samples of the underground formation can be taken and examined to determine the characteristics of the aquifer and its ability to supply the quantity of water needed. Fortunately, a great many small towns in rural, underdeveloped areas have been built along natural watercourses, so that the possibility of finding available ground-water as a source of supply may be somewhat improved in such areas.

## DEVELOPMENT OF WATER SOURCES

### BASIC CONSIDERATIONS

Development of a water source includes all work which increases the quantity and improves the quality of the water, or makes it more readily available for treatment and distribution. The development of surface water sources and springs is considered in this section.

In developing a source, dams, floats, galleries, and similar improvements may be used to increase the quantity and quality of the water. Some of the more common improvements are discussed in succeeding paragraphs.

Elaborate developments should be avoided; simplicity brings more rapid results. A temporary water source should not be converted into a permanent one until the area has been reconnoitered for a source requiring less development. All intake hoses or pipes should be equipped with an intake strainer regardless of the clearness of the water source. Suction strainers should be protected from floating debris which may damage, clog, or unnecessarily pollute them. Proper anchorage of suction lines and strainers prevents loss of prime, punctured or kinked lines, and damage to strainer. Figures 11,12,13 and 14 depict several of the common methods of suction inlet anchorage.

Water at the intake point should be as clear and deep as possible. The strainer on the suction hose is placed at least 4 inches below the water level. This precaution reduces the possibility of the strainer becoming clogged with floating debris, or the prime being lost due to air getting into the suction line.

### SURFACE WATER SUPPLIES

Advantages. For normal field water supply, surface water is the most accessible type of water source. This source also lends itself readily to the purification equipment common to most engineer units. Surface water is the most easily developed source of water. Various methods of constructing intake points for inland surface water sources are discussed below.

Rocks and Stakes. If the stream is not too swift and the water is sufficiently deep, an expedient intake may be prepared by placing the intake strainer on a rock. This will prevent clogging of the strainer by the streambed and provide enough water overhead to prevent the suction of air into the intake pipe. If the water source is a small stream or shallow lake the intake pipe can be secured to a post or pile as shown in Fig. 11.

Pits. When a stream is so shallow that the intake screen is not covered by at least 4 inches of water, a pit should be dug and the screen laid on a rock or board placed at the bottom of the pit. Pits dug in streams with clay or silt bottoms should be lined with gravel to prevent dirt from entering the purification equipment (Fig. 12 ). The screen is surrounded by gravel which prevents collapse of the sides of the pit and also shields the screen from damage by large floating objects. The gravel also acts as a coarse strainer for the water. A similar method may be provided by enclosing the intake screen in a bucket as shown in Fig. 13 .

Dams. The level of the water in small streams can be raised to cover the intake strainer by building a dam as shown in Fig. 14 . In swiftly flowing streams, a wing or baffle dam can be constructed to protect the intake screen without impounding the water (Fig. 15 ).

Floats. Floats made of logs, lumber, sealed cans, or empty fuel drums can be used to support the intake strainer in deep water. They are especially useful in large streams where the quality of the water varies across its width or where the water is not deep enough near the banks to cover the intake strainer. The intake point can be covered by an adequate depth of water by anchoring or stationing the float at the deep part of the stream. The intake hose should be secured to the top of the float, allowing enough slack for movement of the float. If support lines are used to secure the float to the banks, the position of the float can be altered to correspond to changes in depth by manipulation of the lines. The chief advantage of a float intake is the ease with which the screen can be adjusted vertically. Fig. 16 illustrates two types of improvised floats.

Galleries. 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 into it so it intercepts ground water flowing toward the stream. The trench is filled with gravel to prevent the sides from collapsing. The intake strainer is placed in the gravel below the water line (Fig. 17 ). The amount of work required to produce the gallery is justified by a reduction in the amount of chemicals needed to coagulate the water, the elimination of the necessity of frequently backwashing the filter and the higher quality of water obtained.

Drive Points. Many times it is advantageous to utilize shallow ground water sources or percolated waters adjacent to a turbid surface water. Well points are issued in 2-inch diameter, 54-inch lengths. A drive

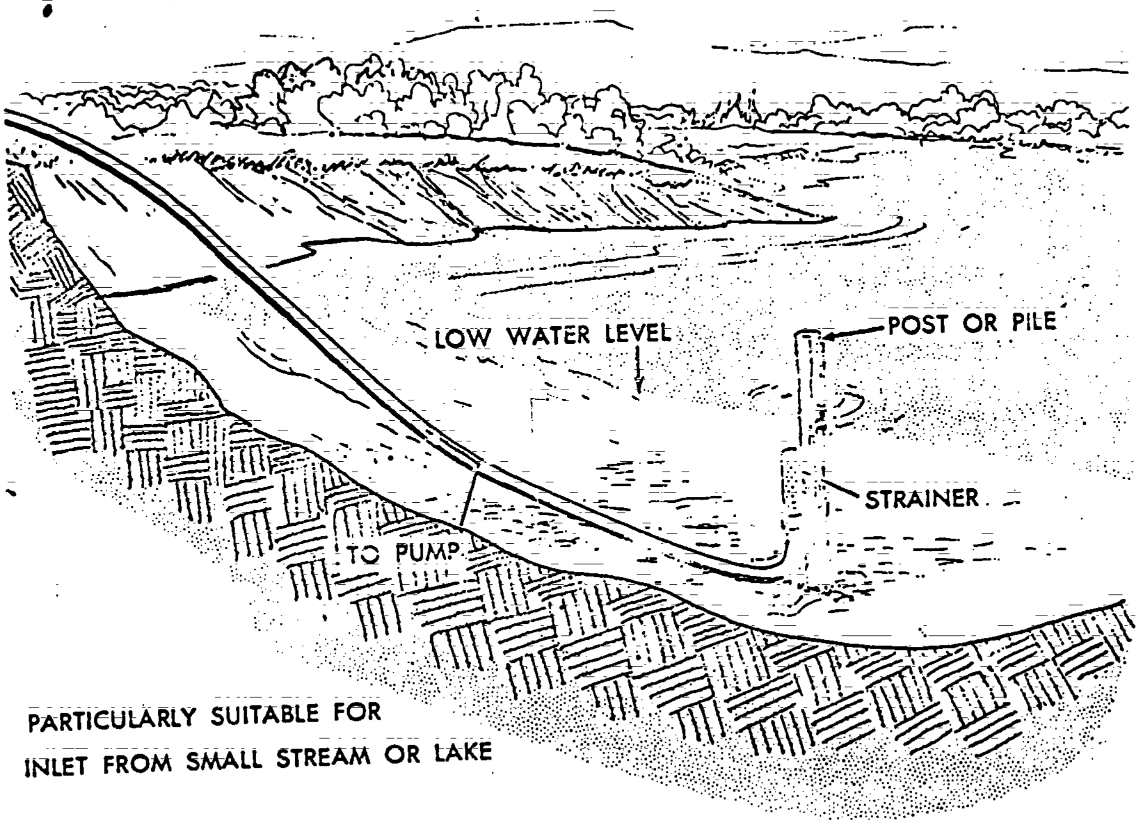



Fig. 11 Direct intake, with hose on bottom of water source

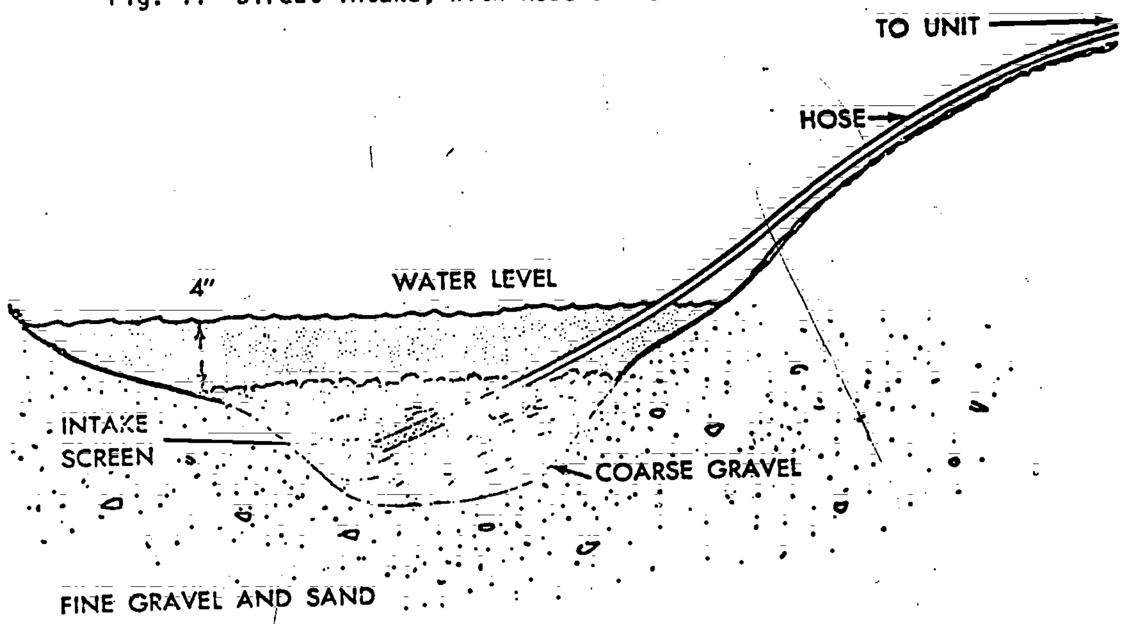



Fig. 12 Surface intake with hose buried in gravel-filled pit.

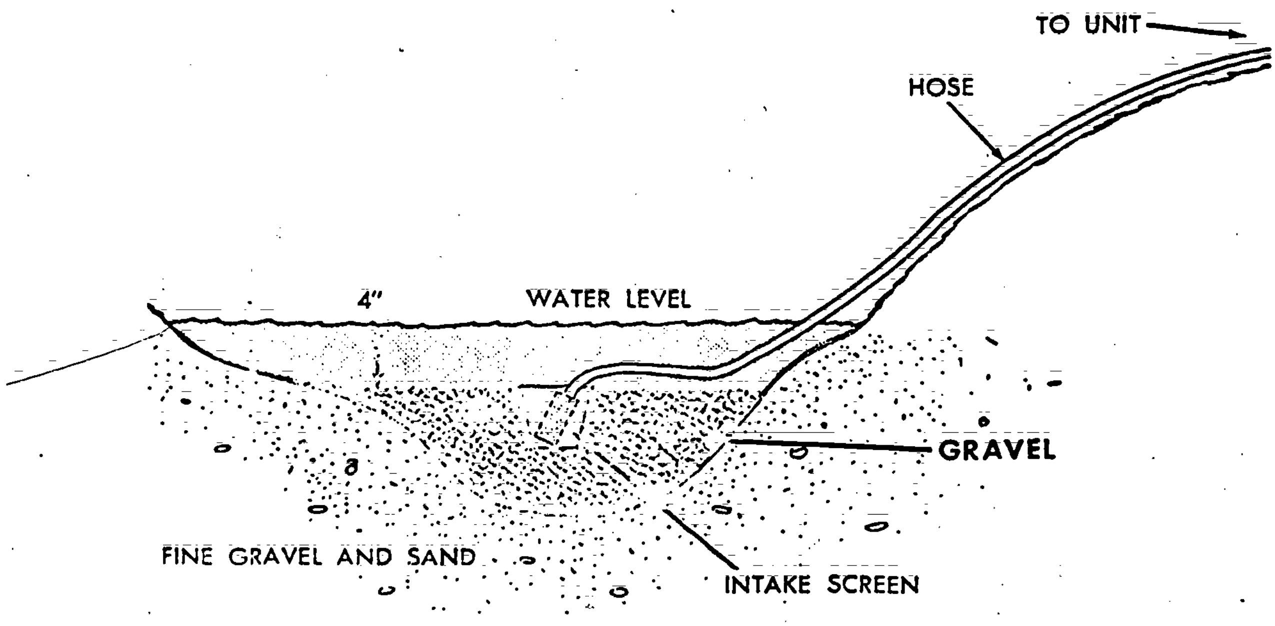



Fig. 13 Use of bucket on end of surface intake.

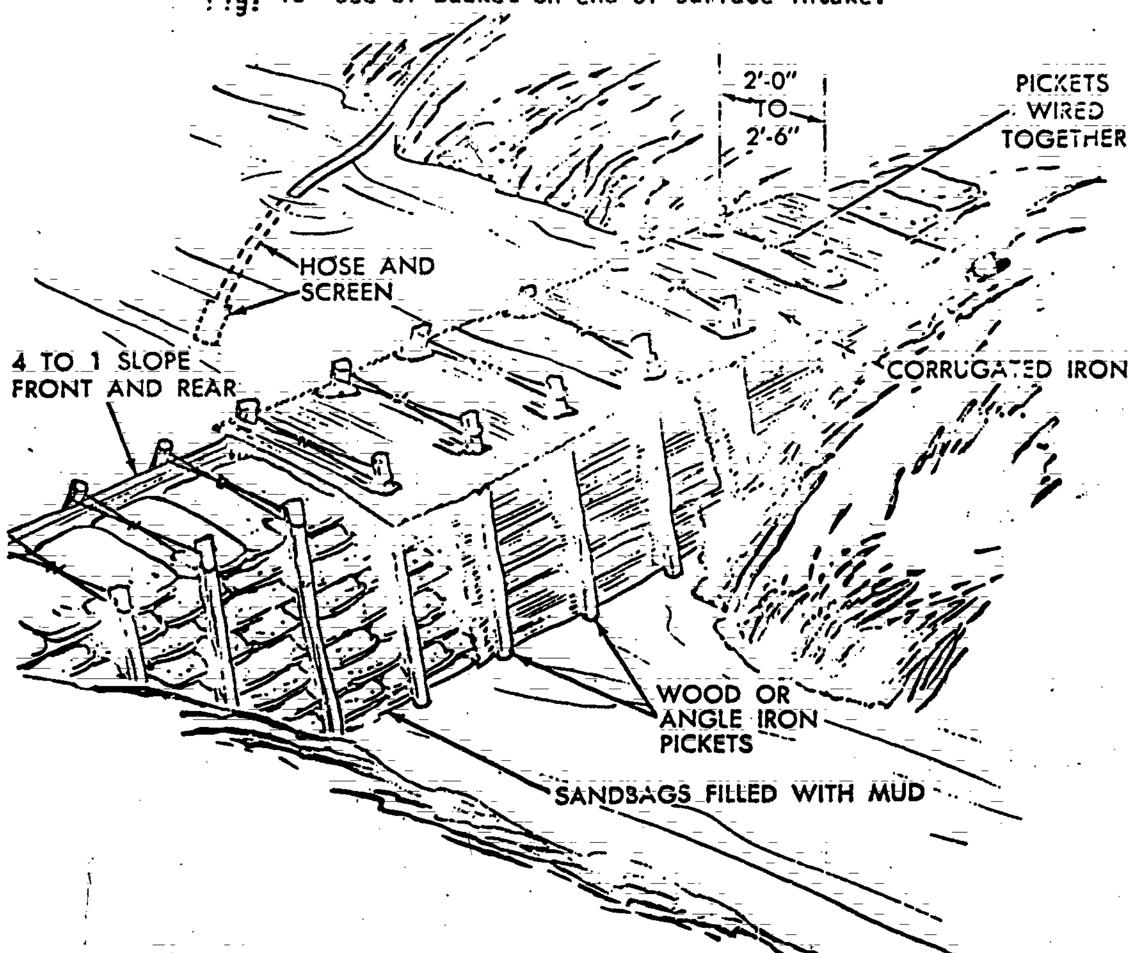



Fig. 14 Improvised dam for impounding small streams.

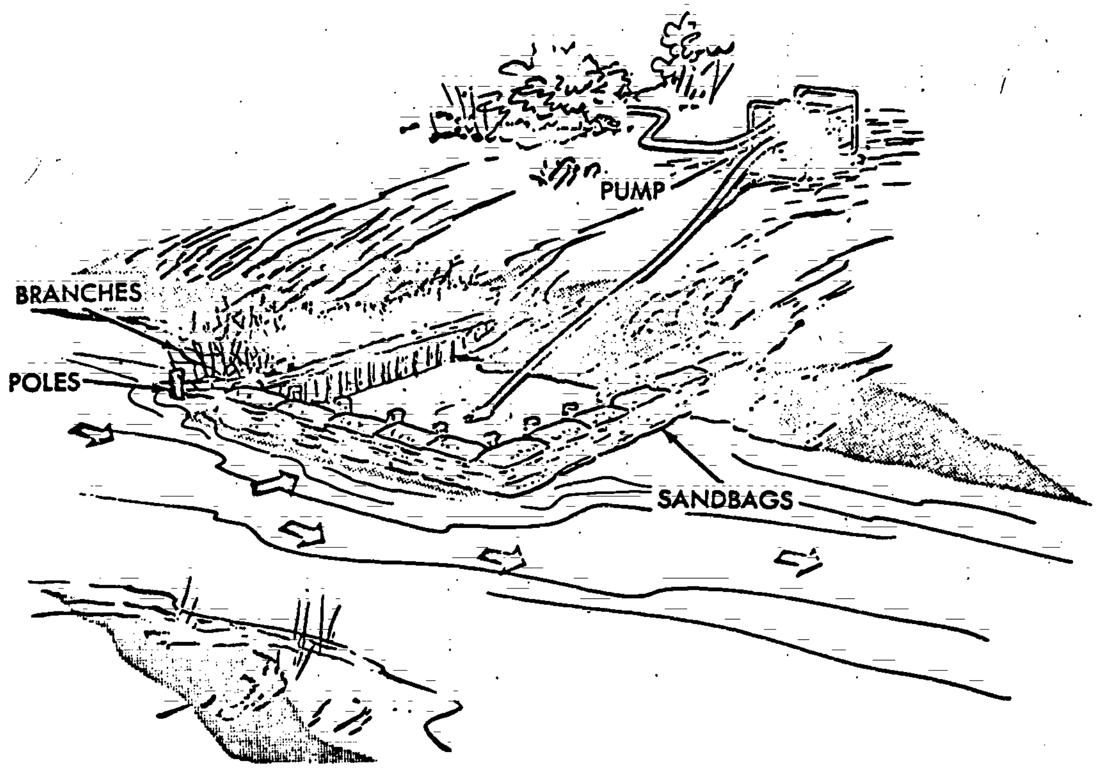



Fig. 15 Baffle dam for protecting inlet strainer.

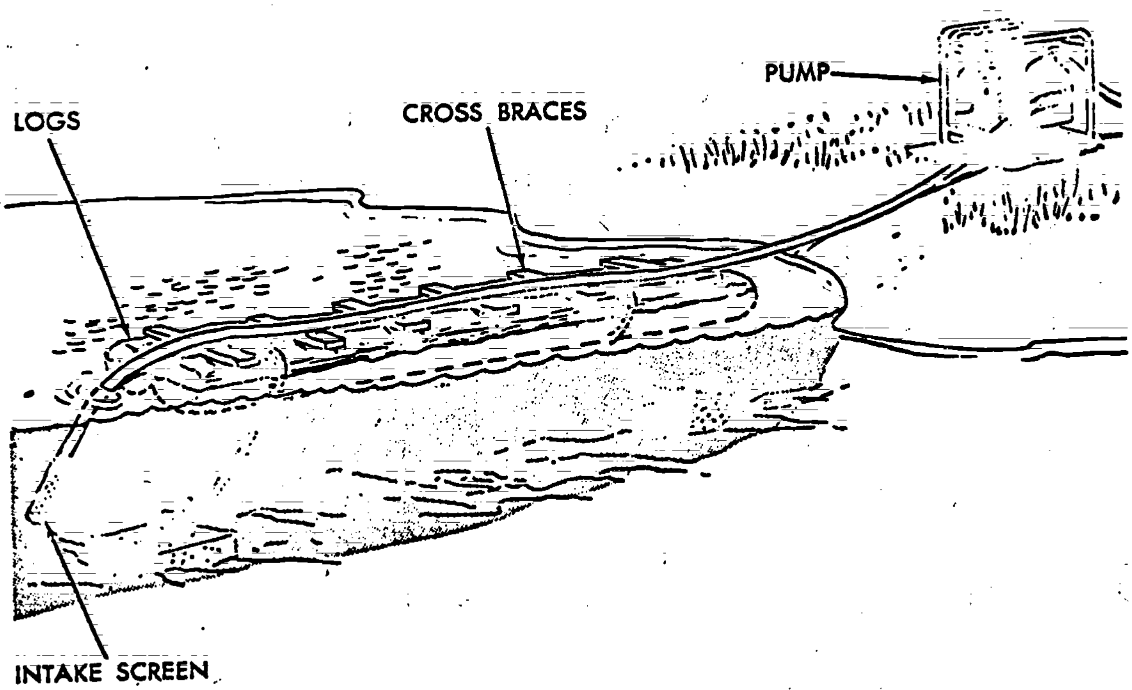



Fig. 16 Float-type surface intake, with anchors.

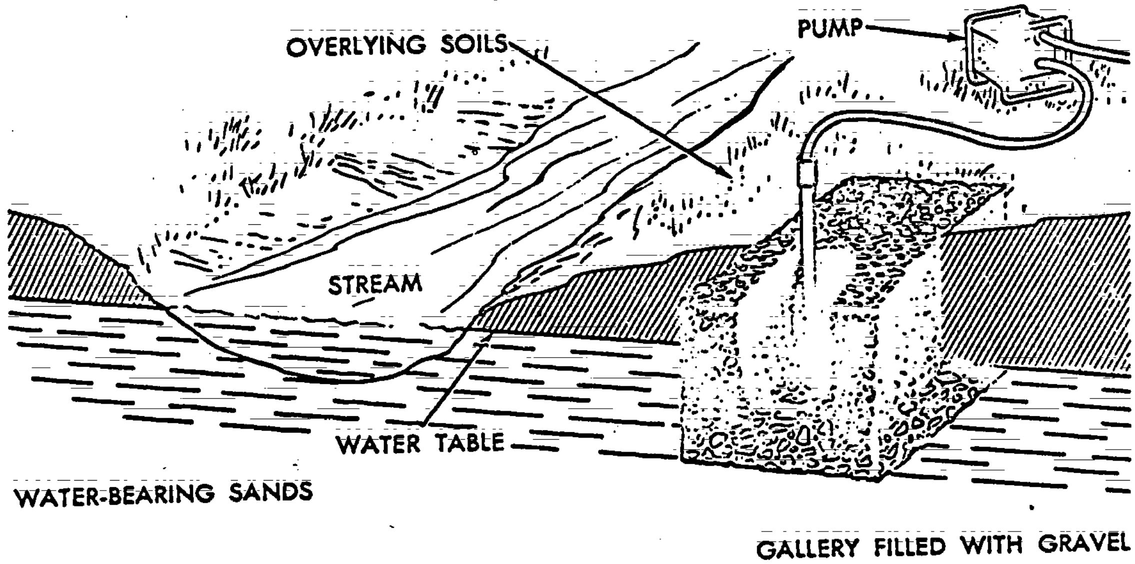



Fig. 17 Gravel-filled gallery intake.

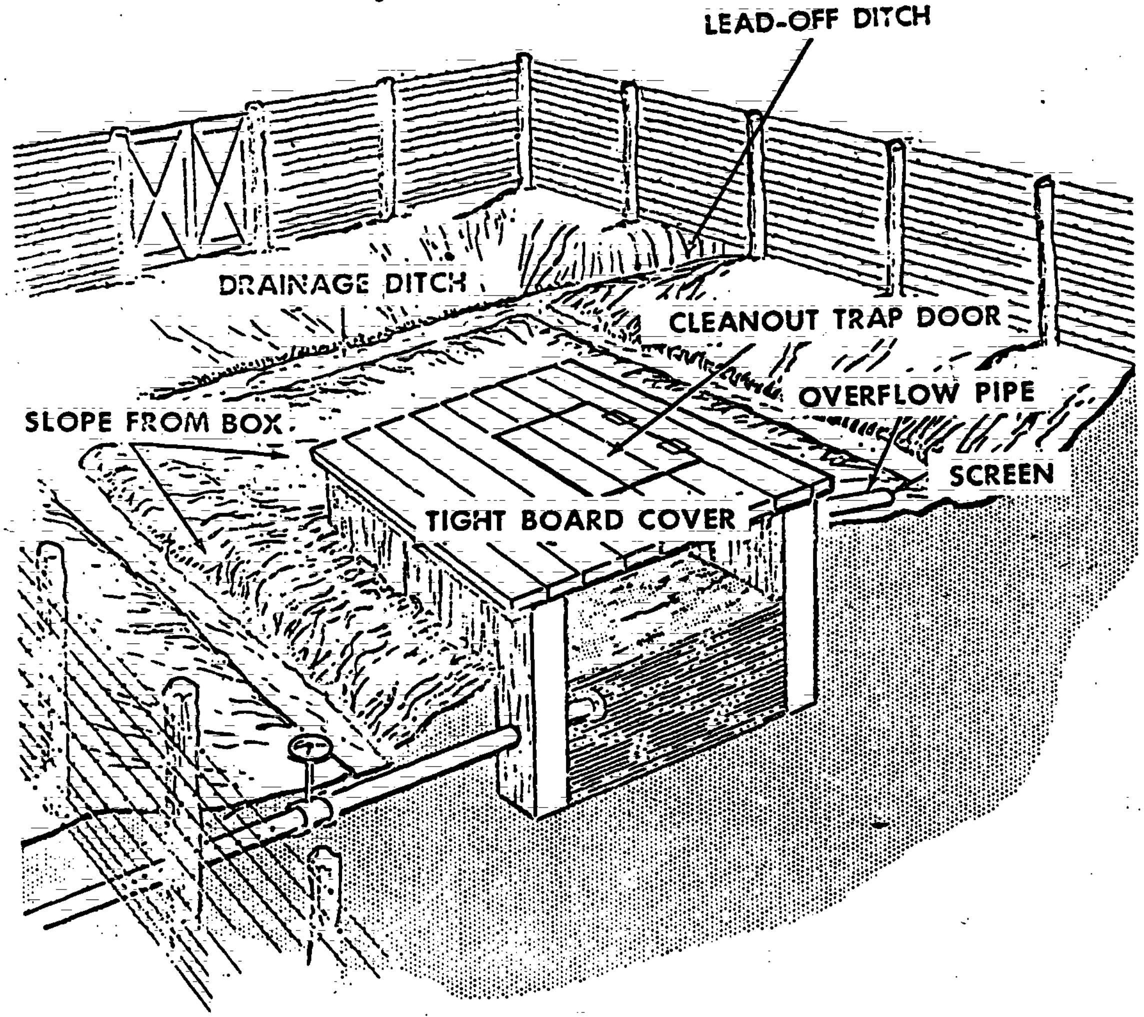



Fig. 18 Spring inlet.

cap is driven into the ground with a sledge. Successive sections of pipe, each 5 feet long, are added and driven until the screen is well within the water bearing media. Several well points may be connected in parallel to supply sufficient water to the raw water pump. In developing drive point sources, it must be remembered that the practical limit of suction lift of the pumps issued with field equipment is 22 to 25 feet at sea level. Suction lift pumps can be used, therefore, only where the pumping level in the well will be within the limit of suction lift, or 22 to 25 feet below the position of the pump. At 5,000 feet above sea level, the practical limit of suction lift is only 20 feet. It should be noted that since a suction-lift pump must create a partial vacuum in the suction line, it is necessary that the line be absolutely airtight if the pump is to function properly.

SPRINGS

Springs yielding 20 gallons per minute or more of water can be used as a source of field water supply if properly developed. Springs may be developed by enlarging the outlet of the spring, and by reducing loss by damming and conducting water to storage. To reduce possible pollution, springs should be cleared of all debris, undergrowth, top soil, loose rocks, and sand.

Water which flows from rocks under the force of gravity and collects in depressions can be collected in boxes or basins of wood, tile, or concrete. The collecting box should be large enough to impound most of the flow, and should be placed below the ground level so that only the top is slightly above the surface. The box should be covered tightly to prevent contamination and lessen evaporation. The inlet should be designed to exclude surface drainage and prevent pollution. This requires fencing off the area and providing proper drainage. Fig. shows a spring inlet which has been protected in this manner. The screen on the overflow pipe prevents the entrance of insects and small animals. Another screen on the intake pipe prevents large suspended particles from being ingested by the pump used to distribute the spring water, thereby preventing mechanical failure or reducing it to a minimum.

The flow of water from a spring located on a steep slope of loose earth can be obtained by the following two methods:

1. Constructing deep, narrow ditches leading from the spring to the point of collection.

2. Constructing pipeline tunnels from the spring to the collecting point. Pipe of large diameter is more suitable for this purpose. The water from the tunnels can be trapped by constructing a dam at the point of collection.

Digging is a more positive and more economical method of developing a spring than blasting. In using explosives in developing the yield from springs you should exercise great caution. Blasting in unconsolidated rocks may shift the sand or gravel in such a way as to divert the spring to a different point.

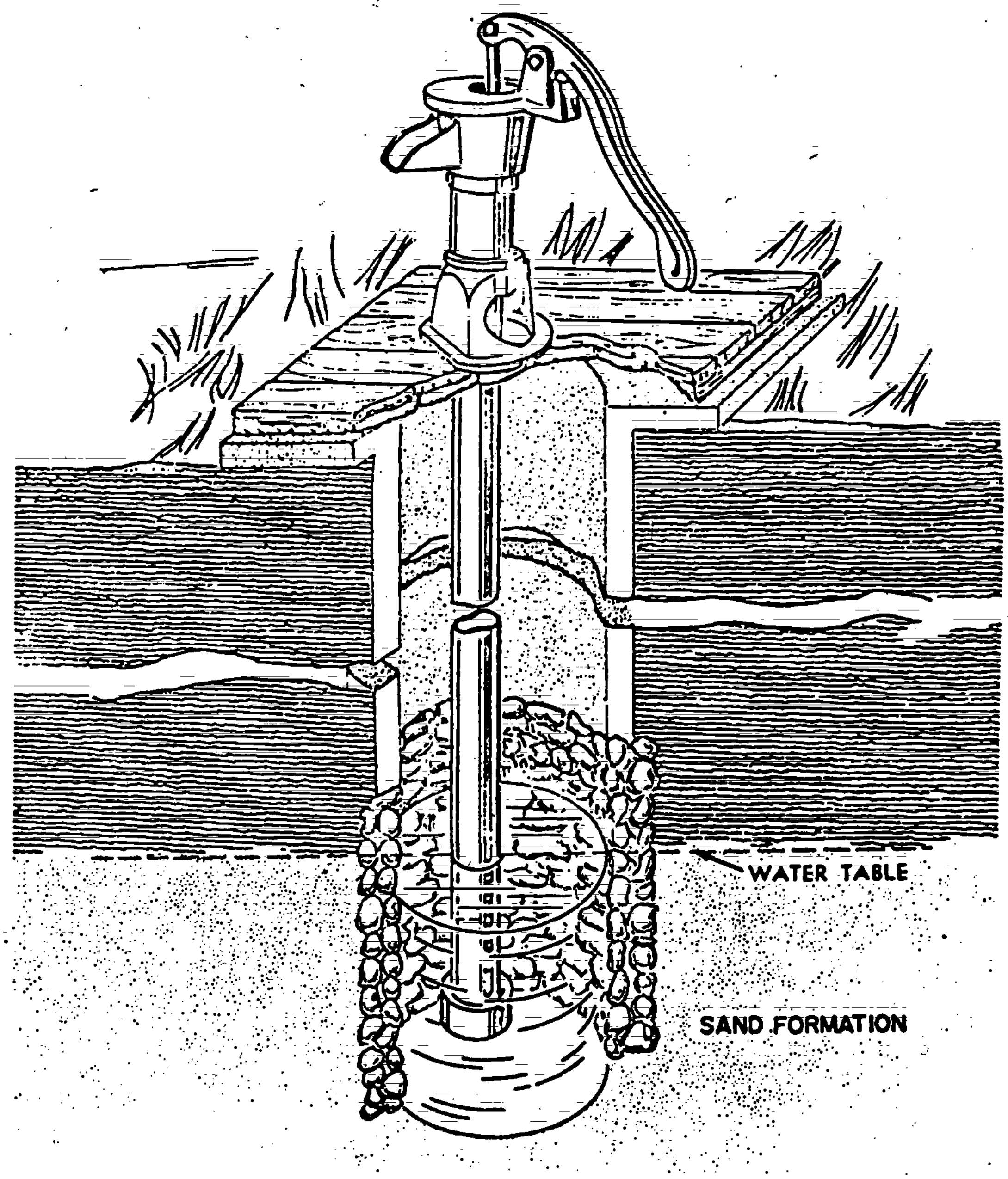



Fig. 19 Typical dug well with suction pump.

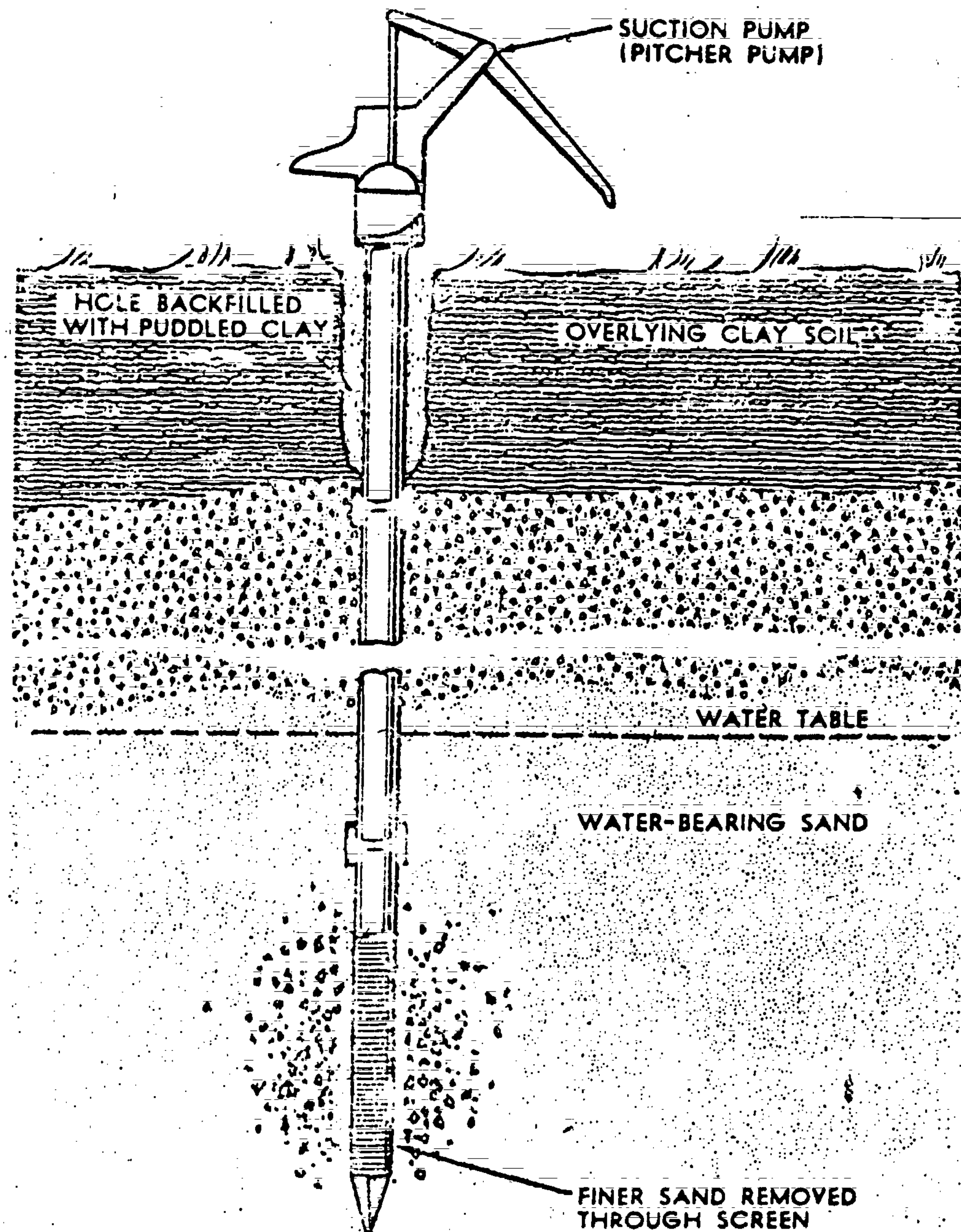



Fig. 20 Finished drive point well.

WELLS

When ground and surface water supplies are inadequate or cannot be used, ground water supplies are developed by constructing wells. Wells are classified into five types, according to their method of construction. These are dug, bored, driven, jetted and drilled wells. Each type of well has its particular advantages, which may be ease of construction, type of equipment required, storage capacity, ease of penetration into certain types of formations, or ease of safeguarding against pollution.

## THE BASIC REQUIREMENTS OF A WATER SUPPLY

The objectives of any water supply, big or small, are to provide the consumers with safe and wholesome water in adequate amounts and to make that water readily available to users.

### SAFE AND WHOLESOME WATER

Safe and wholesome water is water that may be consumed without risk from its chemical and bacteriological contents. Its color and odor should be unobjectionable and it should be free of visible suspended matter.

Much information concerning its sanitary quality may be obtained by chemical examination of a water but it is impossible to say that a water is free of sewage pollution by chemical analysis alone. Where the presence of pollution is being investigated, bacteriological examination is essential. Water which the tests have shown to be safe may be polluted after the samples have been taken and the only way of ensuring the early detection of intermittent pollution is through frequent routine bacteriological examinations. In rural areas it is often difficult enough to have one such examination done but to insist on weekly repetitions would be quite unrealistic. The Bacillus coli which normally lives in the bowels of warm-blooded animals and which is present in human faeces in enormous numbers is used as the bacterial indicator of pollution. Unfortunately there is no ready method of differentiating B. coli of animal origin from those of human origin.

In view of the foregoing it is of the utmost importance that the supply system be correctly located and constructed so as to provide natural protection against outside contamination. A careful inspection of the pertinent area must, therefore, be carried out, and it should be repeated at regular intervals to ensure that this area is maintained in the necessary sanitary state.

### ADEQUATE QUANTITY

The average amount of water required daily by an individual is about 10 gallons for domestic purposes, i.e. drinking, cooking, bathing and laundry. People can do with less for short periods when necessary, but public health is best served by encouraging the use of water and discouraging its waste. The provision of 25 or more gallons per person per day does not include water needed for gardening purposes or for animals.

The former usually affects only the bungalows and varies considerably in amount. The standard daily allowances for animals are:--for horses and cattle--10 gallons per capita: and for sheep, goats and pigs, 2 gallons each. Hospitals require about 50 gallons per patient daily, and schools need approximately 10 gallons daily for each child.

AVAILABILITY

From the purely public health view-point there is no question but that the aim should be to supply safe and wholesome water in adequate quantity to every family in its home. Generally, when individual families are provided with taps in their own houses they look after the taps and the wastage of water is minimal. On the other hand, where the distribution of water is by public stand-pipes, the taps are generally left running and many of them are repeatedly broken so that they cannot be turned off. Unfortunately the capital cost of a waterpoint in each house is often too great and it is then necessary to compromise between economic realities and the desired sanitary conditions.

Until they actually experience the benefits of safe water, villagers rarely understand or appreciate its advantages and they will continue to use their old polluted sources unless the new sanitary supply is superior in some respects obvious to them, such as greater convenience or greater reliability. They may bathe themselves and wash their clothes at the new water-point but the general standard of household cleanliness will vary inversely with the distance the water has to be carried. If the new water-points are not as handy or as dependable as the old ones the people will continue to use unprotected shallow wells near their homes or persist in going to the river for polluted water. Such practices defeat the real object for which the new supply is being installed, namely, to improve the public health. As many stand-pipes and household connections as possible should, therefore, be supplied and the layout of the whole pipe system should be such as to facilitate the future provision of a tap in each house. The following are suggested as minimum standards:--one stand-pipe should not serve much more than 40 people; and in the case of wells to which the people must go for their water there should be at least one well for every 250 people (approximately).

SELECTION OF THE SOURCE OF SUPPLY

The choice of a source of supply for development depends on a number of factors, chief among which are:--the quantity and quality of the water available; the possibilities of sanitary control of the catchment area; whether the water can be supplied to the consumers by gravity or has to be pumped; and the distance from the source to the houses. In order to obtain full information on these points it is necessary to carry out a very careful preliminary survey.

SOURCE OF SUPPLY

The first step in starting any water scheme is to determine what source of supply are available. Frequently a good source is not difficult to find but it is usually advisable to check all alternatives as some may be more economical and safer to develop. Sometimes suitable sources are not obvious and a search should then be made in the valleys, along the foot of the hills, where the vegetation is greener, and such places. In this reconnaissance the inhabitants are generally very willing to assist with their local knowledge.

If the search fails to reveal a satisfactory source an investigation of the ground-water becomes necessary, and for this a knowledge of the local geological formations is most helpful. Study of any existing wells will provide some information about the layers it penetrates, and the location, quantity, and quality of the water. Unless a good deal is already known about the aquifer it is expedient to sink test holes at various likely spots. These holes may be made with a pipe, about 2 inches in diameter, tipped with a point, and driven into the ground by a hammer, or a pipe sunk by an earth auger or by boring. This method is generally successful provided the water is not more than 30 feet or so from the surface. If it is necessary to probe any deeper, it is usually wise to obtain the services of an engineer possessing the experience and the equipment for this type of work. Deep well exploration and construction are expensive and are not jobs for amateurs.

The next step is to determine the quantity of water available. The rainfall figures may be obtained and the history of springs and existing wells may often be secured from the local residents. An estimate of the capacity of the aquifer may be made by pumping a well and noting the rate at which the well refills but the approximate yield in the dry season must be determined as that is often a decisive factor.

THE SANITARY SURVEY

The sanitary conditions prevailing in the immediate areas of possible sources should be thoroughly investigated. This is most important because the methods of purification of water, under rural conditions, are limited, and the process is too often neglected. Animal contamination of the water is very undesirable, and in some places may be dangerous, but the greatest hazard lies in pollution from human sources. It may be possible to find a spring, or stream, coming from a safe catchment area situated uphill from human habitation, or it may be practicable to render a source safe by moving potential origins of contamination or to protect the source by suitable intercepting drainage etc. Though the water from a stream may be liable to pollution it is often feasible to obtain wholesome water through wells and infiltration channels sunk in sand and gravel layers near the stream. Wherever possible the water should be examined chemically and bacteriologically and results considered in the light of the sanitary survey.

SOURCE AND TREATMENT

In the final selection of a source the following priorities should be adopted.

First-priority Consideration

Water which requires no treatment to meet bacteriological, physical, and chemical requirements and which can be delivered to the consumer by a gravity system should be given first consideration. This would usually be limited to springs and protected drainage areas. Such a system requires no treatment and no pumping and, therefore, is ideal from the point of view of maintenance, which is thus reduced to an absolute minimum.

Second-priority Consideration

Water which requires no treatment to meet bacteriological, physical, and chemical requirements but which must be pumped to consumers, would be the second choice. Well supplies would fall within this category.

Pumping can be an economical and simple solution, but it can also be an expensive and complicated one, according to local circumstances. It depends on the availability of qualified operators and on the local cost of fuel. Such factors vary widely from country to country and even from one rural area to another of a given country; they vary also with the types and efficiency of operation and maintenance programs developed for providing aid to municipalities from centrally located headquarters.

Third-priority Consideration

Water which requires simple treatment before it can meet bacteriological, physical, or chemical requirements but which can be delivered to the consumer through a gravity system should be given third-priority consideration. Simple treatment is considered to be limited to: (1) storage which would provide plain sedimentation and some reduction in bacteria, (2) chlorination without the use of a mechanically operated chlorinator, (3) slow sand filtration; or a combination of these.

For rural areas this is normally an inferior solution. It is usually more expensive than the above solutions and involves operational procedures which are most difficult to maintain in small rural communities. In such places, when the chlorine stock runs out, chlorination is abandoned in almost every instance; and, when the slow sand filter becomes clogged, a by-pass is often considered an easy arrangement. Such is the history of treatment measures in most rural areas where routine technical assistance is not provided by a responsible agency.

Fourth-priority Consideration

Water which requires simple treatment, as mentioned above, and which must be delivered to the consumers by pumping would obviously be the most expensive choice to make.

DETERMINING THE RELATIVE COST OF A DEVELOPMENT

The easiest method of determining the relative cost of a development is to:

(A) Estimate the cost of the various components for a given design;
(B) Calculate the time required for construction;
(C) Determine the total labor cost from the price per hour;
(D) Sum items A and C.

WATER SUPPLY SOURCES

LESSON NO. 1

LESSON OBJECTIVE: Describe the methods used to locate and record existing water supply sources with respect to the community to be served.

| TOPIC | INSTRUCTIONAL PROCEDURE | SUPPLEMENTAL MATERIALS RELATED READING |
|---|---|---|
| Topographic Contouring | Hand out exercise on topographic contouring and assist students where necessary. | |
| Topographic Mapping | Discuss the use of the compass and the interpretation of topographic maps. | Manual of Field Geology p. 21-25. Any basic laboratory manual of Physical Geolo |
| | Demonstrate drawing a crude topographic map of a prominent topographic feature. | Manual of Field Geology p. 36-50. |
| | Outline what features are to be included and how they are to be represented in a topographic sketch map. | A.F.M. TM 5-700 p. 6-15. |
| | Assign students to groups of five. Have each group map a quarter mile area. Each map should include the following features:<br>1) man-made structures<br>2) livestock grazing areas<br>3) water supply sources<br>4) disposal systems | |
| Plane Table Mapping | Demonstrate how to construct a more serviceable map, the plane table map. | |

WATER SUPPLY SOURCES

LESSON NO. 2

LESSON OBJECTIVE: Demonstrate how to identify and evaluate various water supply sources.

| TOPIC | INSTRUCTIONAL PROCEDURE | SUPPLEMENTAL MATERIALS / RELATED READING |
|---|---|---|
| Rock and Soil Type | Outline the physical characteristics and discuss the hydrological properties of the basic rock and soil types.<br><br>Assist students in identifying the basic rock and soil types.<br><br>Have each student identify rock and soil types from a series of circulating samples. | |
| Physical and Chemical Pollutants | List the major chemical and physical pollutants and discuss the nature of these pollutants. | Manual of Individual Water Supply Systems p. 5-13. |
| Identification of Physical Pollutants | Demonstrate how to identify turbidity with the measuring cup.<br><br>Assist students in identifying physical pollutants from a suite of water samples. Water samples should reflect the various pollutants: turbidity, color, odor, taste and temperature. | |
| Water Supply Sources | Outline the factors that influence the quality and quantity of a given water supply source.<br><br>List and discuss the characteristics of the various water supply sources.<br><br>Demonstrate evaluating these sources in the field.<br><br>Assign students to groups of five.<br><br>Assign each of these groups to a three mile area. | Manual of Individual Water Supply Systems p. 13-20<br><br>WHO Monograph #42 Chapter 5.<br><br>WHO Monograph #42 Annex 4 (p. 271-275). also p. 39-42. |

WATER SUPPLY SOURCES
Lesson No. 2
(Continued)

Have each group evaluate each source in its area in terms of
1) location
2) quantity
3) quality as determined from any physical pollutants present and possible sources of contamination.

Assemble groups to have each group report on the feasibility of the water supply sources in its area.

WATER SUPPLY SOURCES

LESSON NO. 3

LESSON OBJECTIVE: Discuss developments that will improve the quality and yield of the various water supply sources.

| TOPIC | INSTRUCTIONAL PROCEDURE | SUPPLEMENTAL MATERIALS / RELATED READING |
|---|---|---|
| ater Point evelopments | Recall the need for water source developments and describe several of these. | WHO Monograph #42 Chapter 5. Small Water Supplies p. 14-25. |
| | Demonstrate a method for determining the relative cost of a source development from a list of its components and an estimate of the labor cost. | VTH #2, p. 5-7, 11-13. WHO Monograph #42 Annex 7, p. 297-310. |
| | Supervise students in estimating the relative cost of basic developments for<br>1) lakes and ponds<br>2) streams and rivers<br>3) cisterns<br>4) springs | Diagrams or charts of these types of developments. |
| | Have each student describe and estimate the relative cost of a development for each of the four sources listed above. | |

## SECTION 2

## WATER TREATMENT

OVERVIEW:

When the source of water supply is not entirely satisfactory treatment is necessary to insure that the quality of the water meets certain requirements. The trainees are instructed in the basic requirements of water treatment and receive detailed plans for the installation of two simple yet effective treatment systems.

SECTION 2 WATER TREATMENT

OBJECTIVE: Determine which of the potential water supply sources are the most economically feasible in terms of any treatment process requirements.

TASKS:

1. Define minimal standards of concentration for each pollutant.
2. Identify the nature and extent of pollution for each water supply source.
3. Determine which type of treatment system would most probably be necessary to reduce the pollution level of each source to a safe level.
4. Determine the cost of a treatment process or processes for each source.
5. Select the most economical source(s) in terms of capacity to serve appropriate numbers of people, and treatment process requirements.

FUNCTIONAL SKILLS:

1. Describe the four methods used in treating polluted water.
2. Identify the relative costs of different types of treatment systems.
3. Know the effect various pollutants have on different delivery systems.
4. Know what pollutants make water esthetically objectionable.
5. Know what concentrations of chemical pollutants and coliform bacteria constitute health hazards.
6. Identify the factors that influence the future population trends of a given locale.
7. Recognize the relationship between number of water system users and treatment process capacities.

WATER TREATMENT (cont.)

TERMINAL PERFORMANCE TESTS:

1. Given the designs for various types of treatment systems, calculate with reasonable accuracy the cost of each.

2. Given a list of pollutants, correctly list after each one, if applicable:

   a. in what circumstances it can contribute to the destruction of a delivery system.

   b. in what concentration it makes water esthetically objectionable.

   c. in what concentration it constitutes a health hazard.

# WATER SUPPLY SOURCES AND TREATMENT

## WATER TREATMENT

### SELF PURIFICATION

Under favorable conditions, any polluted body of surface water--stream or river, lake or pond--will rid itself of a certain amount of its pollution by means of natural processes. This self-purification cannot de depended upon to bring about complete purification, but it may well improve the water quality sufficiently to ease the load on mechanical purification equipment.

#### STREAMS AND RIVERS

When sewage is discharged into water, a succession of changes in water quality takes place. If the sewage is emptied into a lake in which currents about the outfall are sluggish and shift their direction with the wind, the changes occur in close proximity to each other and, as a result, the pattern of changes is not crisply distinguished. If, on the other hand, the water moves steadily away from the outfall, as in a stream, the successive changes occur in different river reaches and establish a profile of pollution which is well defined. However, in most streams, this pattern is by no means static. It shifts longitudinally along the stream and is modified in intensity with changes in season and hydrography.

When a single large charge of sewage is poured into a clean stream, the water becomes turbid, sunlight is shut out of the depths, and green plants, which by photosynthesis remove carbon dioxide from the water and release oxygen to it, die off. Depending on the stream velocity, the water soon turns nearly black. Odorous sulfur compounds are formed and solids settle to the bottom, forming a sludge. The settled solids soon decompose, forming gases such as ammonia, carbon dioxide, and methane or marsh gas. Scavenging organisms increase in number until they match the food supply. The oxygen resources are drawn upon heavily and, when overloaded, become exhausted. Life in such waters is confined to anaerobic bacteria (which exist when no oxygen is available), larvae of certain insects such as mosquitoes, and a few worms. There are no fish; turtles are generally the only forms of higher life present. This condition is known as the zone of degradation.

In a second zone, or zone of decomposition, more solids settle out, the the water becomes somewhat clearer, and sunlight penetrates the surface. Oxygen is absorbed from the atmosphere at the air-water interface permitting the establishment of aerobic (oxygen available) conditions. The aerobic bacteria continue the conversion of organic matter into nitrates, sulfates, and carbonates. These, together with the carbon dioxide produced by decomposition as well as by bacteria and plant life, are food sources. With sunlight now penetrating the water, and with abundant food, algae begin to flourish and form a green scum over the surface.

In the third zone, or zone of recovery, algae become more numerous and self-purification proceeds more rapidly. Green plants utilizing carbon dioxide and oxygen will liberate in the say time more oxygen than is consumed, thus hastening the recovery of the stream. Simultaneously, the fish that require little oxygen such as catfish and carp, are also found. As the dissolved oxygen increases, more types of fish appear. After recovery, in the zone of cleaner water, fish find the stream highly favorable, as the algae support various aquatic insects and other organisms on which fish feed. The water is clear or turbid according to concentration of algae, and may have odor for the same reason.

Throughout the stages of recovery of self-purification, disease organisms are greatly reduced in number because they lack proper food, and experience unfavorable temperatures and pH values of water. However, the water is still dangerous since all disease organisms have not perished.

### LAKES AND PONDS

Self-purification in lakes and ponds is brought about by the same processes as in rivers and streams. However, currents are not as strong and sedimentation plays a larger role. Large deposits of sludge, dead algae, and other organic material build up on the bottom. In deep lakes, self-purification is aided by seasonal "overturns." This is simply an exchange of bottom water for surface water which occurs in the spring and fall, caused by the difference in the temperature of the water at the surface and bottom of deep lakes.

## BASIC STEPS IN TREATING WATER

### COAGULATION

Turbidity in water consists of finely divided negatively charged colloidal materials which are kept in suspension by mutual repulsion. Turbid water is difficult to clarify by filtration because these fine particles can cause rapid plugging or even pass through a filter. The agglomeration of these colloids into settleable or filtrable aggregates through the action of certain chemicals is called coagulation. Iron and aluminum salts are the most widely used coagulants in water treatment plants.

### SEDIMENTATION

Plain sedimentation is the natural settling of solids heavier than water without the addition of chemical coagulants. Solids heavier than water are held in suspension while in moving water, but gradually settle to the bottom as the water velocity is reduced. The time required to clarify water by sedimentation depends on the size of the suspended particles and their specific gravity. 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.

Plain sedimentation is not ordinarily used 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 emergency situations, such as the necessity of taking water from a swift-flowing stream which is heavily silt-laden after a rainstorm, special sedimentation tanks may be set up as a first step. This initial removal of turbidity reduces the load on the coagulation and filtration steps of the water treatment process, and the frequency of filter backwashing is reduced.

FILTRATION

Filtration consists of passing the water through some porous material to remove the suspended impurities. Filtration is one of the oldest and simplest procedures known to man for revoving suspended matter from water and other fludis.

The simplest form of water filter is the sand filter. This filter resembles a small reservoir, the bottom of which is a bed of filter sand which in turn rests on a bed of well-graded aggregate with the largest size aggregate being at the bottom. An underdrain system of tile or brick is provided under the gravel to collect the water from the filter area. The underdrain system consists of a header or main conduit extending across the filter bed. Means are provided for regulating the flow of water out of the filter through this header and also for controlling the rate of flow on to the filter. This allows the filter to be operated at controlled rates which should not exceed 3.0 gallons per minute per square foot of filter area. An average filter bed consists of about 12 to 20 inches of gravel and 20 to 40 inches of sand. The depth of water over the sand bed varies from 3 to 5 feet.

DISINFECTION

In addition to coagulation, sedimentation, and filtration, water must undergo an additional treatment step: disinfection. This is necessary because no combination of the other three steps can be relied upon to remove all disease-producing organisms, the pH and temperature of the water, the presence of interferring substances, and the degree of protection afforded organisms from the disinfecting solution by materials in which they are imbedded. Therefore, various concentrations of disinfectant are required depending upon the local environmental conditions and the amount of particle removal effected.

Chlorine is the most commonly used chemical for disinfection of water. It is employed in field water supply in the form of calcium hypochlorite, a standard item in the supply system (commercially known as HTH powder). When the calcium hypochlorite is dissolved, the chlorine goes into solution and a calcium carbonate sludge settles out. The chlorine is present in the solution as hypochlorous acid or hypochlorite ion depending on the pH, both of which are powerful oxidizing substances. The chlorine available in either of these two forms rapidly oxidizes the organic and inorganic matter including the bacteria in the water. In this reaction the chlorine is converted to chloride and is no longer available as a disinfectant. The organic matter as well as such material as iron and manganese consume the chlorine. The use of chlorine makes it possible to introduce an accurately measured dosage to insure the destruction of disease-producing organisms as well as provide a readily measured residual to safeguard against recontamination during further handling.

Chlorine Dosage

Dosage is the amount of chlorine added to water to satisfy the chlorine demand as well as to provide a residual after a specified time. The amount required to disinfect water varies with the organic content and pH value of the water, the temperature, the time of contact, and the chlorine residual required. The dosage is usually stated in terms of parts per million (ppm) or milligrams per liter (mg/l). In water supply terminology, ppm means the same thing as milligrams per liter or "mg/l".

Chlorine Demand

The chlorine demand of water is the difference between the quantity of chlorine applied in water treatment and the total available residual chlorine present at the end of a specified contact period. The chlorine demand is dependent upon the nature and the quantity of chlorine-consuming agents present and the pH value and temperature of the water (high pH and low temperatures retard disinfection by chlorination). For comparative purposes, it is imperative that all test conditions be stated. The smallest amount of residual chlorine considered to be significant is 0.1 ppm. The relationship of the demand to the length of the contact period is discussed below. Some of the chlorine--consuming agents in the water are non-pathogenic (non-disease causing organisms), but this bears no relationship to the fact that they contribute to the total chlorine demand of the water.

Residual Chlorine

As indicated above, residual chlorine is the amount of unreacted chlorine remaining at a specified time after the chlorine compound is added. Chlorine in aqueous solution is highly unstable. It may change quantitatively and qualitatively under numerous conditions, including the presence of other elements or compounds. The total residual chlorine in the water can be chemically divided into the following types:

1. Total available residual chlorine. This is the sum of the free available chlorine and the combined available chlorine.

2. Free available chlorine. Refers to hypochlorous acid and hypochlorite ion present in the water. These are the most effective disinfection forms of chlorine. The free available chlorine is a rapid-acting type, important because it can be relied upon to destroy bacteria relatively quickly, and thus is active during the period immediately following chlorination. The relative amount of each present in the water is dependent upon the pH value of the water. It is important to remember that when the pH is raised the quantity of free available chlorine required to kill the same number of micro-organisms increases. With decreasing temperature the same situation of increasing dosage to maintain the same kill is encountered. If the contact time is varied, then the dosage applied must also be changed. For example, to shorten the contact time the dosage would have to be increased.

3. Combined available chlorine. This results from the presence of ammonia or organic nitrogen that will react to form simple chloramines. Thus the term "combined available chlorine" arises from the fact that the chlorine has combined with another substance. Chloramines are a slower acting and less active form of disinfectant. Therefore, a much higher concentration than that of free available chlorine is needed to produce the same germ destroying effect. The specific chloramines present are also a function of pH.

Disinfecting Time

Chlorine demand in most water is likely to be largely satisfied 10 minutes after chlorine is added. After the first 10 minutes of chlorination, disinfection continues but at a diminishing rate. A standard period of 30 minutes contact time is used to assure that highly resistant or high disease-producing organisms have been applied. Given a sufficiently large chlorine content, and if certain other conditions are met, even such special water purification problems as the presence of amoebic cysts or schistosomes will be solved with the 30-minute contact period.

DISINFECTION REQUIREMENTS FOR ENGINEER OPERATED FIELD WATER TREATMENT EQUIPMENT

As has been previously discussed, the efficiency of the chemical disinfection process is dependent upon numerous factors which include the type and concentration of micro-organisms, the pH and temperature of the water, presence of interferring substances and whether or not the organisms are protected from the disinfection solution by being embedded in tissue cells, or clumps of tissue cells, or other material. Therefore, various concentrations of disinfectants are required. Minimum concentrations of disinfectants are prescribed below.

Engineer operated mobile and portable water treatment units employ coagulation and filtration as a part of the treatment process and are capable of a high degree of removal of particulate material. When those units are employed, sufficient chlorine will be added to the water, preferably before coagulation so that the residual in the finished water after 30 minutes of contact will be at least as much as that indicated by the following table.

TABLE 2: COAGULATION RESIDUALS

| pH | 30 Minute Free Chlorine Residuals in ppm |
|---|---|
| 5 | 0.75 |
| 6 | 0.75 |
| 7 | 1.00 |
| 8 | 3.00 |
| 9 | 5.00 |
| 10 | 5.00 |

If adequate provisions are not made for accurate and frequent measurement of pH, 5.00 ppm must be used.

The following guidelines were used in developing the above table:

1. The water to be treated would be natural surface or ground water of average composition and not grossly or deliberately contaminated.

2. Water temperature would be above the freezing point.

3. The prescribed concentrations of free chlorine should provide a reasonable margin of safety for all bacteria and viruses pathogenic to man. Parasitic ova would have been removed in the coagulation and filtration steps of the treatment process.

## SAMPLE DESIGNS FOR TREATMENT SYSTEMS

### SAND FILTER

Sand filtration does not make polluted water safe for drinking. But a properly built and kept sand filter will prepare water for boiling or chlorination that will make it safe. Trickling sand filters if built properly and cleaned periodically, provide clear water that must be boiled or treated with chlorine.

The following tools and materials are required:

Steel drum, 2 feet wide by 29 1/2 inches high
Sheet metal to make cover, 29 1/2 inches square,
9.8 feet of wood, 2 x 4 inches
Sand, 7 cubic feet
Gravel
Blocks and nails
Pipe to attach to water supply
Optional...valve and asphalt roofing compound to treat drum.

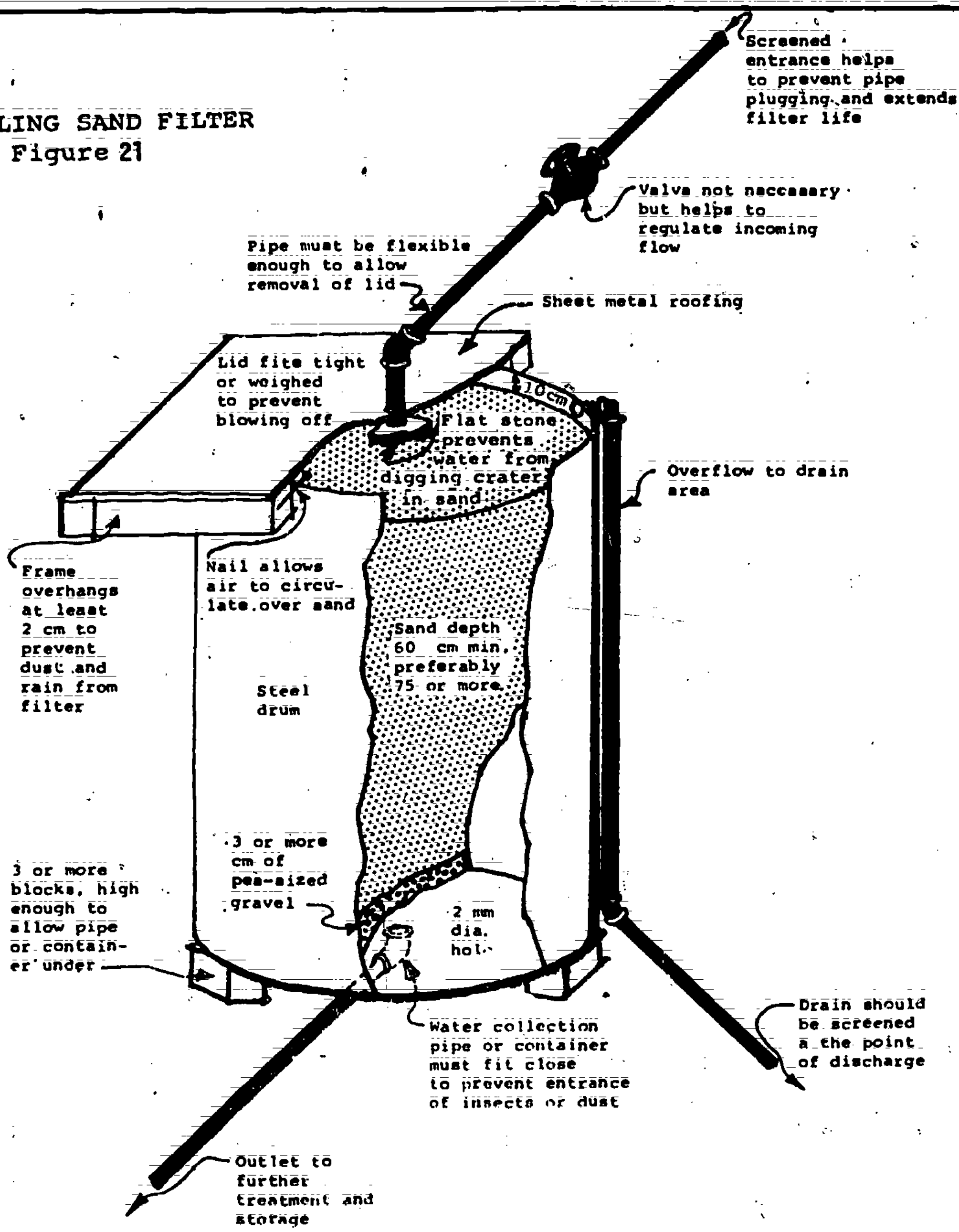
Surface water, from ponds, streams or open wells is very likely to be contaminated with leaves and other organic matter. A trickling sand filter can remove most of this organic material but will always allow virus and other bacteria to pass through. For this reason it is always best to boil or chlorinate water after filtering.

There are several sand filters, but the trickling filter is easiest to set-up and understand. The trickling filter uses sand to strain the organic matter from the water, although this does not always stop small pieces of organic matter or bacteria. But in time, biological growth forms on the top six inches of sand. This slows down the flow of water through the sand but will trap more small organic matter and, at times, up to 95 percent of the bacteria. But if not operated correctly, the sand filter can actually add bacteria to the water.

By removing most of the organic matter, the filter achieves the following results.

1. Removes larger worm eggs, cysts, and cercariae, which are the hardest to kill with chlorine.
2. Allows the use of smaller and fixed doses of chlorine for disinfecting, which results in drinkable water with less taste of chlorine.

TRICKLING SAND FILTER
Figure 21



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3. Makes the water look cleaner
4. Reduces the amount of organic matter, including living organisms and their food, and the possibility of recontamination of the water.

The unit shown in Fig. 21 should give about 1 quart of water a minute. The drum should be of heavy steel and can be coated with asphalt material so that it will last longer. The 2 millimeter hole at the bottom regulates flow and must not be made larger (slightly less than 1/13th of an inch.)

It is important to use clean, fine sand, but not too fine. The sand should be able to pass through a window screen and it is best to wash it.

The following points are very important in assuring that your sand filter operates properly:

1. Keep a continuous flow of water passing through the filter and do not allow the sand to dry out, as this will destroy the microorganisms that form on the surface layer. The best way to insure a continuing flow is to fix the water intake so that there is always a small overflow. Screen the intake and provide a settling basin to help keep pipes from becoming plugged, which would stop the flow of water. This will also delay your having to clean the filter.

2. Never allow the filter to run faster than 0.6 gallons of water a minute per square foot, as it will prevent the growth of microorganisms in the sand and wash them out through the outlet.

3. Keep light from the sand surface but allow air to circulate, as this will prevent the growth of green plant matter on the surface but help the growth of microorganisms that aid the filtering action.

4. When the flow drops below daily needs, clean the filter. This is done by scraping off and discarding the 1/2 inch of sand and lightly raking or scratching the surface. After several cleanings, the sand should be raised to its former height by adding clean sand. Before doing this, scrape the old sand down to a clean level. Cleaning should not be more often than every several weeks or even months.

WATER PURIFICATION PLANT

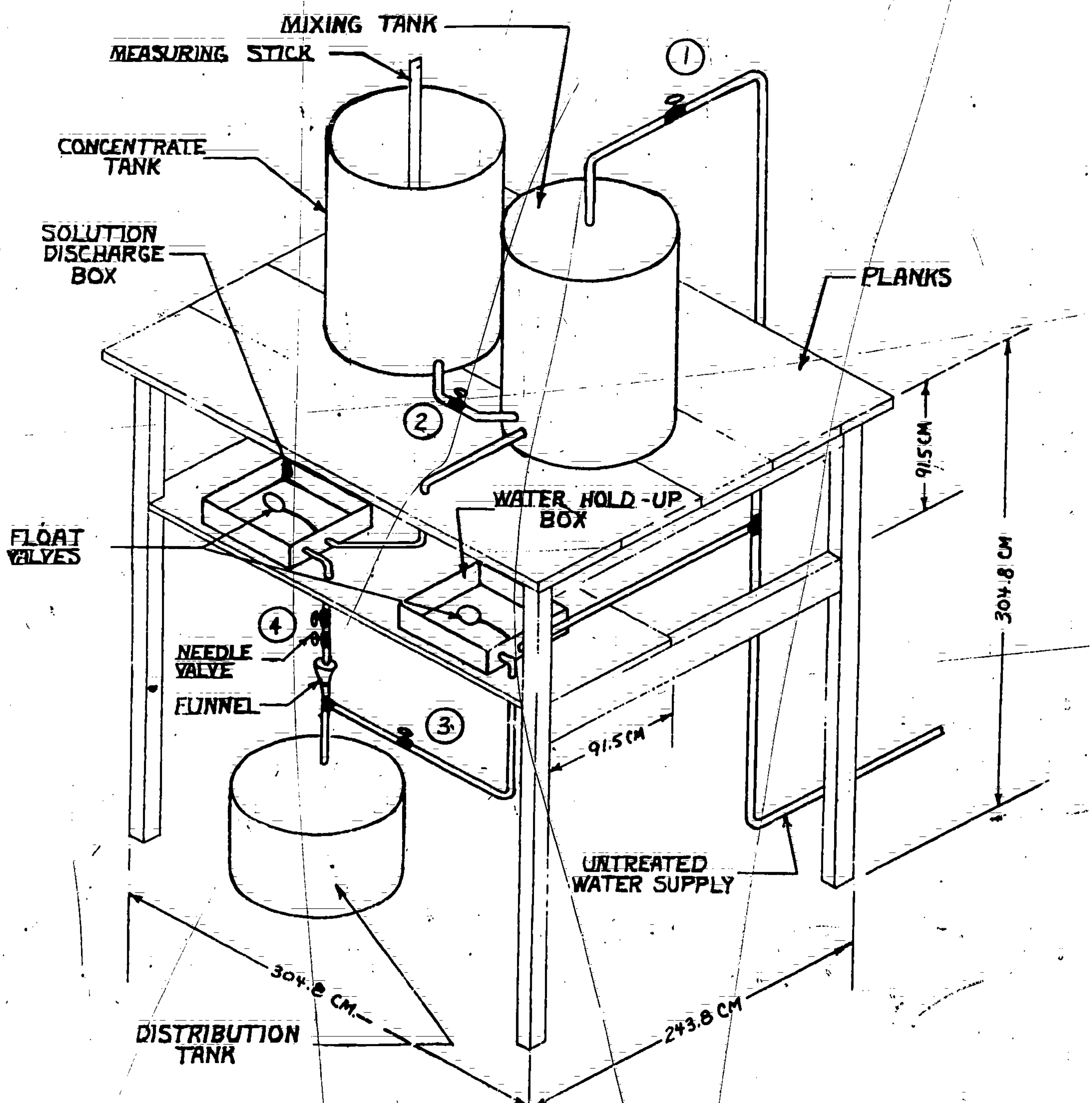
A crude water purification plant is described which uses laundry bleach as a source of chlorine. Although lacking the reliability of a modern water system, this manual plant will provide safe drinking water. Many factors in this system depend upon operating experience. When starting to use the system, it is best to have the assistance of an engineer experienced in water supplies. For constuuction details see section II, C.

Operation

1. Mix concentrated bleach with water in the concentrate barrel with all valves closed.

# CHLORINATION SYSTEM

Fig. 22



2. Fill the pipe from the mixing barrel to the solution tank with water after having propped the float valve in a closed position.

3. Allow a trial amount of concentrate to flow into the mixing barrel by opening Valve #2.

4. Use the measuring stick to see how much concentrate was used.

5. Close valve #2 and open valve #1 so that untreated water enters the mixing barrel

6. Close valve #1 and mix solution in the mixing barrel with a stick.

7. Remove the prop from the float valve of the solution tank so that it will operate properly.

8. Open wide the metering valve and valve #4 to clean the system. Allow a gallon to drain through the system.

9. Close down the metering valve until only a stream of drops enters the funnel.

(steps 2, 8 and 9 may be omitted after the first charging of the system, if the pipe mentioned in the second step is not permitted to empty before recharging the mixing barrel).

10. Open valve #3.

Trial and error must be used to learn how much concentrate should be put in the concentrate barrel, the amount of concentrate to flow into the mixing barrel and the amount of solution to allow past the funnel. The result should be water with a noticeable chlorine taste in the distribution barrel.

The flow into the funnel and the taste of the water in the distribution barrel should be checked regularly to insure proper treatment.

CHLORINATION FOR POLLUTED WATER

Chlorination, when properly applied, is a simple way to insure and protect the purity of water. These guidelines include tables to give a rough indication of the amounts of chlorine bearing chemicals needed. The amount of chlorine specified will normally make reasonably safe water. Try to have your water treatment system inspected by an expert, and the water itself periodically inspected.

The surest way to treat water for drinking is to boil it--see "Boiler for Potable Water". However, under controlled conditions chlorination is a safe method, and often more convenient and practical than boiling. Water properly treated has residual free chlorine which resists recontamination. The chlorine in water is not harmful since water with a harmful amount of chlorine in it is extremely distasteful. Proper treatment of water with chlorine requires some knowledge of the process and its effects.

When chlorine is added to water, it attacks and combines with any suspended organic matter as well as some minerals such as iron. There is always a certain amount of dead organic matter in water, and almost always live bacteria, virus, and perhaps other types of life. Enough chlorine must be added to oxidize all of the organic matter, dead or alive, and to leave some excess uncombined or "free" chlorine.

Some organisms are more resistant to chlorine than others. Two particularly resistant varieties are amebic cysts (which cause amebic dysentary) and the cercariae of schistosomes (which cause schistosomiasis). These, among others, require much higher levels of residual free cholrine and longer contact periods than usual to be safe. Often special techniques are used to combat these and other specific diseases. It always takes time for chlorine to work. Be sure that water is thoroughly mixed with an adequate dose of the dissolved chemical, and that it stands for at least 30 minutes before consumption.

Since both combined and uncombined chlorine has an unpalatable taste, it is best (and safest) to choose the clearest water available. A settling tank, and simple filtration can help reduce the amount of suspended matter, especially particles large enough to see. Filtration that can be depended upon to remove all of the amebic cysts, schistosomes, and other pathogen normally requires professionals to set up and operate. NEVER depend on home-made filters alone to provide potable water. However, a home-made slow sand filter is an excellent way to prepare water for chlorination.

Thus, depending on your water, different amounts of chlorine are needed for adequate protection. Measuring the amount of free chlorine after the 30 minute holding period is the best way to control the process. A simple chemical test using a special organic indicator (orthotolidine) can be used. When this is not available, Table 3 may be used.

TABLE 3: TEST FOR PROPER CHLORINATION DOSAGE

| Water Condition | Initial Chlorine Dose in Parts Per Million (ppm) | |
|---|---|---|
| | No hard-to-kill organisms suspected | Hard-to-kill organisms present or suspected |
| Very clear, few minerals | 5 ppm | Get expert advice; in an emergency boil and cool water first, then use 5 ppm to help prevent recontamination. If boiling is impossible, use 10 ppm. |
| A coin in the bottom of an 8 oz. glass of the water looks hazy. | 10 ppm | Get expert advice; in an emergency boil and cool first. If boiling is impossible use 15 ppm. |

In the chart, parts per million or "ppm" means the ratio of:

$$\frac{\text{Weight of active material (chlorine)}}{\text{Weight of water}}$$

In water supply terminology, ppm means exactly the same thing as milligrams per liter or "mg/l"

The second chart, **Table 4**, gives the amount of chemical to add to 1000 gallons of water to get a solution of 1 ppm. Multiply the amount of chemical shown in Table4 by the number of ppm recommended in Fig. 3 to get the amount of chemical you should add to 1000 gallons of water. Usually it is convenient to make up a solution of 500 ppm strength which can then be further diluted to give the chlorine concentration needed. The 500 ppm solution must be stored in a sealed container in a cool dark place, and should be used as quickly as possible since it does lose strength. Modern chlorination plants use bottled chlorine gas, but this can only be used with expensive machinery by trained experts.

TABLE 4 CONVERSION OF PPM TO OUNCES PER 1,000 GAL.

| Compound | % by weight of active material | Quantity to add to 1000 gallons of water to get a 1 ppm solution |
|---|---|---|
| High Test (Calcium hypochlorite) $Ca(OCl)_2$ | 70% | 1/5 ounce |
| Chlorinated lime | 25% | 1/2 ounce |
| Sodium hypochlorite (NaOCl) | 14% | 1 ounce |
| Sodium hypochlorite | 10% | 1.3 ounces |
| Bleach - a solution of chlorine in water | usually 5.25% | 2.6 ounces |

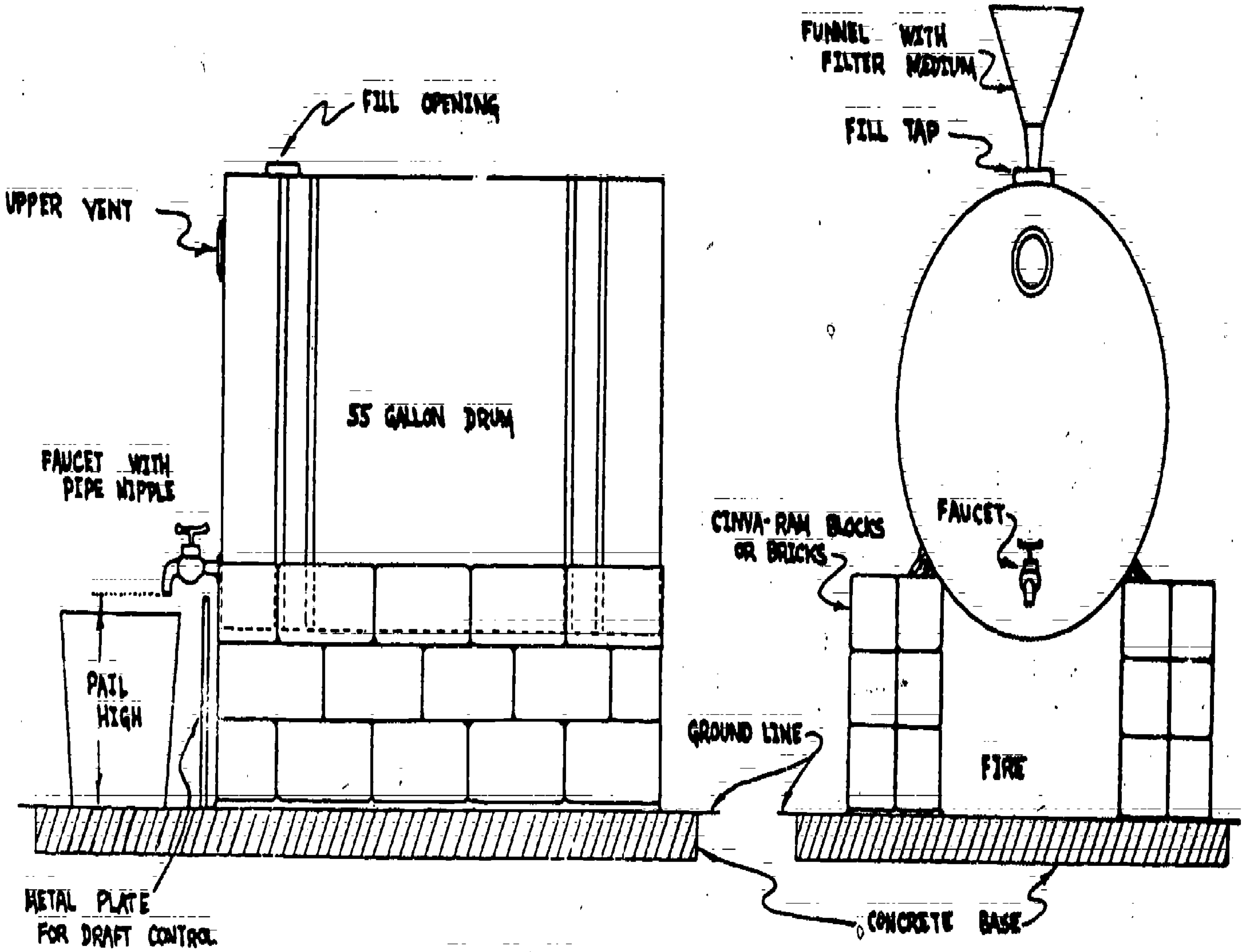



Fig. 23 Chlorination System

no, this is a boiler system
See Village Tech. p. 125-6

# WATER TREATMENT

## LESSON NO. 1

LESSON OBJECTIVE: Describe and demonstrate how to estimate the cost of the four methods used in treating water.

| TOPIC | INSTRUCTIONAL PROCEDURE | SUPPLEMENTAL MATERIALS/ RELATED READING |
|---|---|---|
| Treatment Processes | Discuss the process of self-purification.<br><br>List and describe the four basic methods of water treatment:<br>1) coagulation<br>2) sedimentation<br>3) filtration<br>4) disinfection.<br><br>Outline the essential components of sand filtration and two chlorination units.<br><br>Estimate the costs of construction, operation, and maintenance for these units. | Manual of Individual Water Supply Systems p. 64-83.<br>WHO Monograph Series #42 p. 171-193.<br>Small Water Supplies p. 26-47. |

# WATER TREATMENT

## LESSON NO. 2

LESSON OBJECTIVE: Define the pollutants that must be eliminated;

(a) to provide esthetically pleasing and safe water; and,

(b) to prolong the life of the delivery system.

| TOPIC | INSTRUCTIONAL PROCEDURE | SUPPLEMENTAL MATERIALS / RELATED READING |
|---|---|---|
| Permissible Levels of Chemical, Physical and Bacteriological Pollutants | List and describe pollutants that are<br>1) esthetically objectionable<br>2) health hazards<br>3) contribute to the destruction of a delivery system.<br><br>Establish permissible levels of concentration for each of these cpollutants.<br><br>Recall the processes that will eliminate or reduce these pollutants.<br><br>From a list of pollutants, have each student state the undesirable property (ies) of each and recall a method of elimination (if applicable). | WHO Monograph Series #42 p. 46-54. |

WATER TREATMENT

LESSON NO. 3

LESSON OBJECTIVE: Define the criteria that must be applied in selecting the most economically feasible source.

| TOPIC | INSTRUCTIONAL PROCEDURE | SUPPLEMENTAL MATERIAL RELATED READING |
|---|---|---|
| Criteria of Water Supply Selection | Review the basic requirements of a water supply source.<br><br>Outline the criteria to be used in the selection of water supply sources. | Small Water Supplies p. 8-14 |

# SECTION 3

## PLANNING THE DISTRIBUTION SYSTEM

OVERVIEW:

A water distribution system is a large project requiring great expense in time and capital. The health of the community will be affected by the results of the project. The planning of the project is necessarily of great importance, so as to ensure an economic, efficient, and safe result.

The trainee must be aware of the effects that the existing facilities, the community, the material and financial requirements, impose upon the plans he must prepare prior to the start of the project. This section covers these basic requirements of the planning for a water distribution system.

SECTION 3: WATER DISTRIBUTION SYSTEMS

A. PLANNING THE DISTRIBUTION SYSTEMS

OBJECTIVE: Develop a plan for a distribution system which will meet the requirements of the given community, utilizing the existing and proposed facilities.

TASKS:

1. Assemble a list of existing man-made facilities and potential water sources.

2. Determine average demand; peak demand and when it occurs; and the capacity of the system required to meet both the present and projected requirements of the community.

3. List the components and characteristics of the proposed system. These include:

   a. Water source

   b. Pumping equipment -- type of pump

   c. Capacity of distributing reservoir or storage

   d. Location of distributing reservoir with relation to service connections.

   e. Source of energy used in the system

   f. Pipe sizes and pipe laying system

4. Choose the most economical and practical source from among existing and proposed sources, with the following characteristics:

   a. Supplies required quantity

   b. Requires no treatment or very simple treatment

   c. System easily installed

   d. Located in such a position that gravity can be used as supply energy.

5. Choose most suitable site for the system facilities. Choice guided by:

   a. Proximity to and accessibility from residence

   b. Safety from contamination

PLANNING THE DISTRIBUTION SYSTEMS

c. Safety from destruction

d. Availability of room for future expansion

6. Estimate the expected cost of construction, operation and maintenance of the whole system.

7. Identify the source of finance, amount to be financed and conditions related to the transaction.

FUNCTIONAL SKILLS:

1. Classify type of water sources

2. Measure the yield of different water sources.

3. Draw topographic map. Estimate distance and scale this on a sketched map.

4. Classify climatic types and state construction precautions, e.g., Tropical: heavy rain, insect pests, etc.

5. Recognize useful local materials which can be used instead of a relatively expensive imported one, e.g. bamboo pipes.

6. Calculate projected population.

7. Calculate the capacity of a storage tank from data on population and rate of individual consumption.

8. State factors which determine and guide the selection of pumping equipment.

9. Recognize conditions which make a distribution reservoir a necessity.

10. Decide what traditions can be changed without much social discontent and which must be contended with.

11. Prepare a chart projecting expected costs of materials and labor, and estimate the required amount of money.

TERMINAL PERFORMANCE TESTS:

1. In a field exercise:

a. Classify and measure yield of various water sources which exist in the area.

b. Describe the rest of the existing facilities.

PLANNING THE DISTRIBUTION SYSTEMS (cont.)

c. Sketch the system on a labeled map of the area.

d. Classify climatic types.

e. List all local materials which can be used to improve the system.

2. In a given community:

a. Estimate the present, and project the future population.

b. Determine average daily demand, the peak demand and when it occurs.

c. Calculate the capacity required by the population.

3. From among many sources in the area, choose the best one to develop, and justify.

4. Estimate the cost of establishing the proposed system, and prepare a plan for financing that would be feasible in a local village environment.

# WATER DISTRIBUTION SYSTEMS

## PLANNING THE DISTRIBUTION SYSTEM

### DESIGN

One of the most difficult and baffling problems in the planning of a small water-supply system for a rural community is the lack of criteria upon which a design can be based. The volunteer needs answers to such questions as: "What increase should be allowed for future population growth?"; "Should provision be made for periods of peak demand?"; and "What about storage?" Such technical questions have been thoroughly studied and standardized in textbooks dealing with design of water supplies for urban communities. However, for most rural, underdeveloped areas of the world, reliable design guides have not yet been established. Furthermore, certain elements of design are matters for local decision, depending on geography, local economy, custom, and other factors.

The experience gathered from several rural water-supply programs has been analyzed and is summarized below to serve only as a broad guide. It is realized that there are wide variations in water-supply practice throughout the world and that every designer should not apply blindly the criteria listed here; instead, you should be able to make a critical analysis of the conditions and problems of the area under study and should develop applicable criteria. In so doing, you should contact the health administration of the area concerned with a view to consulting the minimum standards for design and construction which this administration may have issued through its public health engineering division.

There is, however, general agreement on the following fundamental point; in the design of rural water-supply systems, primary consideration should be given to the protection of the quality of the natural water selected, since treatment should be considered only as the very last resort. This requires the incorporation in the design of necessary sanitary safeguards, beginning with the proper location of intake structures and pipes. Except, in unusual circumstances, other engineering and structural elements should be conceived around this need.

Before beginning the actual construction of a village water system, a well defined plan needs to be drawn. The water system, when completed, will be the result of a large commitment from all the local people, both in finances and labor. To be sure that the system is what they want and need, careful planning is a requisite. In planning the water distribution system, there are seven major categories to be defined.

1. Existing Facilities: What already exists? How good is it? Can it be made part of the overall system?

2. Size and Nature of the Community? How many people will be users? How are they distributed? What customs or traditions do they have that must be considered in the overall plan?

3. System Capacity: How much water is needed daily? When are the peak demands?

4. Water Source: What type of source will provide the most economical and satisfactory water for the system?

5. Proposed System: Location of facilities, pipes, outlets, etc.

6. Site of Proposed Facilities: An outgrowth of the proposed system, What problems will there be in obtaining the land needed for the proposed facilities?

7. Financing: How will the materials be obtained? Will this project be financed by government, cocoperatives, on a cost basis, etc?

EXISTING FACILITIES

From data collected in Section I, you have already quite fully analyzed the types of sources available, and evaluated each as a potential water source for a water system. How you need to concentrate on matching the sources of water to the existing community. This is accomplished by:

1. Adding to the topographical map already started, the distribution of the users in the community.

2. Considering local customs and traditions regarding water uses, and needs.

3. From (2) above, calculating system capacity requirements, and system proposals to satisfy those requirements.

SIZE AND NATURE OF THE COMMUNITY

The proposed water system has to be built around the customs and traditi of the community it will be serving. For example, if the social patterns of the community are built around family structures, the system should strive to provide sources of water to families, and not to the community through centrally located water distribution facilities.

In many developing countries there are some traditions which appear "primitive" to western culture. For example, in most parts of Africa, men swim upstream, and women downstream. Or men first, then women. In Moslem countries women do not appear in public unveiled. For an outsider, Peace Corps are outsiders, to institute an acceptable new system in such areas, he has to study very carefully all such traditions and then modify his system to suit the community. If he cannot adjust the system, he should try to get his point across by explaining to the people (or their representatives) why it is important that he interferes with their life. For example: in the Moslem community cited, the best plan would be to distribute water into houses instead of establishing public wells. It must be emphasized that in order to establish the most effective plan, a thorough study of the community must be done by the planner. Usually a discussion with the local authorities will yield a good result. Remember, when help is imposed from above, it meets with resentment and failure.

In describing the community, care should be taken to determine population, both present and projected.

Population growth is determined by:

1. Future economic developments in the community.

2. The character and location of the community in relation to other population centers.

3. The presence or possible introduction of small industries into and around the community (the installation of water scheme itself will cause population growth.)

A common acceptable estimate for future population growth in most rural areas is a 50% increase in population over a ten year period, or approximately 5% per year. This should be the minimum figure upon which the rural water-supply design should be based.

If this estimate appears too high for a particular situation, the system should be designed for present population in a way as to allow for future expansion.

Example on projecting population:

| | |
|---|---|
| Original population | 100,000 |
| Increase over 10 year period 50% | 50,000 |
| Projected population in 10 years | 150,000 |

Relationship between population and storage capacity:

The required capacity for a storage tank equals half the total daily water requirement.

Total daily water requirement = average demand x population + larger users.

(Large users would include public centers, schools and factories. If these are not in the community, then the last term is left out)

Storage Capacity = 1/2[average demand x design population + large users]

SYSTEM CAPACITY

The methods for evaluating each type as a potential water system source was covered in Section I. For each source you will have to determine its yield. This is the maximum quantity of water that can be drawn from a source in a given period of time. To calculate the yield for a source of water you:

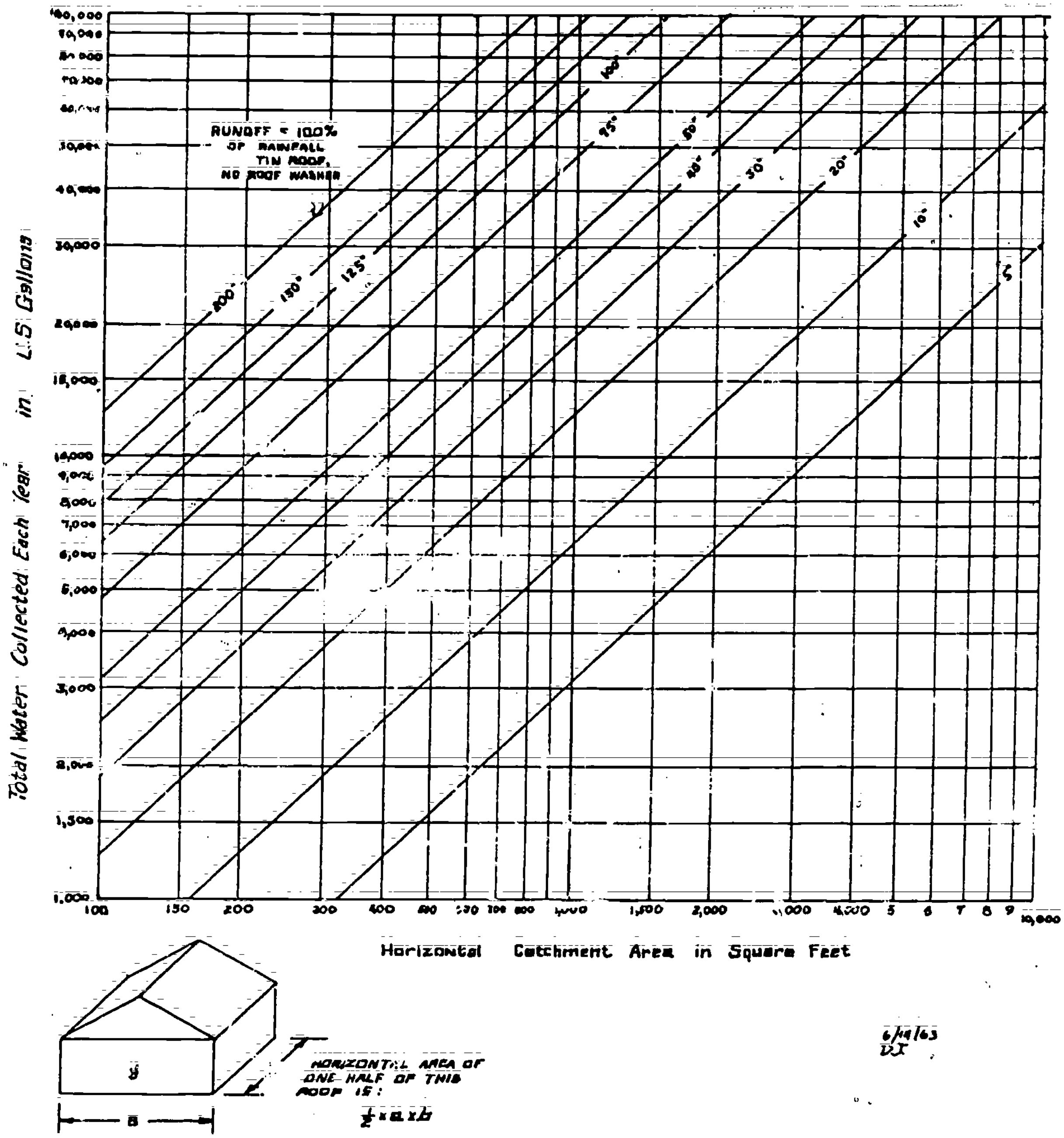
1. Draw a measured quantity of water from the source;

2. Time how long it takes the source to replenish the drawn quantity;

3. Divide the amount of water drawn by the time taken to refill.

Yield is usually stated in gallons per minute. Below are examples for estimating yield for various types of water sources.

Fig. 24 Cistern Catchment Yield



a. Cistern Catchment Yield

To estimate your catchment area, the minimum yearly rainfall and the amount of water required by the family during one year, must be estimated. Sometimes, the government meteorological section can give you the minimum rainfall expected. If they do not, you can estimate the minimum rainfall at two-thirds of the yearly average. Take the average amount of water needed by the family for one day and multiply it be 365 to learn how much is needed for one year. Then use the chart to find how much roofspace is needed (Fig. 24 )... Suppose you have a rainfall of 60 inches a year and the family needs 20 gallons a day, then...

2/3 x 60 equals a minimum rainfall of 40 inches a year

365 days x 20 gallons a day equals 7300 gallons a year

The chart shows that a catchment area of about 300 square feet is needed to supply the family with enough water for one year.

b. Yield of Small Streams

This is a rough but very rapid method of estimating water flow for small streams. The number of streams that must be used and the flow variations are important factors in determining the necessary facilities for utilizing the water. Here is a way to survey a water supply problem quickly by allowing you to take rapid flow measurements.

The equation for stream flow is --- $Q = K \times A \times V$

Q = flow in gallons per minute (8.33 pounds = 1 gallon)

A = cross section of stream, perpendicular to flow, in square feet.

V = stream velocity, feet per minute.

K = a corrected conversion factor since surface flow is normally slower than average flow. For normal stages use K = 6.4; for flood stages use K = 6.7 to 7.1.

Fig. 25 Determine Stream Yield

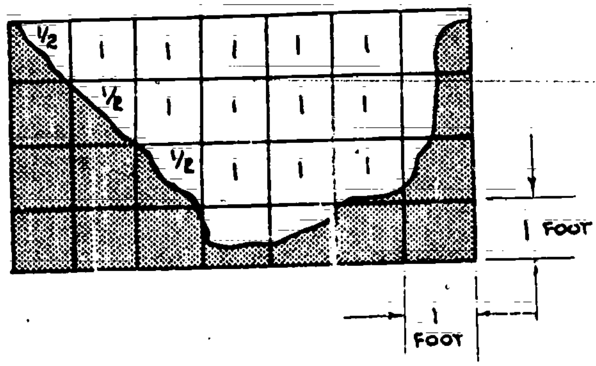



Fig. 26 Cross Section of Stream

To find "A"... the stream will probably have different depths along its length so select a place where the depth of the stream is average...take a measuring stick and place it upright in the water about one foot from the bank...note the depth of water...move the stick two feet from the bank in a line directly across the stream...note the depth...move the stick three feet from the bank, note the depth, and continue moving it at one-foot lengths until you cross the stream. Draw a grid, like the one above, and mark the varying depths on it so that a cross-section of the stream is shown. A scale of one inch equals one foot is often used for such grids. By counting the grid squares and fractions of squares, the area of the water can be estimated. For example, the grid shown here has about 15 square feet of water.

To find "V"...put a float in the stream and measure the distance of travel in one minute (or fraction of a minute, if necessary.) The width of the stream should be as constant as possible and free of rapids, when measuring the velocity.

Example:

Cross section = 15 square feet.
Velocity of float = 20 feet traveled in 1/2 minute
Stream flow is normal

$$Q = 6.4 \times 15 \times \frac{20 \text{ feet}}{.5 \text{ minute}}$$ 3800 gallons a minute

WATER SOURCE

Factors to be considered in the selection of a water source include the following:

a. Purity of the source.

b. Proximity of the source to the community

c. Altitude of source above service connections

d. Temperature variations of water from the source.

Guide to choosing a source:

a. First choice, a source that

- requires no treatment
- uses gravity for distribution energy
- requires minimum maintenance
- is cheap to develop
- e.g. springs

b. Second choice, that which

- require no treatment
- but must be pumped out and into the supply lines.
- e.g. wells.

c. Third choice that which

- requires simple treatment
- uses gravity for distribution energy
- e.g. catchment cisterns.

d. Fourth choice, that which

- requires simple treatment
- must be pumped
- e.g. rivers

PROPOSED SYSTEM

SELECTING SITES FOR THE SYSTEM'S FACILITIES

1. Source - must be near to the community (see above).
2. Pump station - should be above the highest probable flood level; or be suitably protected against flood.
   - should be accessible at all times
   - should be large enough to meet future expansion.
   - should have suitable topography
   - should be well protected from possible sabotage-e.g. by en sing it within an industrial type wire fence with a locked gate.
3. Storage Tanks - should be centrally located
   - if possible, should be put on the highest ground in the area.

PUMP SELECTION

The most important considerations in selecting a pump are:

1. The skill of the operators and maintenance men available
2. The initial cost of pump and driving equipment
3. The cost of operation and maintenance
4. The capacity and lift required
5. Availability of power to operate the pump
6. The sanitary features of the pumps available commercially.
7. Type of source in which the pump is to be installed; including the depth of static water level from ground surface.
8. Reliability of equipment, and availability of spare parts.

The following is a general guide to the selection of pumps for rural water-supply systems:

1. Structure of the pump

   a. All movable parts above ground and easily accessible are easy to maintain. Suitable for areas with no skilled maintenance man.
   b. If skilled maintenance men are available, first choice should be pumps with submerged cylinders.

2. Type of power available; Power-driven pumps must be of high efficiency to reduce the cost of power.

3. Design of the pump: The pump design should be flexible enough to be used in a wide range of sources. There are some pumps which must operate under the conditions for which they were designed, e.g. deep-well turbine and centrifugal pumps.

4. Repairs: The selected pump must be of a type for which repair and replacement parts are easily obtainable.

5. Sanitary Standards: The pump and equipment must be constructed as to prevent contamination of water either at source or enroute to storage. Specific sanitary conditons to be considered:

   a. Pump head should be designed to prevent contamination from environment from reaching the water-chamber of the pump
   b. The base should be waterproof.
   c. The pump should not need priming

Information required when ordering or inquiring about a pump.

1. The inside diameter of hole or casing in which the pump is to be installed.

2. The static level of water in well, measured from ground level.

3. The desired output in gallons per minute.

TABLE: 5 : ADVANTAGES AND DISADVANTAGES OF VARIOUS TYPES OF PUMPS

| | POSITIVE DISPLACEMENT | | | VELOCITY | | |
|---|---|---|---|---|---|---|
| Types pumps | hand plunger type | motor, wind driven, plunger type | chain or continuous bucket | centrifugal | deep-well turbine | jet |
| Usual well pumping depth (ft) | 22-25 ft shallow well; up to 600 deep well | 22-25 ft shallow well; up to 600 deep well | Depends on valve being lifted and type of power | 10-20 ft | 50-300 ft | 15-20 ft below ejector |
| Capacity Gallons/ Minute | 3-15 | 10-25 | 4-20 | Very wide range: 2 to unlimited | Very wide range: 25-5,000 | 5-125 |
| Efficiency range (%) | Low; can be improved with double-acting cylinders; 25%-60% | Low; can be improved with double-acting cylinders; 25%-60% | Low | Good: 50%-85% | Good: 65%-80% | Low: 40%-60% |
| Operation | Very Simple | Simple | Very Simple | Simple | More difficult; needs attention | Simple; air locks can cause trouble |
| Maintenance | Simple, but valves and plunger require attention; more difficult when pump cylinder is in the well | Same as hand pump; maintenance of motors sometimes difficult in rural areas | Simple | Simple, but attention is necessary | More difficult and constant; skilled attention is necessary | Simple, but attention is necessary |
| Cost | Low, but higher when cylinder is in the well | Low, but higher when cylinder is in the well | Reasonable | Reasonable | Higher, especially in deep wells | Reasonable |

TABLE 5 (Con[illegible]ANTAGES AND DISADVANTAGES OF VARIOUS TYPES OF PUMPS

| | POSITIVE DISPLACEMENT | | | VELOCITY | | |
|---|---|---|---|---|---|---|
| Types of pumps | hand pumps, plunger type | motor, wind driven, plunger type | chain or continuous bucket | centrifugal | deep-well turbine | jet |
| Power | Hand or animal | Wind, motor | Hand, animal, wind, motor | Motor | Motor | Motor |
| Advantages | Low speed; easily understood by unskilled people; low cost | Low cost; simple; low speed | Simple; easy to operate and maintain | Efficient; wide range of capacity and head | Good for small-diameter boreholes; ease of operation | Moving parts on surface; ease of operation |
| Disadvantages | Low efficiency; limited use; maintenance more difficult when cylinder is in the well | Low efficiency; limited use; maintenance more difficult when cylinder is in the well | Low efficiency; limited use | Moving parts and packing require attention | Moving parts in well; rather expensive; requires good maintenance and operation | Limited application; low efficiency; moving parts require attention |

4. The lowest water level expected during pumping.

5. The desired water pressure at ground level.

6. The type of power available (If electric, specify voltage, phase, frequency, etc.)

7. The total depth and nature of source.

PUMPS AND PIPES

Generally, pump size determines appropriate pipe sizes, and vice versa.

Pumps

The types most commonly used in small community water systems are:

1. Hand-or power-operated reciprocating pumps with the cylinder above the ground.

2. Power-operated centrifugal pumps with pump mechanism above ground.

3. Hand-power-, or wind-operated reciprocating deep-well pumps, with cylinder in the well.

4. Deep-well turbine pumps driven either from the surface or from a submersible electric motor.

5. Jet pumps, power-driven at surface.

6. Hydraulic rams

7. Air-lift pump, operated by power-driven compressor on the surface.

Classification of pumps (see Table 5)

1. Displacement
   a) Reciprocating
   b) Rotary
   c) Chain

2. Velocity
   a) Centrifugal
   b) Jet

3. Airlift

4. Hydraulic rams

Where various pumps are used:

1. Reciprocating plunger - in wells mainly. The most commonly used pump.

2. Semi-rotary pumps - for low lift - e.g. from wells and cisterns to overhead tanks.

3. Rope-and-bucket systems - in open dug wells. Either hand or windless operated.

4. Chain-bucket pump - in open dug wells.

5. Chain-and-plug bucket.

6. Multicellular band pump.

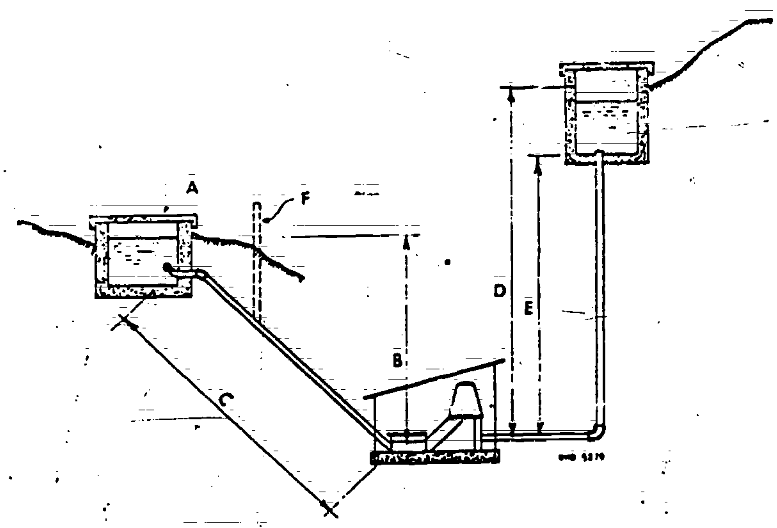
7. Centrifugal pump - in deep wells.

8. Jet pump - in deep wells.

9. Airlift pumps - in drilled wells and wells with irregular sides, also for pumping muddy water.

10. Hydraulic Rams - in springs, streams and rivers.

Examples of various pumps.



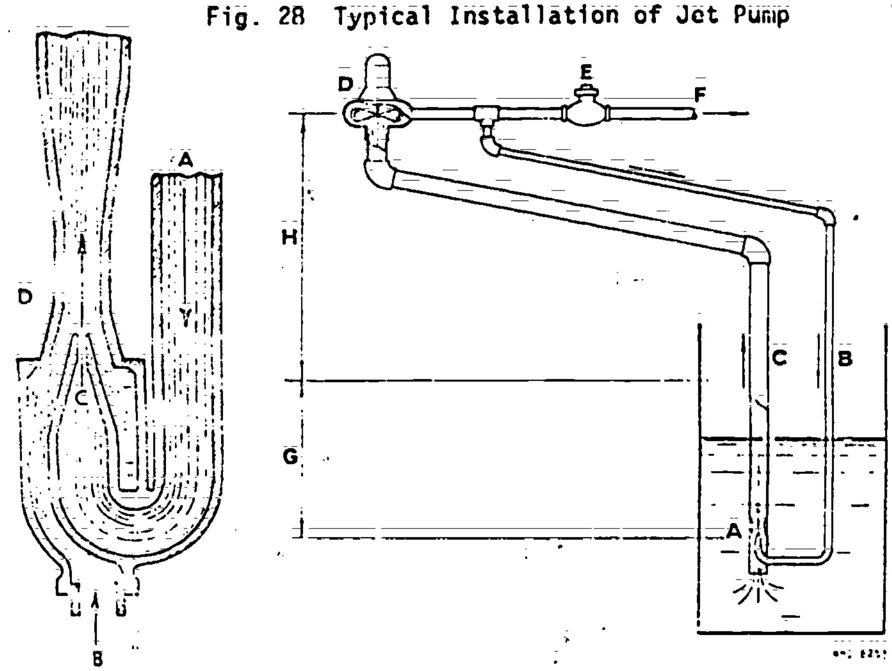

A = Supply—litres/minute.
B = Difference in elevation between ram and supply-power head
C = Length of drive pipe
D = Difference in elevation between ram and highest point to which water is to be elevated—pumping head
E = Total length of supply pipe
F = Stand-pipe, necessary in case of exceedingly long drive pipe

Under the proper circumstances—a situation similar to that shown, in which the supply of water is considerably in excess of the needs, and is situated so that the ram can be located well below the supply—the hydraulic ram can be an excellent solution to a pumping problem.

When writing to manufacturers about ram sizes, the information in items A, B, C, D, and E is necessary. With this the factory will be able to recommend the correct size, feasibility, etc.

Fig. 27 Hydraulic Ram

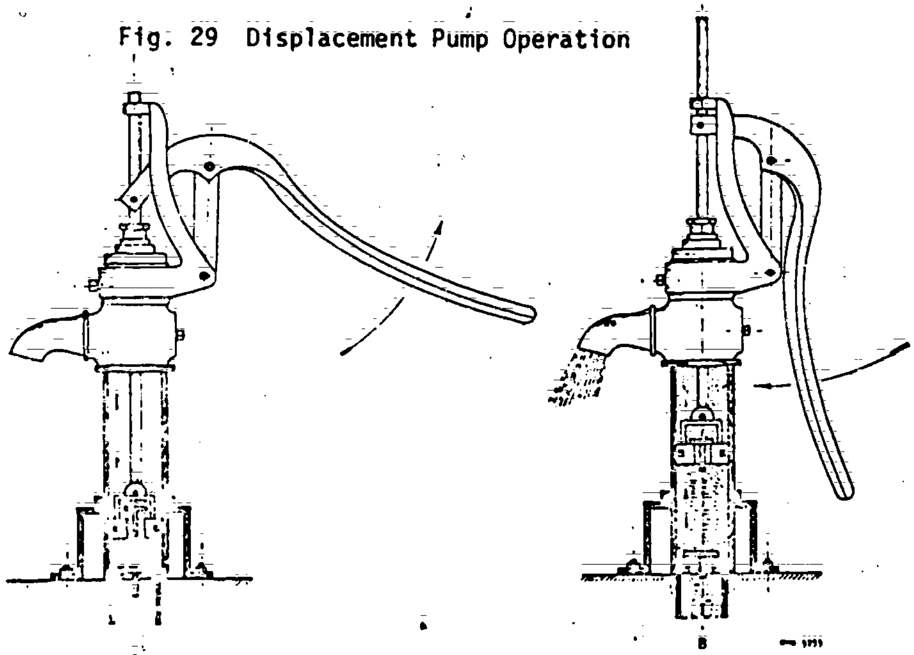
Fig. 28 Typical Installation of Jet Pump



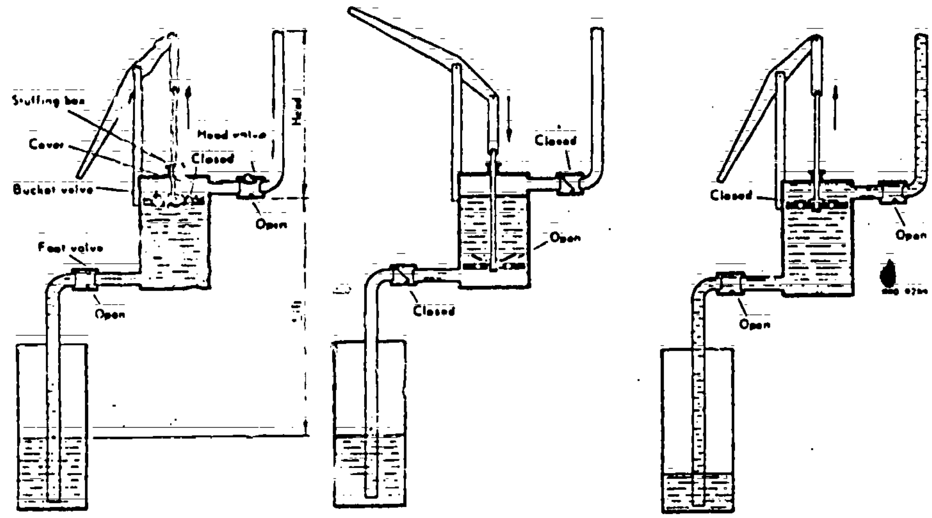

A - Water being returned from pump above
B - Water from well being sucked up into throat (D) by high-velocity discharge (C)

A = Jet assembly
B = Water line from pump to nozzle
C = Rising water
D = Centrifugal pump
E -- Pressure-regulating valve
F -- Discharge pipe
G Height of water pushed by jet
H Suction by centrifugal pump (about 4.5-6 m, or 15-20 ft)

Fig. 29 Displacement Pump Operation




A = Down-stroke: Cylinder above plunger fills while valve at base of cylinder closes, and valve in plunger opens.
B = Upstroke: Cylinder full of water above plunger is expelled while, at the same time, valve at base of pump opens, filling cylinder below plunger. As plunger rises, a vacuum is formed below, pulling water into the cylinder.
When the cylinder is above ground, a foot valve is necessary to avoid priming.




Adapted by kind permission from Gr..am, F. D. & Emery, T. J. (1942) *Audel's Plumbers' and steam fitters' guide*, No 1, New York, p. 2748.

Fig. 30 Elementary, Single Acting Force Pump

In addition to the foot and bucket valves of the lift pump, a head valve is provided.

In operation, during the up-stroke, atmospheric pressure forces water into the cylinder; during the down-stroke, this water is transferred from the lower to the upper side of the piston.

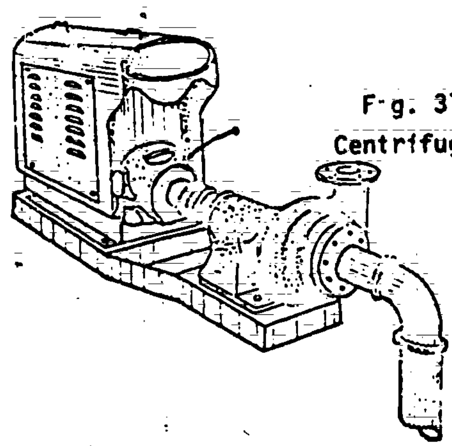
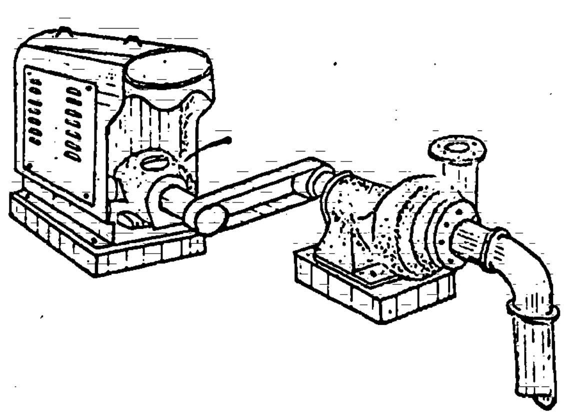


Fig. 31
Centrifugal Pumps



This is the best and simplest arrangement for centrifugal pumps. Power unit may be electric motor or internal combustion engine.

Belt-driven centrifugal pumps are common but introduce belt maintenance. Necessary in order to get the correct engine-pump speed ratio.

The manufacturers' recommendations for operation and maintenance should be followed.

3. Choose a pipe size, so that velocity through it will be about 6 feet per second.

4. Estimate the pipe friction loss "head" (10 foot "head" represents the pressure at the bottom of a 10 foot high column of water) for both suction and discharge piping, using the following table.

TABLE 6 Average friction loss for water flowing through pipe when velocity is 6 ft./second.

| Pipe inside diameter | 1" | 2" | 3" | 4" | 6" | 8" | 12" | 24" |
|---|---|---|---|---|---|---|---|---|
| F = approximate friction head (ft.) per 100 ft. pipe | 16 | 7 | 5 | 3 | 2 | 1 1/2 | 1 | 1/2 |

$$\text{Friction Loss Head} = \frac{F \times \text{length of pipe}}{100}$$

Any bends, valves, constrictions, and enlargements (such as passing through a tank) add to friction. The equivalent pipe length of such "fittings" in the pipe line should be added to the pipe length used in the friction loss equation.

5. Obtain "Total Head" as follows:

Total Head = height of lift + friction loss head.

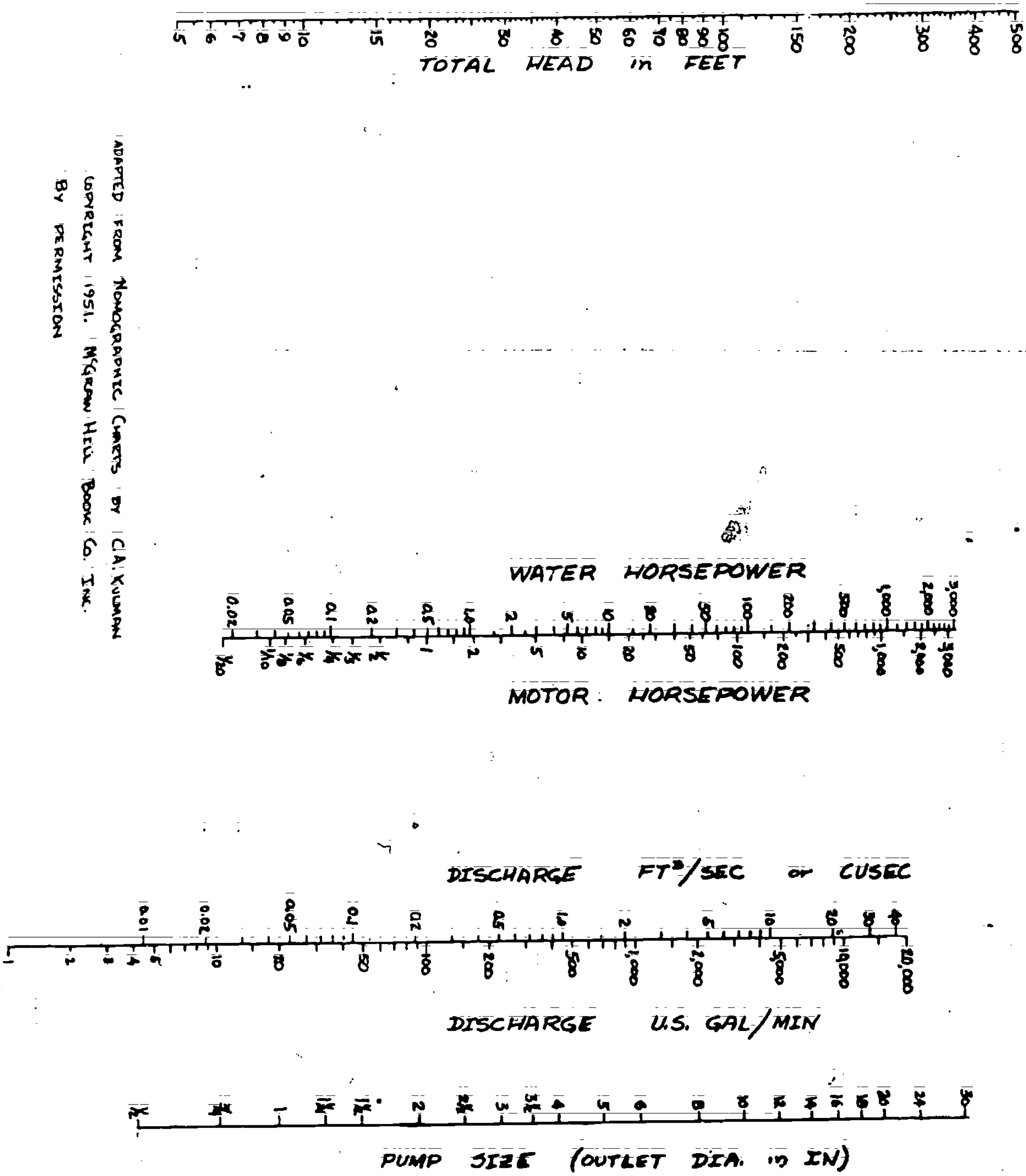
Using a straight edge connect the proper point on the "Total Head (ft.)" line with the proper point of the "Discharge U.S. gallon/minute" line. Read motor horsepower and pump size (diameter of discharge outlet), choosing the printed values just above the straight edge.

Note that water horsepower is less than motor horsepower. This is because of friction losses in the pump and motor. The nomograph should be used for rough estimate only. For an exact determination give all information on the flow and piping to the pump manufacturer. He has the exact data on his pump for various applications. Pump specifications can be tricky especially if suction piping is long and the suction lift is great.

Example:

Desired - to pump 100 gallons/minute 50 feet high, no fittings
Pipe Size - 3" (for 6 feet/second)
reference: Handbook entry "Velocity of Water in Pipes"
Friction loss head - about 3 feet.
Total head - 53 feet.
Pump size - 2"
Motor horsepower - 3 H.P.

Fig. 32




PUMP SIZE AND HORSEPOWER REQUIREMENT

ADAPTED FROM NOMOGRAPHIC CHARTS BY C.A. KULMAN
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If you plan to use human power for the pump, figure that a man can generate about 0.1 H.P. for a reasonably long period and 0.4 H.P. for short bursts. From this and the total head, you can predict the flow you should design the hand pump for.

Pipes

Most commonly used pipes are made of:

a. Galvanized wrought-iron and cast iron
b. Asbestos
c. Transite (mixture of cement and asbestos fiber)
d. Lead
e. Copper
f. Plastic
g. Bamboo stems and other related tropical plants
h. Wood-stave, made out of light wood

Measuring diameters: The diameter of a pipe is determined by measuring the inside diameter.

## FINANCING THE PROJECT

The stock reply to questions about financing is that the country, state, province, or community concerned is too poor to afford the cost of needed improvements. Upon investigation, however, it often turns out that public money is being spent for projects which are of much less importance and which cannot possibly give the same returns as those obtained when the same amount of funds is invested in the construction of public water-supplies. There is usually a way to obtain long-range financing for rural water-supply programs if the individuals concerned with the problem will look far enough for a good case to present to their legislators or to financial institutions. Long-range plans have been effective in many countries throughout the world, both in the Western and Eastern Hemispheres. Most of them are the result of the work of a few people who have succeeded after painstaking efforts, in convincing the right government or bank of the importance of sanitation work.

In almost all successful programs, federal or central governments have shouldered the responsibility for financing the construction of small rural water projects. In many cases this decision will have been made by the time you begin. Because of the lack of credit on the part of most rural towns and villages and the absence of a system of financing public works through direct loans from private banking institutions, the central government must usually fill the role of provider of funds. In some places the states or provinces co-operate. In many countries, the normal pattern is for the central government to loan the necessary funds directly to a local community at a low rate of interest or to make a partial grant, with the community and state jointly, supplying the remainder. Loans or grants are made on the basis of projects presented through proper channels for approval by state or federal engineers. A sanitary engineering section in a central health department would be qualified and might be available to provide this technical service to rural communities.

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# PLANNING THE DISTRIBUTION SYSTEMS

## LESSON NO. 1

LESSON OBJECTIVE: To determine existing facilities which may be useful as part of the planned system.

| TOPIC | INSTRUCTIONAL PROCEDURE | SUPPLEMENTAL MATERIALS RELATED READING |
|---|---|---|
| Water Sources | Lecture on various types of possible water sources and their characteristics. | Pictures of various sources. Chart on characteristics of source |
| | Show how to use tables in determining the yield of a source. | Water sources, floats, current meters, weirs. tables on yield. |
| | Demonstrate how to measure velocity of water. | Individual Water Supply Systems, p. 24-52. |
| Pumps | Ask students the conditions under which a pump is necessary to distribute water. | Models of pumps. Photographs and/or drawings of pumps. |
| | Briefly mention pumps used in large systems (stress it is not the concern now). | Chart giving characteristics of pumps. WHO Monograph Series #42, Chapter 4. |
| | Lecture on the characteristic features of pumps most often used in Rural Water Supply. | |
| Pipes | Ask students to name materials most commonly used for pipes. | Samples of pipes from various materials, measuring scales & gauges |
| | Add local materials omitted by the students. | |
| | Demonstrate how to measure pipe diameters. | |
| Geographic Locations | Show general areas where the Peace Corps will go. | World Map<br>Atlas of climatic regions of the world, showing: relief, vegetation, seasonal rainfall and temperature distributions. |

PLANNING THE DISTRIBUTION SYSTEM
Lesson No. 1 (Continued)

| | | |
|---|---|---|
| | Lecture on climate of each region.<br><br>Discuss in class possible hindrances to construction work.<br><br>Group them on the board under causatives. | |
| Local Materials | Lecture on trade-off values; e.g., quality vs. expenses to achieve convenience.<br><br>Discuss in class the materials which can be adapted to suit an improved distribution system. | |

# PLANNING THE DISTRIBUTION SYSTEMS

## LESSON NO. 2

LESSON OBJECTIVE: To choose the most suitable source for development and select a suitable site for the system facilities.

| TOPIC | INSTRUCTIONAL PROCEDURE | SUPPLEMENTAL MATERIALS RELATED READING |
|---|---|---|
| Selecting Water Source | Discuss the possible combination of characters a source can have. | Section on Sources. |
| | Let each student draw the characteristics of the source he would choose first. | |
| | Discuss the feasibility of each proposal. | |
| | Formulate a guide to quick choices. | WHO Monograph Series #42 pp. 34-35. |
| lecting the te | Discuss the importance of proper locations of facility sites. | Suggested Design Criteri for Waterworks in Recreational Areas, Sections 2.4 and 9.3. |
| | Draw a guide to site selection. | |

PLANNING THE DISTRIBUTION SYSTEMS

LESSON NO. 3

LESSON OBJECTIVE: To select pumping equipment most suited for use in rural areas.

| TOPIC | INSTRUCTIONAL PROCEDURE | SUPPLEMENTAL MATERIALS / RELATED READING |
|---|---|---|
| Characteristics of Pumps | Ask students to recall characteristics of pumps.<br><br>Discuss with students what would be the best guide criteria for choosing a pump. | Section on characteristics of pumps.<br><br>Pumps and/or pump models. |

PLANNING THE DISTRIBUTION SYSTEMS

LESSON NO. 4

SSON OBJECTIVE: To describe the community to be served; specifically, the aspects that affect the plan.

| TOPIC | INSTRUCTIONAL PROCEDURE | SUPPLEMENTAL MATERIALS RELATED READING |
| --- | --- | --- |
| lation | Lecture on how to estimate the population of a community. | |
| | Show how to calculate projected population and relationship between population and demand. | WHO Monograph Series #42, p. 42-43. |
| itions and l Structure | Discuss the importance of long established traditions. | |
| | Discuss what traditions are likely to clash with the planned system and how to avoid such a clash. | |
| ic Standard | Discuss the connection between occupation and water demands. | |
| | Relate type of houses to distribution systems. | |
| | Compare availability of skilled labor in U.S. to underdeveloped countries. | |
| | Discuss how to select workers for the project. | |

PLANNING THE DISTRIBUTION SYSTEMS

LESSON NO. 5

LESSON OBJECTIVE: To prepare a chart projecting expected costs of material and labor. Estimate the required amou money and how to raise the money.

| TOPIC | INSTRUCTIONAL PROCEDURE |
|---|---|
| Cost | Discuss how to estimate the cost of the project. |
| Financing | Discuss various methods. |

## SECTION 4

## CHARACTERISTICS OF AN ADEQUATE SYSTEM

OVERVIEW:

There are many technical problems and factors to be considered in the design of a distribution system. The layout of the system, the sizes of the pipes, the loss of pressure, and many other factors must be considered in the actual planning of the system.

This section provides the trainee with an understanding of the characteristics of an adequate system. With this understanding he will be able to plan the technical aspects of the project and avoid mistakes in the construction phase of the program.

SECTION 4: CHARACTERISTICS OF AN ADEQUATE SYSTEM

OBJECTIVE: Define and evolve a detailed plan for the construction of the basic components in an adequate system.

TASKS:

1. Draw to scale the plan and profile illustrating the relative locations of the component parts of the system.

2. Prepare a detailed account of the characteristics of the chosen source, and state how it is to be developed.

3. Analyze data (collected in Section I) and decide what type of treatment processes are required.

4. Describe how water will be transferred from the source to treatment plant or distribution reservoirs, and the sanitary precautions to be taken.

5. Describe the safety precautions to be taken during the construction and operation of the treatment plant; i.e., to avoid recontamination and protect personnel.

6. Determine the storage requirement for the system.

7. Based on the location of the tank, select the material(s) to be used in its construction.

8. Identify sanitary and servicing provisions to be followed in constructing the storage tank.

9. Decide which system of distribution best suits the community.

10. Determine the required pressures at service connections and design the pipes and joints for distributing.

11. Prepare a map of the distribution pipes and [illegible]

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CHARACTERISTICS OF AN ADEQUATE SYSTEM (cont)

FUNCTIONAL SKILLS:

1. Recall the essential components of an adequate system.

2. Draw topographic, plan, and elevation maps. List data which should be included on a topographic map of an adequate distribution system. Measure elevation of points.

3. Identify safe water.

4. Recall functions of component parts of a treatment plant. Use high and low lift pumps. Describe and evaluate the various treatment processes described in Section 2.

5. Recall relationship between distribution systems and various community patterns.

6. Calculate required head, headloss. Read from tables the relationships between pipe sizes, pipe joints, and headloss.

7. Recall relationship between different pumping facilities and size of community.

8. Identify the relevant structural properties of materials.

9. Identify properties of coating paints.

10. Recall safety standards to be maintained in the construction and operation of a system.

TERMINAL PERFORMANCE TESTS:

1. For a given community layout, design a distribution system which best suits it, and draw to scale the plan and profile showing the locations of the various component parts of the water distribution system, pipe lengths and size, and valve locations along the line.

2. Given a number of water samples, identify those defined as "safe".

3. In a given treatment system, state in detail what happens as the water passes through the successive stages.

CHARACTERISTICS OF AN ADEQUATE SYSTEM (cont.)

4. Given a source and treatment plant, and/or distribution reservoir some distance apart, list all sanitary precautions which should be taken while transferring the water.

5. List all sanitary and personnel safety provisions to be taken into consideration while planning the construction and operation of a treatment plant.

6. Choose the appropriate materials for constructing storage tanks,

   a. underground
   b. on the ground
   c. above the ground

7. Determine the difference in height between a given storage plant and service connection, and calculate the required head and headloss in the section.

8. From given tables, choose pipe sizes that will deliver water with a specified residual pressure at a service connection distance ( ) units away.

# WATER DISTRIBUTION SYSTEMS

## CHARACTERISTICS OF AN ADEQUATE SYSTEM

### ESSENTIAL COMPONENTS OF AN ADEQUATE SYSTEM

#### SOURCE

The source of water for the distribution system must meet the requirements that have been established for quantity and quality. The source will meet the quantity requirement by simply being able to provide enough water to meet the demand. If no single source can satisfy this requirement, the construction of storage tanks and/or reservoirs can be built to compensate for this deficiency. The quality requirements for drinking water are generally established by local or national health departments. (If none exist, you should review the minimum standards for drinking water discussed in Section 2) If no satisfactory water sources exist, you should carefully consider the construction of wells before choosing a source that would require extensive treatment. Although the distribution of water from a central source by means of pipes to each village house is a goal towards which every community should strive, the construction of wells (if necessary) would be an incomplete, but very satisfactory step toward that goal.

Once satisfactory water has been located, it is essential that care be taken not to contaminate the water during its distribution. To insure the preservation of potable water, the following protective measures should be taken:

1. Wells and pump bases should be sealed so that surface water is unable to enter the well;

2. Water used to prime pumps must not be polluted (when possible use pumps that do not need priming).

3. Only trained workers should be responsible for maintaining the system once it has been built. (Initially, care should be taken to select workers who are healthy and free from communicable diseases).

#### TREATMENT FACILITIES

In selecting a water source, the goal is one needing no chemical treatment (other than disinfection) prior to use. As stated earlier. if no such source already exists, explore the possibility of a well construction program.* When an acceptable-but-less-than desirable source is the only alternative, a treatment plant will need to be part of the distribution system. The purpose of the plant will be to upgrade the quality of water that does not meet drinking water standards. The methods for evaluating water and selecting treatment processes is discussed in Section 2.

* For further information refer to the Peace Corps training manual on the Construction of Water Wells

DISTRIBUTION RESERVOIR

In small distribution systems, whether the water is obtained by gravity or by pumping, it is always desirable to provide a distribution reservoir. The main reasons are:

1. Hourly variations in the rate of consumption are more easily satisfied (in small systems, such variations may be three times the average hourly consumption and sometimes more);
2. Adequate pressure can be maintained throughout the distribution system;
3. Adduction pipes between the source of supply and the reservoir may be repaired without interruption of the village water service.
4. Provisions may be made for fire protection.
5. Pumps can be operated uniformly throughout the day. (Such pumps may be much smaller than would be required otherwise).
6. The size of the adduction pipe between the supply source and the reservoir can be made smaller than would be necessary if the village were fed directly from the water source.
7. Fluctuations in peak periods of demand can be more easily observed and compensated for when all water is drawn from a distribution reservoir.

The first consideration when designing storage is the capacity which will be provided. This to a great extent depends on the type of supply, and is influenced by two main factors--the necessity of catering for peak demand periods, and the provision of reserve to cover normal breakdown or maintenance interruptions.

Conditions vary in different parts of the world, but a typical pattern of draw-off in a village is as follows--30% of the day's supply between 7 a.m. and 8 a.m.; 30% between 5 p.m. and 6:30 p.m.; 35% during the other hours of daylight; and 5% between sunset and sunrise. Local custome will produce local variations; for instance, in Moslem countries the demand during Ramadan will be high at about 3 am., and in other parts of the world where Monday is the traditional "wash-day" the Monday morning draw-off may be equivalent to the total supply of another day. These considerations must be taken into account when assessing the extent and duration of peak draw-offs; this must then be balanced against the rate and periods of water delivery.

When water is supplied by gravity from the source it is most economical in cost, as well as most satisfactory from an operational aspect, if a constant flow is maintained throughout the twenty four hours. Obviously in such a method of working a smaller delivery main is needed than if larger quantities are required in shorter periods. When electricity is used for pumping it is usually most economical to operate for about twenty hours a day, leaving the pumps idle during the peak hours of electricity demand. With diesel- or gasoline-driven pumps, the cost of attendance (generally continuous with such engines, but normally unnecessary with electric motors) becomes an important factor and one shift of eight hours, or two totalling 16 hours, is a frequent method of operation.

It is quite common to find schemes designed to operate with a single shift of 8 hours initially, increasing to 16 hours when the demand rises later. More than 16 hours a day is not desirable with such engines; not only do labor costs increase but the wear on machinery working continuously throughout the day and night becomes excessive and the life of the plant is correspondingly shortened.

To determine the amount of storage that will be required to provide uniform serice throughout the day, you must estimate three factors:

1. the hourly consumption throughout the day (measured in gallons)
2. the proposed hours of pumping (as explained above, this is determined by the type of equipment available)
3. the pumping capacity of the system (gallons per hour).

GENERAL REQUIREMENTS FOR AN ADEQUATE SYSTEM

An adequate system is one which will deliver the required amount of potable, palatable water to all outlets at a prescribed or satisfactory pressure.

MAPPING THE PROPOSED SYSTEM

A drawing or map and a profile of the distribution system should be made showing the location of each component in relation to others (see Section 1 on drawing topographic maps). Below are a number of ways that the distribution system layout can be illustrated.

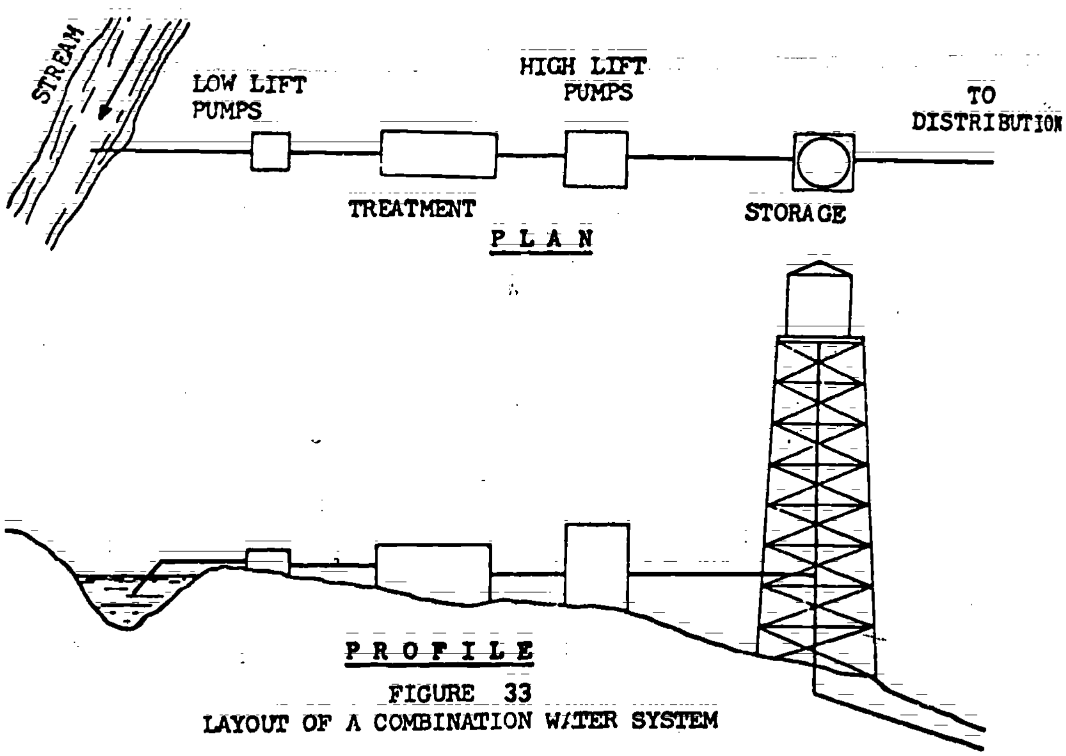



FIGURE 33
LAYOUT OF A COMBINATION WATER SYSTEM

SYSTEM CAPACITY

Once these factors have been determined, the storage capacity can be determined. The following guidelines should be considered in arriving at adequate storage capacity:

1. As a rule-of-thumb, the storage required should be approximately equal to a days consumption of water.
2. Minimum capacity should be large enough to handle morning and afternoon peaks. In no case should it be less than half a day's supply.
3. If it is not possible to store a day's requirement, long periods of pumping should be adopted with no interruptions.
4. Where possible, ground storage is preferable.

PIPES

In selecting pipes, the following suggestions should be followed:

1. The velocity of flow of water should not be more than 6 ft. per second in main pipes; and 3 ft. per second in feeder pipes.
2. Pipe sizes for mains must be at least 2 inches in diameter.
3. Using the nomograph attached, determine the pipe size which will deliver water at a desired rate.

Pipe Flow Calculation

This chart helps determine the flow of water from several sizes of pipe when you know the height of the water source.

The nomograph applies to steel pipe. Fig. 34 should be used to find the equivalent pipe length. The length of pipe run can be paced off. One can crudely sight with their eyes and attempt measuring the reservoir height. To make this measurement with any accuracy requires some type of surveyor's instrument.

To use the nomograph, first find the number of pipe diameters there are in the pipe lengths. This is accomplished by dividing the pipe diameter in inches into 12 x pipe lengths in feet; or divide the pipe diameter in centimeters into 100 x the pipe length in meters.

Then with the straight edge connect the pipe diameter on the d scale in inches (1 inch = 2.54 cm) with the reservoir height in feet on the h scale. Mark on the index scale where the straight edge crosses. Now connect this point on the index with the number of pipe diameters in the pipe length as calculated and observe the reading on the Q scale. This will be the discharge in gallons per minute.

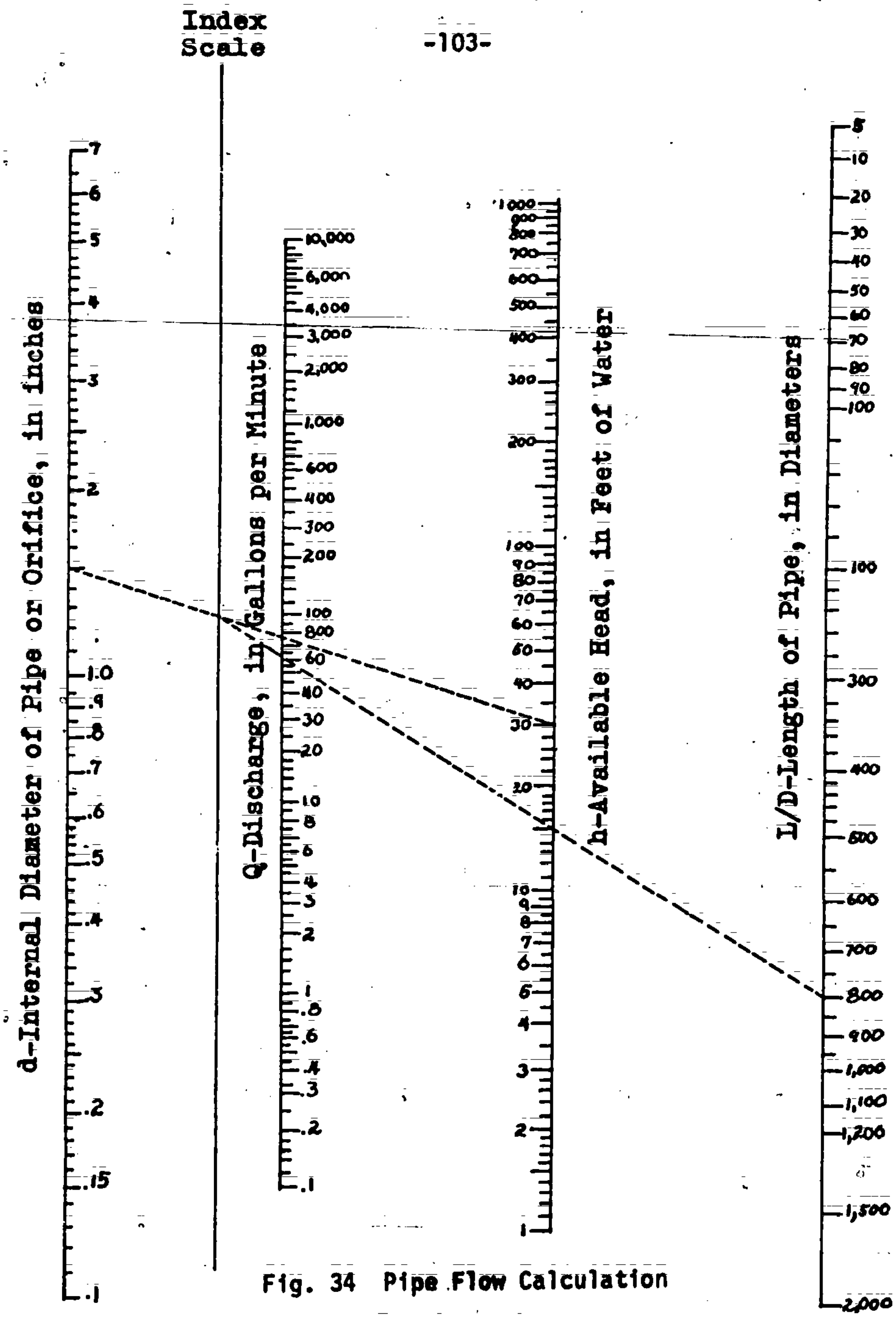



Fig. 34 Pipe Flow Calculation

Pump Size and Horsepower Requirement

For preliminary sizing of a pump used to lift liquid to a known height through simple piping, follow these steps:

1. Determine the quantity of flow desired in gallons per minute. 8.33 pounds = 1 gallon.

2. Measure the height of the lift required (from the point where the water enters the pump suction piping to where it discharges.)

Example:

Assume a reservoir height of 30 feet, a pipe size of 1 1/2" diameter and 100 feet in pipe length, what will the discharge rate be?

First divide the length by the diameter each in inches

$$\frac{1200}{1.5} = 800$$

now convert 1.5 on the d scale with 30 feet on the h scale and make a mark on the index scale. Connect this mark with 800 on the L/D scale and read the flow as 60 gallons per minute on the Q scale.

## Headloss Calculation

How to compensate for the headlosses due to pipe fittings: Express in terms of the equivalent to the length and size of pipe which would produce an equivalent loss if, instead of adding fittings, additional pipe was added. Note in table below that headloss due to pipe fittings can be neglected for relatively long pipes.

TABLE 7

Allowance in equivalent length of pipe for friction loss in valves and threaded fittings

| Diameter of fitting | 90° std. ell | 45° std. ell | 90° side tee | Coupling or straight run | Gate valve | Globe valve | Angle valve |
|---|---|---|---|---|---|---|---|
| *Inches* | *Feet* | *Feet* | *Feet* | *Feet* | *Feet* | *Feet* | *Feet* |
| 3/8 | 1 | 0.6 | 1.5 | 0.3 | 0.2 | 8 | 4 |
| 1/2 | 2 | 1.2 | 3 | 0.6 | 0.4 | 15 | 8 |
| 3/4 | 2.5 | 1.5 | 4 | 0.8 | 0.5 | 20 | 12 |
| 1 | 3 | 1.8 | 5 | 0.9 | 0.6 | 25 | 15 |
| 1 1/4 | 4 | 2.4 | 6 | 1.2 | 0.8 | 35 | 18 |
| 1 1/2 | 5 | 3 | 7 | 1.5 | 1.0 | 45 | 22 |
| 2 | 7 | 4 | 10 | 2 | 1.3 | 55 | 28 |
| 2 1/2 | 8 | 5 | 12 | 2.5 | 1.6 | 65 | 34 |
| 3 | 10 | 6 | 15 | 3 | 2 | 80 | 40 |
| 3 1/2 | 12 | 7 | 18 | 3.6 | 2.4 | 100 | 50 |
| 4 | 14 | 8 | 21 | 4 | 2.7 | 125 | 55 |
| 5 | 17 | 10 | 25 | 5 | 3.3 | 140 | 70 |
| 6 | 20 | 12 | 30 | 6 | 4 | 165 | 80 |

## RELATIONSHIP OF DISTRIBUTION SYSTEM TO COMMUNITY

### ARRANGEMENT OF THE NETWORK

There are two main systems of distributing water in a community:

Dead-end System

This consists of direct lines from the mains to the outlet without inter-connected lines (see Fig.35 ).

Evaluation:
1. Easy to install
2. Takes less material for pipes
3. Best for small, unplanned community layout.
4. Disadvantage: If water not used often may breed bacterial at the stagnant end.

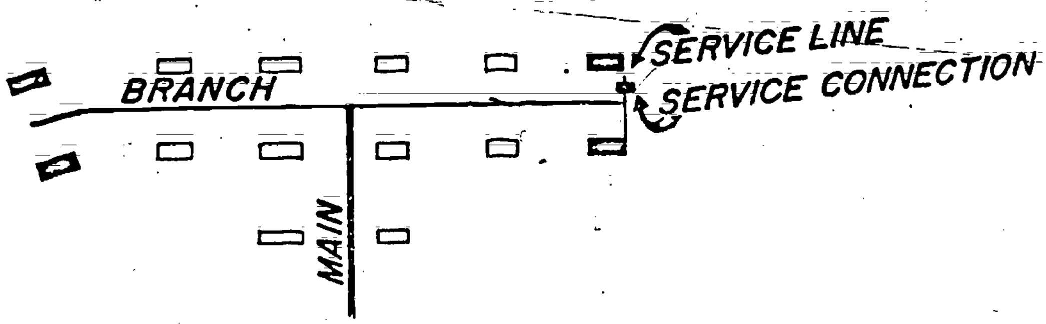



Fig. 35 Dead-End System

Loop System

In this, the ends of all the supply lines are connected so there is continuous flow of water in the system while it is being drawn from any point in the loop (see fig.36 )

Evaluation
1. No stagnant water
2. Less vulnerable to breakdowns since valve arrangements may be made to re-route the flow of water, isolating small trouble areas.
3. Suitable for well-planned community.

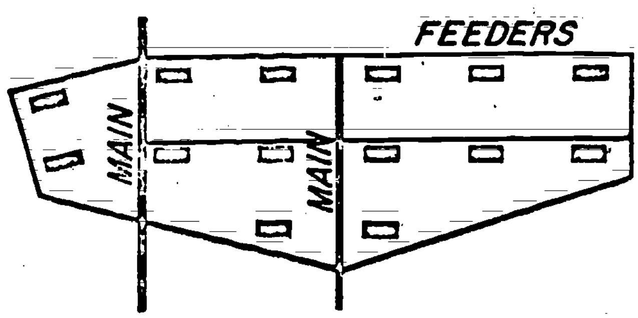



Fig. 36 Loop System

Generally, in a large community, the loop system can be used around main residential or business areas; and the dead-end system for the rest of the system

The network of pipes should be arranged so large primary mains feed smaller secondary pipes. Branches or feeders carry water from mains to service connections. Service pipes carry water from the branch to the building.

## HEADLOSS AND DISTRIBUTION SYSTEMS

### HEAD

In planning a distribution system it is desirable to draw water at a tap with a good pressure- not too high nor too low. Required head is the height (or depth) of water which is required to produce a given pressure. Pressures are expressed in pounds per square inch (psi) or in height units (ft.).

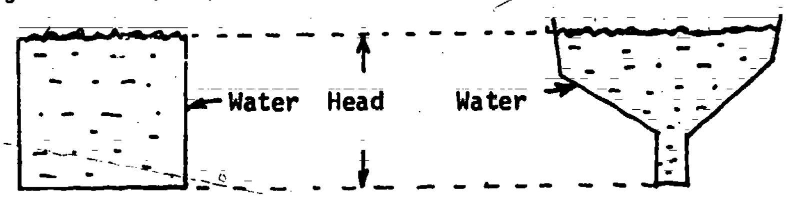



Fig. 37 Head Measurement

Relation of Pressure and head: from the definition of head and some hydraulic factors, it can be shown that 2.31 ft. of water exerts 1 psi at its base or 1 psi exerted at base of water solumn will raise it 2.31 ft.

Example: Calculate the pressure exerted by a column of water 100 ft at its base.

2.31 ft. exert 1 psi
100 ft. exert $\frac{1}{2.31}$ x 100 psi = <u>43.3 psi</u>

### HEADLOSS

This is the reduction of pressure in a pipe which may be due to friction in pipe and pipe fittings, or valves, and can be expressed as a change in head. Allowable headloss is the difference, in feet of water, between the tank elecation, and the elevation of service connection, plus the required head at the service connection. i.e. allowable headloss = Elev. tank - (elev. service connection + required head)

Example: Given elevation of tank = 750 ft.
elevation service conn. = 665 ft.
required head (-20 psi) = 46.2 ft.

allowable headloss = 750 - (665 + 46.2) = 38.8 ft. of head.

Note: The required head recommended by U.N. survey must be at least 10 psi (13.1 ft) for small water supply systems. For multi-storied houses, minimum should be 70 psi (91.7 ft). 20 psi (46.2 ft) is a reasonable figure to work with.

Actual headloss is the headloss which actually occurs in pipe and joints. It must not exceed the allowable headloss. The pipes and joints selected must have a total headloss less than the allowable headloss.

CHARACTERISTICS OF AN ADEQUATE SYSTEM

LESSON NO. 1

LESSON OBJECTIVE: To outline the general requirements for a system to be qualified as adequate.

| TOPIC | INSTRUCTIONAL PROCEDURE | SUPPL R |
|---|---|---|
| Definiti _ of an Adequate System | Discuss in class and draw out a definition of "an adequate system". | Secti |
| Component Parts: | Demonstrate how to draw the map and profile of a system. | Map c Secti |
| Relative Locations | As an exercise let each student draw the profile from a sample map. | Drawi |
| (a) Source and Pumping Facilities | Discuss the requirements for quality and quantity of water at source. | Secti |
| | Discuss the relationship between type of source and type of pump to be used. | Secti Pump |
| | Draw safety provisions required. | |
| (b) Treatment Plant | Discuss the need for water treatment. | Secti Treat |
| | Visit a treatment plant and note the relative location of treatment stages. | |
| | Compare safety requirements to that at source. | |
| (c) Storage | Discuss the need for storage facilities and how the storage capacity is related to the size and the community. | WHO M Chapt |
| | Discuss the various storage systems and the effect of location on them. | |
| | Ask students to outline what particular attention be paid to maintaining the quality of the water. | |

CHARACTERISTICS OF AN ADEQUATE SYSTEM

LESSON NO. 2

LESSON OBJECTIVE: To determine the relationship between the distribution system and headloss in the system; and design a distribution system suited to a given community.

| TOPIC | INSTRUCTIONAL PROCEDURE | SUPPLEMENTAL MATERIALS / RELATED READING |
|---|---|---|
| Definition of Headloss | Define head and headloss. | Water in tank Measuring Scale. |
| | Demonstrate how to measure head.<br>Show how to calculate headloss. | Chart of Headloss vs. Pipe Size. Tables of equivalent pipe lengths and valves and fittings. |
| Relationship Between Headloss and the Distribution Pipes | Demonstrate the effect of valves and threaded fittings on the water flow in a pipe.<br>Show how the above loss may be compensated for in the plan. | Elevated water source; long and short pipes, valves and joints. |
| Relationship Between the Community Layout and the Distribution System | Lecture on how to design a distribution system to fit a given community. | |

## SECTION 5

## CONSTRUCTION TECHNIQUES

OVERVIEW:

The preceding sections have covered the background knowledge that a trainee must have to recognize and evaluate sources of water and to plan the development of a distribution and treatment system. Regardless of the planning, a system is only as good as its construction allows. This section covers the techniques needed by the volunteer to adequately construct the system he has designed.

The emphasis of this instructional material is on doing. The trainee should learn by doing, for no amount of lecture can impart "how", it is only through doing that the trainee will be able to understand when, for example, concrete is wet enough.

This section covers construction with concrete, and specific projects for building and installing the major components of a treatment and distribution system.

SECTION 5: CONSTRUCTION TECHNIQUES

OBJECTIVE: Develop, purify and distribute water in a given community.

TASKS:

1. Develop the selected source to meet the requirements specified in the design.
2. Build an intake site and install intake pumping facilities.
3. Test the water so obtained for sanitary standards.
4. Build a treatment plant appropriate for treating water from the above developed source.
5. Construct a storage tank with a predetermined capacity; apply protective coatings on tank and pipes against heat, chemical corrosion and insect pests.
6. Lay and connect pipes for the conveyance of water from the distribution reservoirs (storage tank) to the various service connections.

FUNCTIONAL SKILLS:

1. Recall characteristics of various types of sources.
2. Dig, drill, and bore a well in such a way as to obtain maximum yield from it.*
3. Mix concrete of a desired strength.
4. Build protective casing for a well, spring, or pump base.*
5. Build a small pumphouse to specification.
6. Determine conditions which would require low or high lift-pumps for intake of water.
7. Build a screen of wire or other materials of desired mesh around an intake terminal in a pond, lake, stream, river or any other reservoir to keep out silt, water life and vegetation, and the stress from water flow.
8. Recognize relevant treatment processes for water from a given source.
9. Construct or assemble the various treatment processes such as, filters, sedimentation tanks, etc.

*This skill is optional, depending on the scope of the particular training program.

CONSTRUCTION TECHNIQUES (Cont.)

10. Connect various treatment stages in their proper order.

11. Read and follow an instruction manual.

12. Put together a prefabricated structure, using reinforced concrete, painting or spraying the needed parts, and welding, soldering or riveting pipes together.

TERMINAL PERFORMANCE TESTS:

1. At a given location develop a water source from underground water which will meet the water demand of the community.*

2. Given raw materials required to produce concrete, mix concrete of a specified strength and show it meets the specification.

3. For a given source, install an intake pump.

4. Given the plan and all materials, build a house over a well (or pump).

5. In a given distribution system, state where you would use:

   a. Low lift pump
   b. High lift pump

6. Design and build a model of an intake terminal of a system if the source is:

   a. Lake or pond
   b. River or stream
   c. Well or cistern

7. For a given source of water, carry out purity tests and state what kind of treatment the water requires.

8. Construct separately the various component parts of a treatment system and test the efficiency at the the various treatment stages.

9. Given a model treatment plant in the laboratory, assemble the various treatment units in order of performance (e.g., sedimentation-filtering).

*This skill is optional, depending on the scope of the particular training program.

CONSTRUCTION TECHNIQUES (cont.)

10. Given a package of all parts of a tank or pump (or the respective models) with an accompanying instruction manual, assemble the parts and test for proper fittings.

11. Given a storage tank and its gross weight, design a foundation for its elevation to a given height above the ground.

12. Construct a tank of specific volume with reinforced concrete.

13. Given a storage tank and distribution pipes, coat to protect them from:

    a. Corrosion from ground and atmospheric chemicals

    b. Excessive heat

    c. Insect and other pests.

14. In a workshop, join several pipe lengths using different methods at each joint, e.g. welding, riveting, etc.

## WATER DISTRIBUTION SYSTEMS

## CONSTRUCTION TECHNIQUES

### SCHEME

The following sketch shows the major components of a distribution system that must be planned and constructed. In total, this represents a complete water distribution system, indicating the location of each component relative to the others.

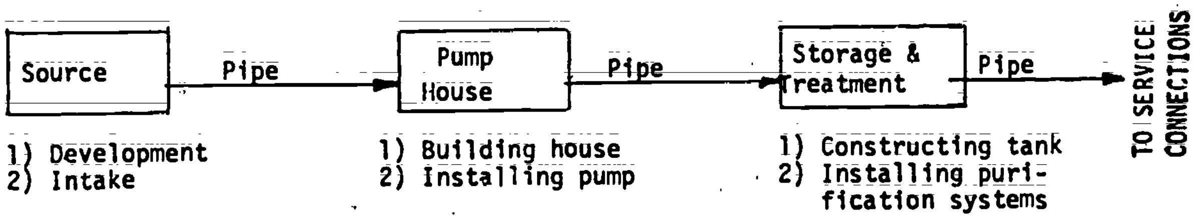



Fig. 38 Distribution System Layout

### CONCRETE

The material which is used at almost all stages is concrete. For this matter, an extensive description of concrete in construction work will be included for convenience.

Concrete is a strong, durable and inexpensive construction material when properly prepared. After concrete has set, there is no simple non-destructive tive test to evaluate how strong it is. Therefore, the entire responsibility for making concrete a strong material in accordance with specificaitons rests with the supervisor on the job and the people who prepare, measure and mix the ingredients, place them in the forms, and watch over the concrete while it hardens.

The most important factor in making strong concrete is the amount of water. Beginners are likely to have too much. See the entry on a slump cone for further details.

The proper proportion of all the materials, designed for the application, is essential. The concrete calculator will help give the proper proportions and amounts for your job.

Properly graded, clean, sharp aggregate and sand is required to make good concrete. When we glue two pieces of paper together, we spread the glue evenly and in a thin layer, and press firmly to eleminate air holes. In concrete, the cement is the glue, and the sand and aggregate the material being joined.

By properly graded we mean that there are not too many of any one size grains or pebbles. Visualize this by thinking of a large pile of stone all 1 1/2" in diameter. There would be spaces between these stones where smaller pebbles would fit. We could add to the pile just enough smaller stones to fill the largest voids. Now the voids would be smaller yet, and even smaller pebbles could fill these holes; and so forth Carried to an extreme, the pile would become nearly solid rock, and only a very small amount of cement would be needed to stick it together. The resulting concrete would be very dense and strong.

Sharp aggregate and sand is desirable. Smooth, rounded stones and sand can make fairly good concrete, but sharp, fragmented particles work better because the cement as a glue can get a better grip on a rough stone with sharp edges.

It is extremely important to have the aggregate and sand clean. Silt, clay, bits of organic matter will ruin concrete if there is very much present. A very simple test for cleanliness makes use of a clear wide-mouth jar. Fill the jar about half full of the finer material available, the sand and small aggregate, and cover with water. Shake the mixture vigorously, and then allow it to stand for three hours. In almost every case there will be a distinct line dividing the fine sand suitable for concrete and what which is too fine. If the very fine material amounts to more than 10% of the suitable material, then the concrete made from it will be weak.

This means that other fine material should be sought, or the available material should be washed to remove the material that is too fine. This can be cone by putting the sand (and fine aggregate if necessary) in some container such as a drum. Cover the aggregate with water, stir thoroughly, and let stand for a minute, and pour off the liquid. One or two such treatments will remove most of the very fine material and organic matter.

Another point to consider in the selection of aggregate is its strength. About the only simple test is to break some of the stones with a hammer. If the effort required to break the majority of aggregate stones is greater than the effort required to break a similar sized piece of concrete, then the aggregate will make strong concrete. If the stone breaks easily, then you can expect that the concrete made of these stones will only be as strong as the stones themselves.

In very dry climates several precautions must be taken. If the sand is perfectly dry, it packs into a smaller space. If you put 20 buckets of bone dry sand in a pile, stirred in two buckets of water you could carry away about 27 buckets of damp sand. The chart does not take this extremely dry sand into account. If your sand is completely dry, add some water to it or else do your measurements by weight instead of volume. The surface of the curing concrete should be kept damp. This is because water evaporating from the surface will remove some of the water needed to make a proper cure. Cover the concrete with building paper, burlap, straw, or anything that will hold moisture and keep the direct sun and wind from the concrete surface. Keep the concrete moist by sprinkling as often as necessary; this may be as often as three times per day. After the first week of curing, it is not so necessary to keep the surface damp continuously.

Mixing the materials and getting them in place quickly, tamping and spading to a dense mixture is important. This is covered on the entry on mixing.

Reinforcing concrete will allow much greater loads to be carried. Design of reinforced concrete structures can become too complicated for a person without special training, if they are large or must carry high loads.

CONCRETE CALCULATOR

Use the alignment chart as follows. Make a light pencil mark on the left-most scale representing the area of concrete needed. Make a similar mark on the slanted thickness scale. Draw a straight line through these marks intersecting the third scale. This is the volume of your concrete. If your project has a complex shape, add up the volumes of all the parts before proceeding.

Now mark the total volume of concrete on the third (volume) scale, and the kind of work on the fourth. (See definitions.) A line through these two points will give the amount of fine aggregate needed. Continue on a zig-zag course as shown in the KEY to calculate the coarse aggregate, sacks of cement, and water.

It may be necessary to make slight adjustments to the mix, depending upon the type of aggregate used. The final mixture should be wet enough and workable enough to go into the forms fairly easily, requiring light spading or tamping to produce a dense mixture. Too much moisture produces a weak cement. The figures in the alignment chart do not allow for waste which may run as high as 10%.

All materials can be measured in "buckets" instead of cubic feet. The nomograph will still give the correct proportions. The total amount of concrete produced, however, will depend upon the size of the bucket used as the measure. Most buckets are rated by the number of gallons they can hold. To convert to cubic feet, then, you must know that one cubic foot equals 7.5 gallons. A four gallon bucket would hold 0.533 cubic feet. Incidentally, one cement sack holds exactly one cubic foot, so "buckets" can also be substituted for "sacks" on the chart.

Similarly, if your volume of concrete needed is less than 15 cubic feet, you can multiply this by some convenient factor (say 10) and then divide the amounts of materials the chart says to use by the same factor to get the actual amounts needed.

Definitions used in the chart are given on the fold-out page.

HAND MIXING CONCRETE:

Proper mixing of ingredients is necessary to get the highest strength concrete. Hand mixed concrete made with these tools and directions can be as strong as machine mixed concrete.

TOOLS AND MATERIALS

Lumber - 2 pieces 6' x 3' x 2"
Galvanized sheet metal - 6' x 3'
Nails
Saw, Hammer--
Or concrete for making a mixing floor. (About 10 cubic feet of concrete are needed for an 8' diameter mixing floor made 2" thick with 4" high rim.)

(See Insert for page 117 foldout)

Fig. 39

Kind of work - "5" means "5 gallon paste" which is concrete subjected to severe wear, weather, or weak acid and alkali solutions. Examples would be the floor of a commercial dairy.

- "6" means "6 gallon paste" for concrete to be watertight or subjected to moderate wear and weather. Examples: watertight basements, driveways, septic tanks, storage tanks, structural beams and columns.
- "7" means "7 gallon paste" for concrete not subjected to wear, weather, or water. Examples: Foundation walls, footings, mass concrete, etc. where water tightness and abrasion resistance are not important.

Fine Aggregate - Sand or rock screenings up to one quarter inch in diameter. Should be free from fine dust, loam, clay and vegetable matter or the concrete will have low strength. Particles should vary in size, not all fine or coarse.

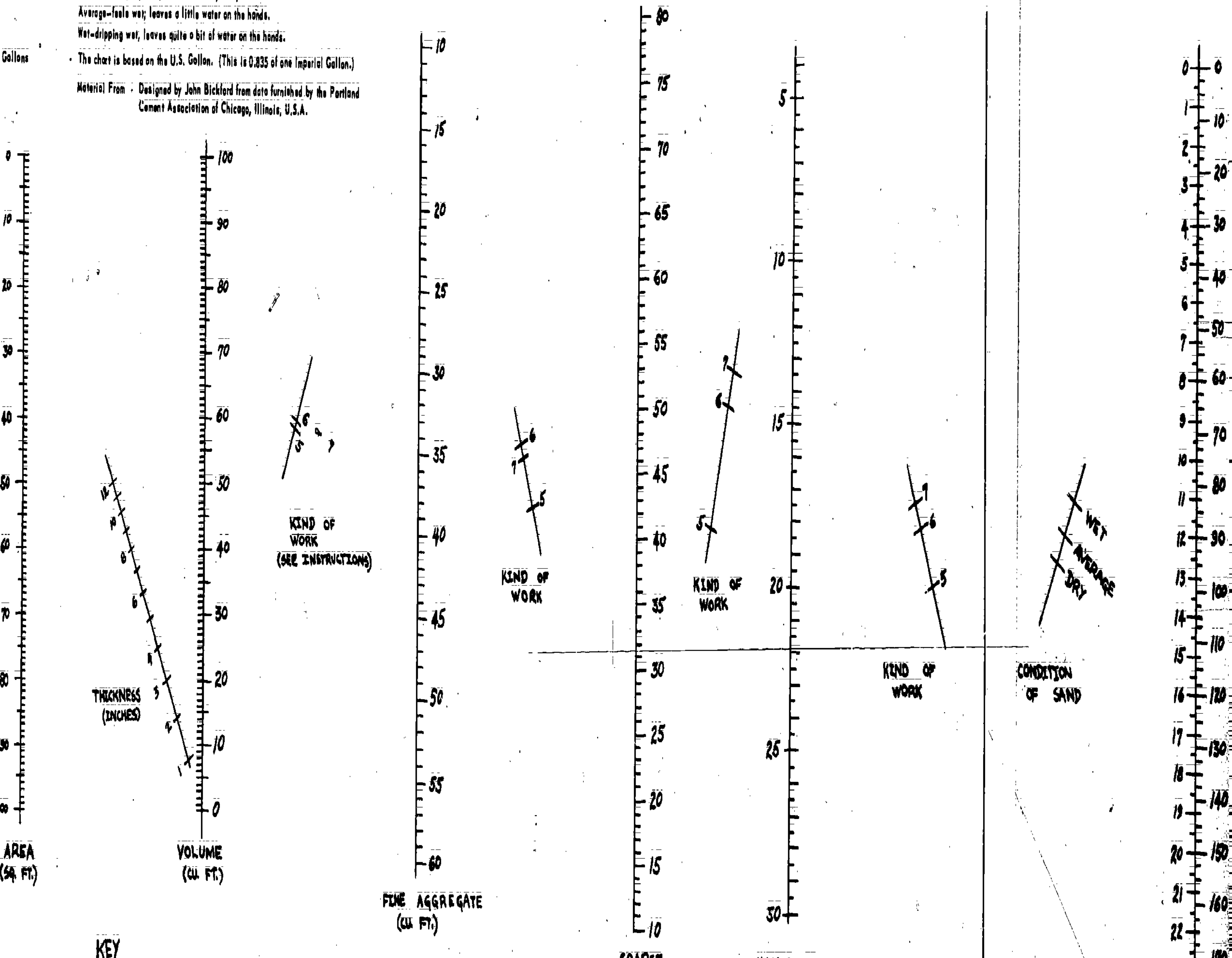
Coarse Aggregate - Pebbles or broken rock from 1/4" up to 1-1/2". Nothing coarser than 3/4" should be used for a 5 gallon paste.

Condition of Sand - Dry–feels slightly damp but leaves very little water on the hands.
Average–feels wet; leaves a little water on the hands.
Wet–dripping wet, leaves quite a bit of water on the hands.

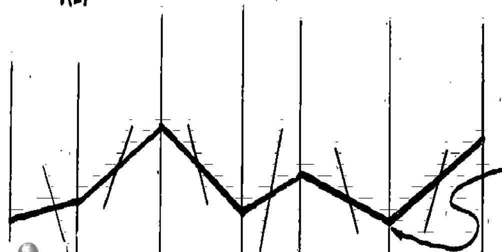
Gallons - The chart is based on the U.S. Gallon. (This is 0.835 of one Imperial Gallon.)

Material From - Designed by John Bickford from data furnished by the Portland Cement Association of Chicago, Illinois, U.S.A.

# CONCRETE CALCULATOR




KEY



Note- use the number of sacks of cement required, and the kind of work to locate this point on the reference line. A line through this point and the condition of sand will give the amount of water needed.

DESIGNED BY JOHN BICKFORD FOR VOLUNTEERS FOR INTERNATIONAL TECHNICAL ASSISTANCE INC. 9/8/62

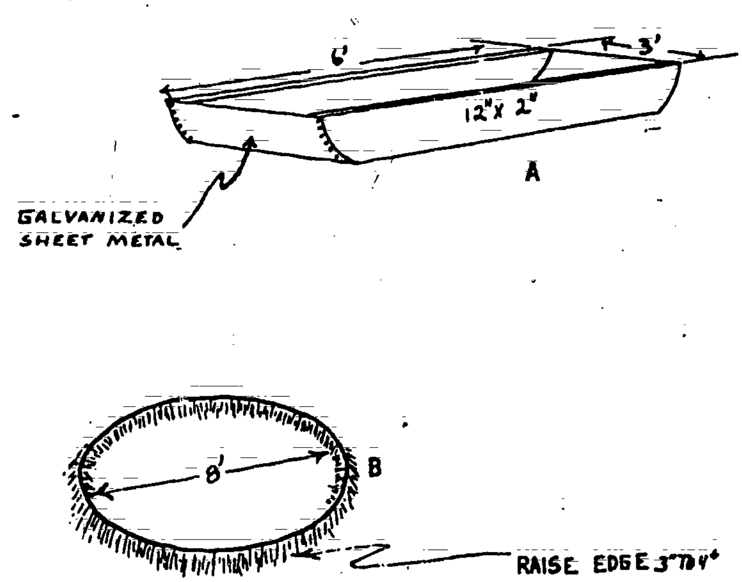



Fig. 40 CONCRETE MIXING

On many self-help projects the amount of concrete needed may be small or it may be difficult to obtain a mechanical mixer. Under these circumstances hand mixing of the concrete will be necessary and, if a few precautions are taken, the quality of concrete can be made equivalent to that from a mechanical mixer.

The first requirement is a watertight and clean base upon which the mixing can be done. This can be a wood and metal mixing boat (Fig.40A) or a simple round floor made of concrete (Fig.40B).

The ends of the wood and metal mixing boat are curved to make emptying easier. The raised edge of the concrete mixing floor serves to prevent loss of water form the concrete.

The procedure for mixing is similar to that for mechanical mixers in that the dry materials should be mixed first. As a minimum it is recommended that the pile of stone, sand, and cement be turned completely once. It should be completely turned a second time while the water is being added. Then it should be turned a third time. Anything less than this will not adequately mix all materials. When this last step is completed the mix can be placed as usual.

Correctly placing the fresh concrete in the forms or shuttering is important in making strong structures. The wet concrete mix should not be handled roughly either in carrying to the shuttering or putting into the shuttering. In either case it is very easy, through joggling or throwing, to separate the fine from the coarse material. We have said before that the strongest concrete comes when the various sizes of aggregate and cement are well mixed together. The concrete mix should be firmly tamped into place with a thin (3/4") iron rod.

Be sure to rinse concrete from the mixing boat and tools when finished each day with the work. This will prevent rusting and caking of cement on them for smooth shiney tool and boat surfaces make mixing surprisingly easier, and the tools will last much longer. Also try to keep wet concrete off your skin, for the material is somewhat caustic.

When the shuttering is full the hard work is done, but the process is not finished. The shuttering must be removed and the concrete protected until adequate strength is attained. The hardening action of cement begins almost immediately after the water is added, but the action may not be fully completed for several years.

Concrete reaches the strength used in the designing after 28 days and is strong enough for light loading after 7 days. In most cases the shuttering can be removed from standing structures such as bridges or walls after 4 to 5 days. In small ground supported structures such as street drains it is possible to remove the shuttering within 6 hours of completion provided this is done carefully. Special conditions, usually specified on the plans, may require leaving the shuttering in place for a much longer time.

During the early stages of hardening or curing the cement in the concrete continues to need moisture. If there is insufficient water available the cement is unable to complete its job of gluing the aggregate together. Because of this, it is recommended that new concrete be protected from drying winds and the sun, and that the surface of the new concrete be kept damp. For cement floors or open construction a covering of banana or palm leaves will be adequate, but these should be given a sprinkling of water at least once and perhaps twice each day for a period of not less than one week.

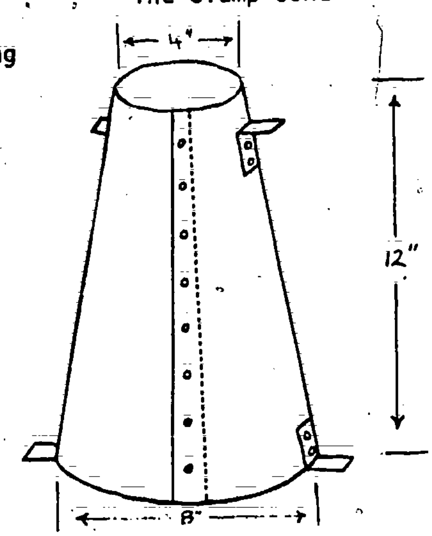
## TESTING THE STRENGTH OF CONCRETE

### The Slump Cone

The following tools and materials are needed:

Heavy galvanized iron
Strap iron - 4 pieces 1/8" x 3" x 1"
16 iron rivets 1/8" diameter x 1/4" long
Wooden Dowel 24" long, 5/8" diameter

Fig. 41
The Slump Cone



In making reinforced concrete, it is important to have just enough water to make the concrete settle firmly into the shuttering (forms) and around the reinforcing when it is thoroughly tamped.

The easiest way is to look at the mix and at the way the workmen place the wet concrete. If the mix appears soupy and the aggregate shows up clearly in the mix, then it is too wet. At the same time it will be noticed that the workmen dump the mix into the shuttering and do very little tamping because, if they do any amount of tamping, large amount of water will immediately appear on the surface. The workmen will soon complain if the mix is too dry.

A more accurate method of making a decision on the proper amount of water is to use the slump test. This test requires a small cone made of fairly strong metal and open at both ends. Dimensions of the cone and tamping rod are shown in the sketch. Once this simple equipment is available the slump test becomes very easy. The steps to follow are listed below.

1. Set the slump cone on a smooth clean surface and stand on the hold-down clips at the bottom of the cone.
2. Have someone fill the cone to 1/4 of its height and tamp this layer 25 times.
3. Fill the cone to 1/2 its height and tamp this layer 25 times. Avoid tamping the first layer again.
4. Fill the cone to 3/4 its height and tamp 25 times. Avoid tamping the previous layers.
5. Complete filling of the cone and tamp this layer 25 times.
6. Step off the hold-down clips and lift the cone vertically and very carefully off the concrete.

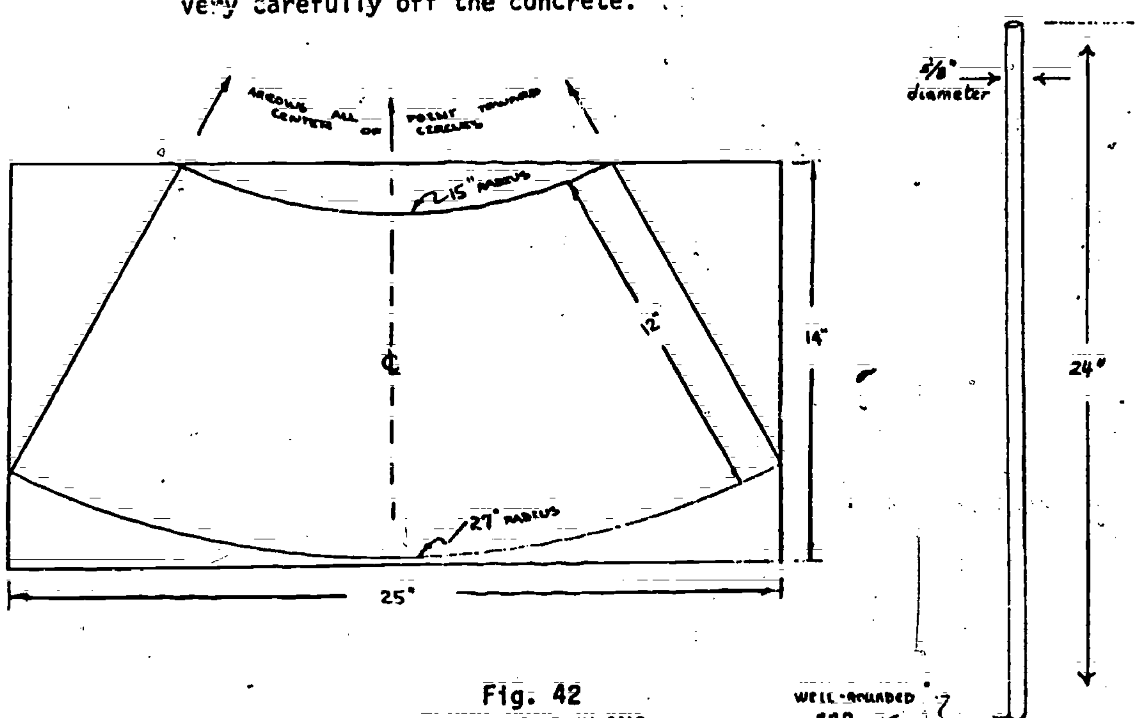



Fig. 42
SLUMP CONE PLANS

Since this process will have taken only a few minutes the concrete will still be very soft when the cone is removed and the top will fall to some extent while the sides bulge out. This is called the slump. Obviously, if the mix is too wet the concrete will lose its shape completely and become just a soft pile. A good mix, as far as the water-cement ratio is concerne will slump about 3" to 4" when the cone form is removed. It is well to keep in mind that dirty or muddy water can cause as muc trouble as aggregate with excessive fine materials. Use clean c settled water.

## CONSTRUCTION AT THE SOURCE

### DEVELOPING THE SOURCE:

Sources which require much development are ground water sources. The development of wells, is covered extensively in the "well constructi manual". Constructions in spring development are similar to those fc wells.

The quantity of water from a spring can very often be substantially increased by digging out the area around the spring down to an impervious layer to remove silt, decomposed rock, and other rock fragments and mineral matter (usually calcium carbonate) sometimes deposi by the emerging ground water. In doing this, particular care should be taken, especially in fissured limestone areas, to avoid disturbing underground formations to the extent that the spring is deflected in another direction or into other fissures.

Springs in general, and gravity springs in particular, are subject to contamination in the area close to the point of emergence. A thoroug sanitary survey should be conducted before development work is initia Such a survey should yield information on the origin of the ground water, the nature of the water-bearing strata, the quality of the wat its yield in various seasons of rainfall, the topography and vegetati of the surrounding area, and the presence of possible sources of contamination. To protect the spring, the collection structures should be so located and built as to force surface water to pass through at least 10 ft of soil before reaching the ground water. It is also customary to exclude all animals and habitations from a substantial area (perhaps 100-300 ft), around the collection chamber, and to dig a diversion ditch above and around this to interrupt surface run-off and divert it away from the ground-water collection zone. Springs emerging from solution channels in limestone formations should be carefully investigated and observed, since under such conditions very little, if any, natural filtration takes place in the ground.

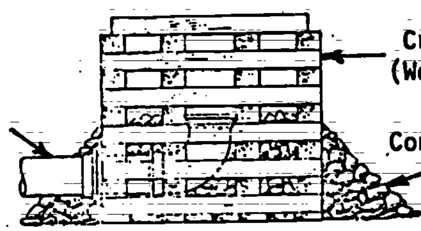
Such springs are likely to yield grossly polluted and turbid water so after heavy rains, and should not be used as a source of domestic supply without a thorough study, including frequent bacteriological examination, and without the provision of corrective measures, such as filtration and/or disinfection. Other protective measures are discus below.

Springs, especially those which can be piped to the user by gravity, often provide an economical and safe solution to the water-supply problems of rural communities. Fig.43 show typical methods of collec ing water from springs.

INTAKE STRUCTURE

The intake may consist of a submerged pipeline used with a submerged crib or a screened bellmouth at the open end. It should be placed well below the water surface since the water is cooler at a greater depth and, also, because of ice formation in cold climates; but it should not be close to the river bottom, in order to avoid sediment and suspended matter moving along there. The intake should also be located some distance from the shore and should be large enough for entrance velocities to be kept to a minimum, preferably less than 6 in. per second. Fig.43 shows a simple intake structure for small water-supply systems from rivers or lakes.

Fig. 43 Small Intake Structure




Reproduced from Hardenbergh, W. A. (1952) *Water supply and purification*, p. 52, by kind permission of International Textbook Co., Scranton, Pa., USA

Intakes from small streams frequently require the construction of small diversion dams. In this manner provision can be made for a sufficient depth of water at all times above the intake pipe; for the settling of suspended matter, thereby reducing the turbidity of the water; and for keeping floating leaves and other debris from obstructing the intake structures. Depending upon circumstances such as the depth of water in the river, location, and degree of permanency of the structure, a floating intake made of empty oil drums held in place by a suitable frame and supporting a flexible inlet hose may be used. Intakes should always be designed to function with a minimum of attendance. More elaborate designs are shown in Section 2.

CONSTRUCTION AT THE PUMPING STATION

The pump-house will vary, depending on the type of pump used, the materials available and the capacity of the system. In general, the pump base should be built of concrete.

Precast concrete slabs are suitable for floors and walls of a cheap but efficient pump-house.

Corrugated iron (or asbestos) sheets should be used for roofs for larger houses. For small houses, precast concrete slabs can also be used.

The roof (at least part of it) should be removable so that a crane can be used to haul out the pump in case of repairs.

The manufacturers usually supply a manual for installing their pumps. Such directions must be followed closely. If necessary, an expert should be called to install the pumps, especially where electric power is used to run the pump.

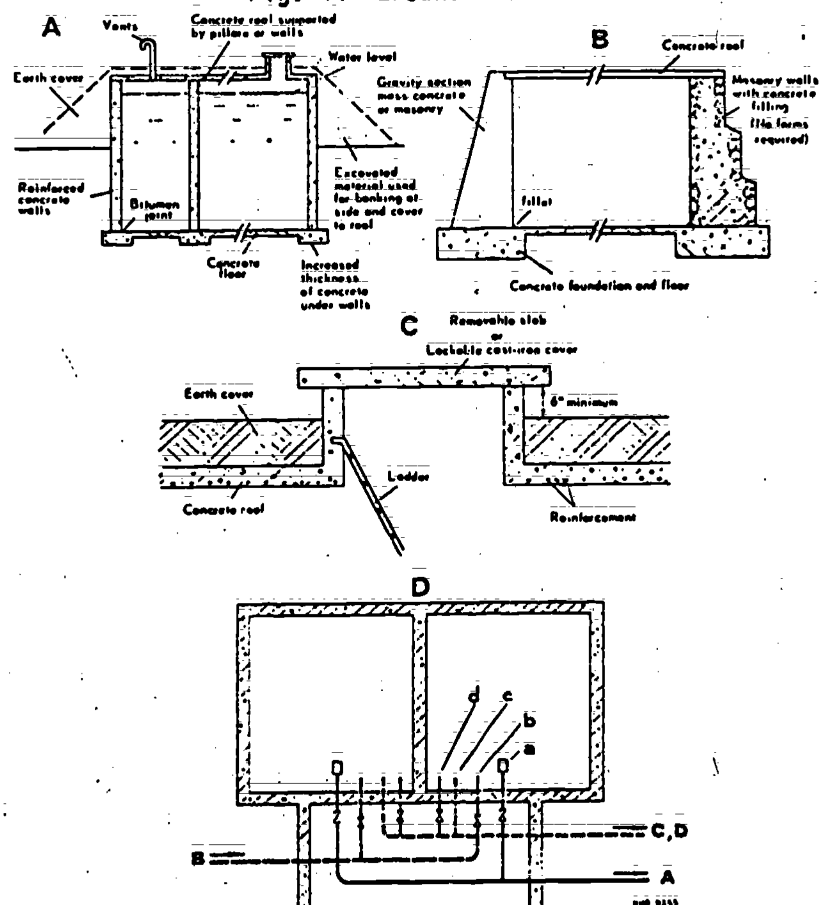
## CONSTRUCTION AT STORAGE FACILITY

### STORAGE TANKS

Storage tanks can be built on high grounds in which case they are termed ground-level reservoirs, or they are elevated reservoirs.

Ground-level reservoirs are usaully built of masonry, mass concrete, or reinforced concrete, according to the materials and local skill available (see below)

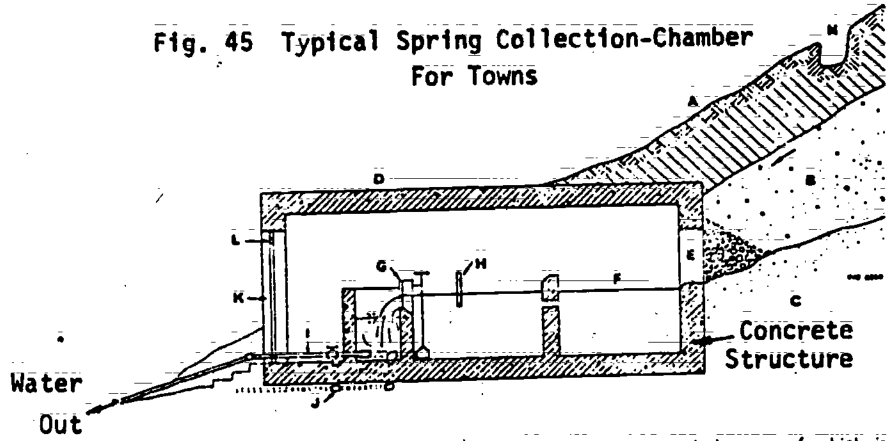
Fig. 44 Ground-Level Reservoirs




A — Cross-section of reservoir
B — Types of walls for reservoirs
C — Sketch detail of manhole opening in reservoir cover

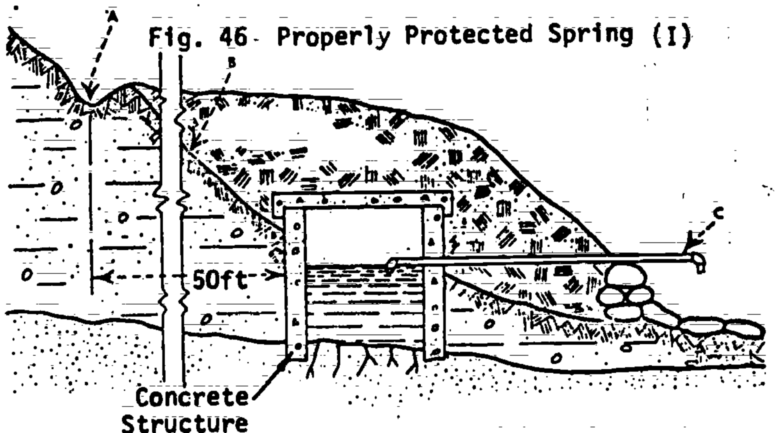
D — Typical valve arrangement for ground-level reservoir with two compartments
Aa — Effluent
Bb — Supply
Cc — Overflow
Dd — Drain

Fig. 45 Typical Spring Collection-Chamber For Towns




A = Ground level
B = Water-bearing formation
C = Impervious stratum
D = Collection chamber
E = Openings protected by a stone-and-gravel pack in order to exclude sand and debris
F = Collecting room
G = Measuring weir
H = Measuring rod, bottom of which is level with lower edge of weir
I = Outlet pipe to reservoir or town
J = Floor drainage
K = Locked entrance door
L = Screened opening through door for ventilation purposes
M = Diversion ditch for surface run-off. Should be at least 15 m (49 ft) away from the collection structure

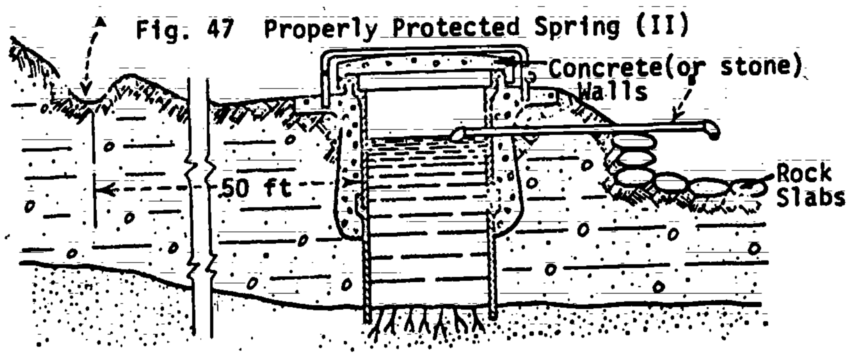
Fig. 46 Properly Protected Spring (I)




A = Protective drainage ditch to keep drainage water a safe distance from spring
B = Original slope and ground line
C = Screened outlet pipe : can discharge freely or be piped to village or residence

Springs can offer an economical and safe source of water. A thorough search should be made for signs of ground-water outcropping. Springs that can be piped to the user by gravity offer an excellent solution. Rainfall variation may influence the yield, so dry-weather flow should be checked.

Fig. 47 Properly Protected Spring (II)




A = Protective drainage ditch to keep drainage water a safe distance from spring
B = Screened outlet pipe : to discharge freely or be piped to village or residence

In order to prevent leakage in the reservoirs, the following should be done:

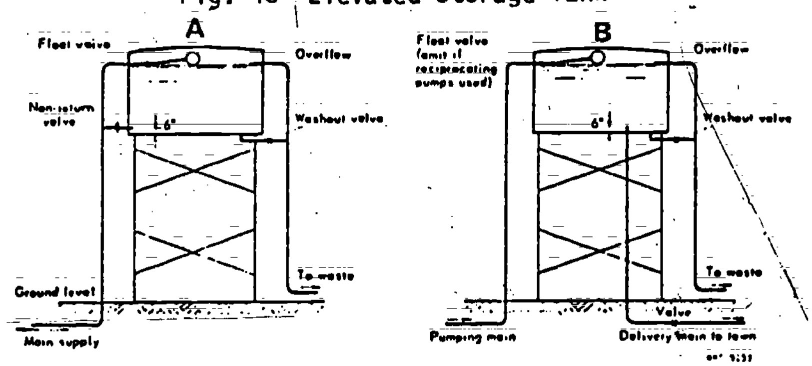
1. Build concrete walls with as few joints as possible
2. Copper or polyethylene strips should be built in vertical joints if possible.
3. Paint the whole inside surface with a bitumen compound or with a solution of sodium silicate (water glass).
4. Render interior surface with about 3/4 inch thickness of mortar composed of water-proof cement and sand, after thoroughly roughening the surface to be rendered to ensure a good key.

Elevated reservoirs may be of reinforced concrete or of steel. Reinforced concrete is suitable when many tanks of similar size are to be built in a series of villages, so that the system is used over and over again. The construction techniques involved are the same as for ground-level storage, except that the elevating walls should be built first.

Steel reservoirs are suitable for single reservoir plans. The tank can be ordered from the manufacturers and comes complete with the accompanying assembly manual which is easy to follow. The tower foundations are to be locally built of concrete.

Steel reservoirs can also be used for ground-level tanks on rocky sites or in areas where masonry rocks are scarce. In such cases, the tank must be slightly elevated to allow painting of lower parts. Elevated storage tanks have valves to stop overflowing. When a float valve is used to control the level in the tank, the overflow should never come into action if the valve is working properly. In the case of a "floating" tank it is usual to control the inflow through a float valve and the outlet joins the delivery pipe through a non-return (see Fig.48 ). A depth gauge operated by a float and wire shows the amount of water within the tank, and is visible from the outside.

Fig. 48 Elevated Storage Tank

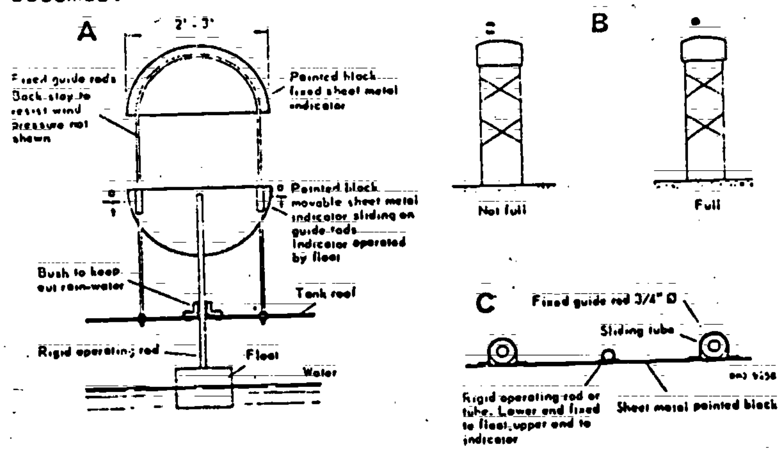



Outlet always taken from 6 in. above tank floor; wash-out at extreme bottom of tank

A – Diagrammatic arrangement of pipes when overhead tank acts as balancer (floating tank). / Not suitable for use with reciprocating pumps.

B – Diagrammatic arrangement of pipes when pumping direct to storage tank

When a float valve is not used, there is no control on the depth of water except the intelligence of the operator of the supply pump and the overflow, and carelessness in adjusting the hours of pumping to the the draw-off can result in considerable waste, while the farther the tank is from the pump-house the easier it is to overlook such waste. The simple indicator shown below is one way of reducing this to the minimum as, properly sited, it can be seen for a considerable distance. However, the nearer the tank is to the pump-house the easier this control becomes.




A = Suitable indicator for top two to three feet of water in tank

B = Appearance of indicator from a distance: it should be orientated so that it appears against the skyline from observation point: it can be seen clearly a mile away.

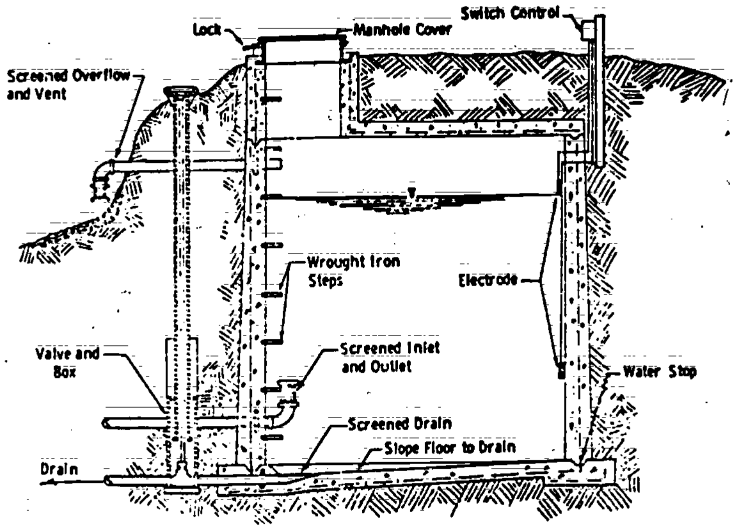
C = Section at a; showing construction and operation of lower indicator

Fig. 49 Water-Level Indicator For Elevated Storage Tanks

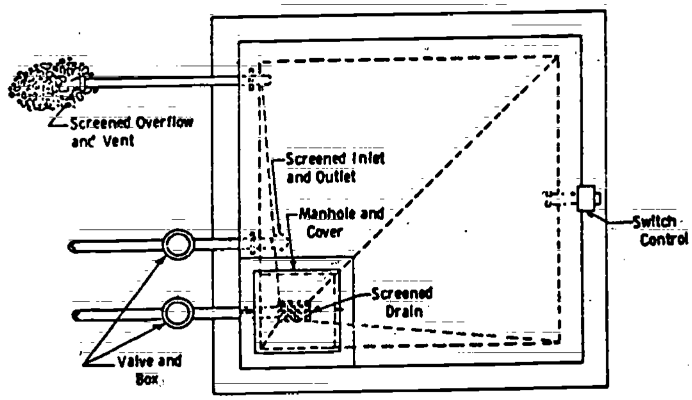
In the construction of storage facilities, the following provisions should be made:

1. Manhole covers must be tightly fitting to prevent surface water from entering the reservoir . They should be locable.
2. Surface covers must be water-tight and light-proof to prevent algae growth.
3. Ventilation must be included to let out air as water fills the tank. These must be covered with fine-mesh wires (not less than 18-mesh).
4. Inlet and outlet pipes, overflow and wash-out pipes should have mesh at their open ends. The outlet pipe should be 6 in. above the bottom of the tank. If the tank has concrete floors, the floor should slope towards the wash-out pipes to enhance cleaning. The diagrams below illustrate the proper design for a concrete storage tank.

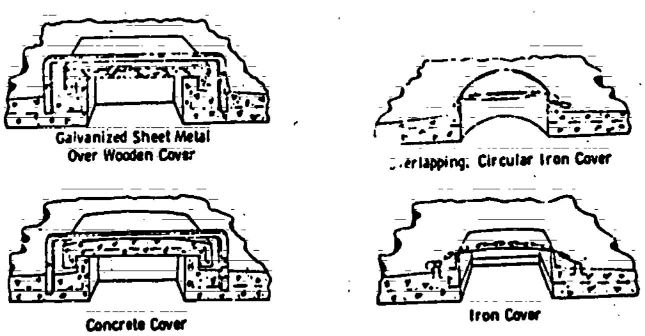
Fig. 50
Storage Tank




A. ELEVATION




B. PLAN




MANHOLE COVERS
Fig. 51

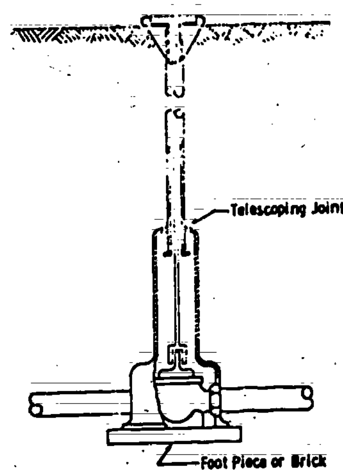



Fig. 52
TYPICAL VALVE AND BOX

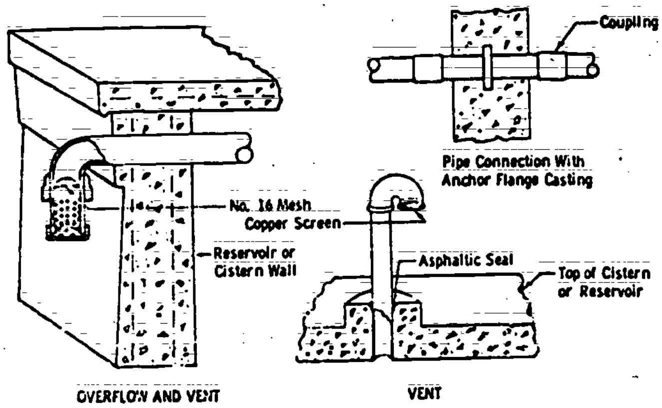



Fig. 53 Piping Installation

WATER PURIFICATION SYSTEM

Water purification systems are usually incorporated in the storage tanks. Where only disinfection (chlorination) is required, the treatment tank can act as distributing reservoir. The cistern is a typical storage-purifier combination.

The cistern filter is a sand filter which keeps organic matter from entering the cistern. The water may then be disinfected and stored in the cistern. The diagrams below show the construction design for such a filter.

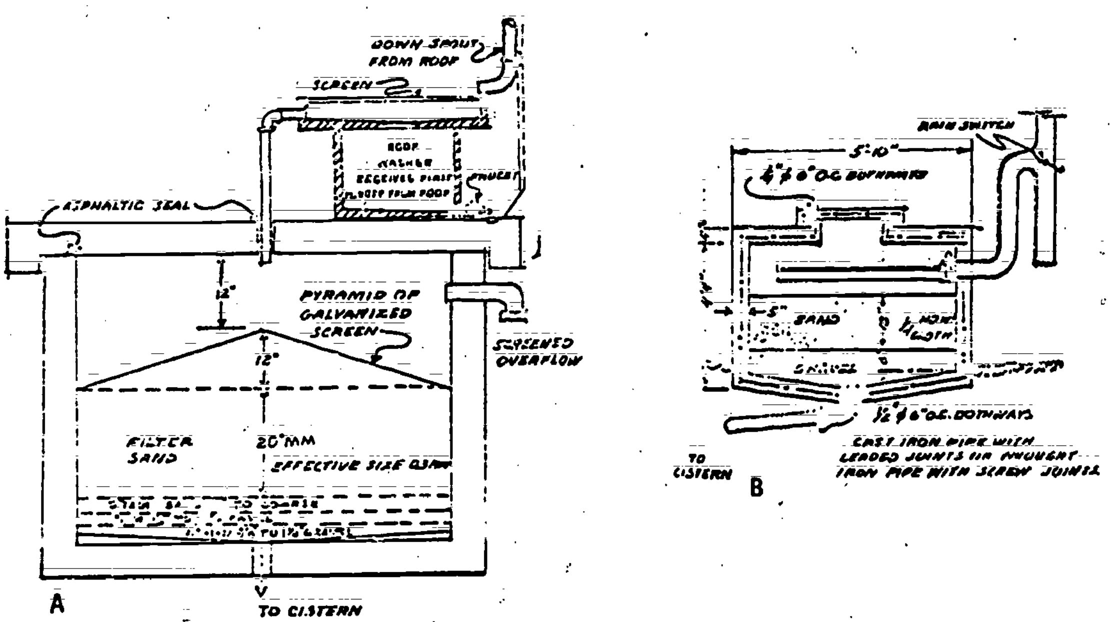



Fig. 54 Cistern Filters

A catchment area always collects leaves, bird droppings, road dust, insects, etc. A cistern filter removes as much of these as possible before the water enters the cistern.

The sand filter is usually built at ground level and the filtered water runs into the cistern, which is mostly underground. The largest pieces, such as leaves, are caught in the splash plate. The splash plate also serves to distribute the water over the surface of the filter, so that the water does not make holes in the sand. A piece of window screen forms the splash plate.

Most filters are made too small to handle the normal rush of water from rainstorms. This results in the filter always overflowing or a channel being dug in the sand, which will ruin the filter. The filter area should be not less than one-tenth of the catchment area. A typical filter area would be 4 feet by 4 feet for a family-sized unit with average rainfall intensity.

About every 6 months, the manhole cover to the filter must be removed and the filter cleaned. Remove all matter from the splash plate and scrape off and remove the top half-inch of sand. When the depth of sand becomes only 12 inches, rebuild it with clean sand to the original depth of 18 inches.

A simple way to discard the first runoff from the roof, which is usually mostly leaves and dirt, should be provided. This will make your filter last longer between cleanings. The easiest way is to have a butterfly valve (like a damper in a stovepipe) in the downspout. After the rain has washed the roof, the valve is turned to allow the runoff water to enter the filter. A semi-automatic system is shown in Fig. .

When building the filter, it is important to insure easy cleaning and to use properly-sized sand and gravel. The filter is usually mounted right on the cistern but can also be close to it. It must have a screened overflow.

Water Purification Plant

Tools and Materials

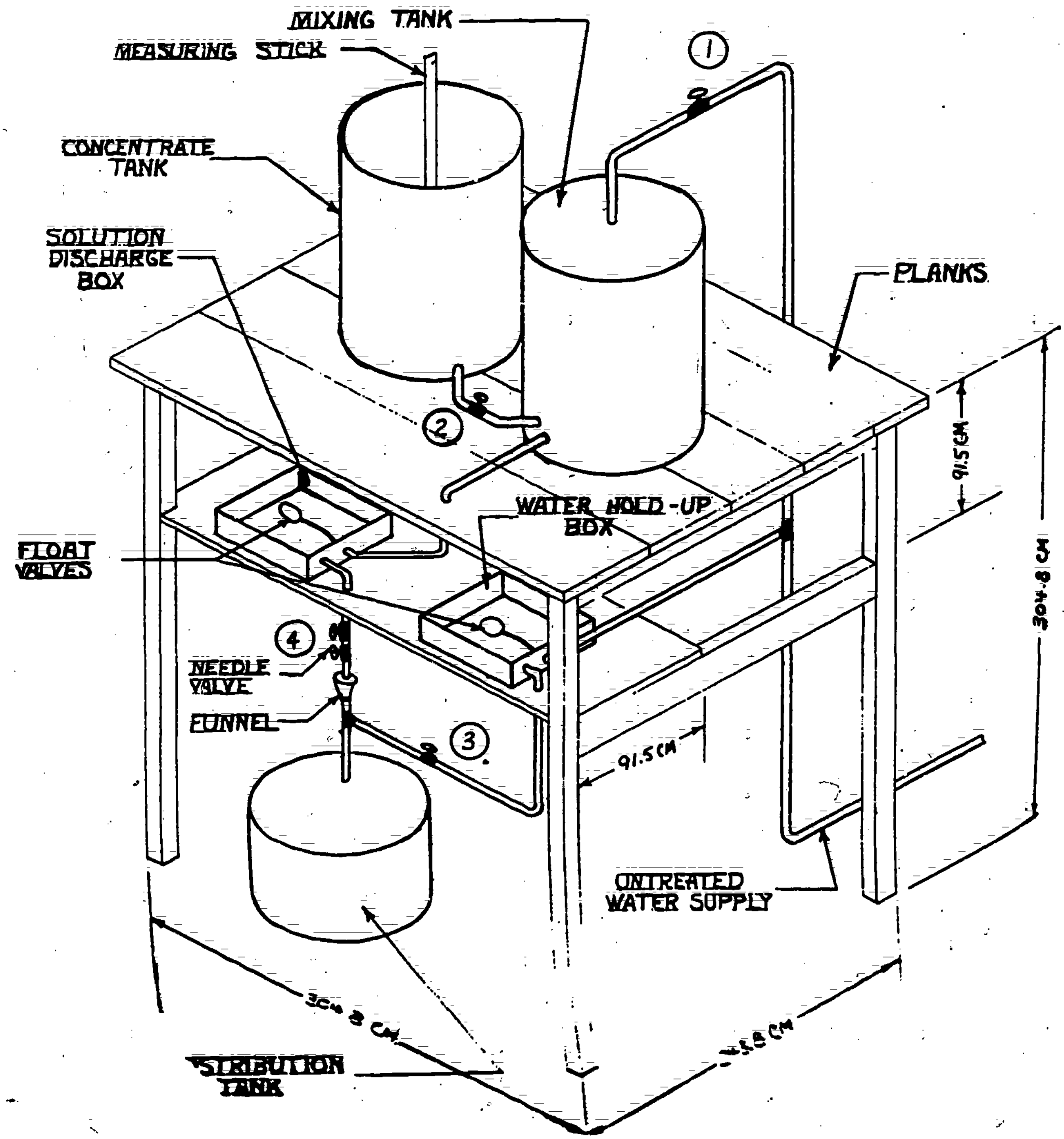
- 3 barrels, concrete tanks or 55-gallon drums
- 1 eight inch funnel or sheet metal to make a funnel
- 2 smaller tanks, about 5 gallon or 20 liters in size, equipped with float valves
- 4 shut-off valves
- 1 throttle or needle valve (clamps may be used instead of the valves, if hose is used)
- some pipe or hose with fittings
- hypochlorite of lime or sodium hypochlorite (laundry bleach)

This plant can be used in small systems, using laundry bleach as a source of chlorine.

The water purifier should be made as in the drawing. The two large barrels on top of the structure are for weakening the bleach. The two smaller tanks on the shelf below are for holding equal amounts of weakened bleach solution and of water, at a

Fig. 55

# CHLORINATION SYSTEM



constant pressure. This makes a constant flow of the solution water, at the same speed, into the hoses leading to the mixing points. The mix is further controlled by the valves and may be seen through the open funnel. If a throttle valve is not available, a shut-off valve may be used and a throttle action obtained by this valve and valve #4 in series.

Placing the two barrels at a height of 10 feet causes a pressure of only about five pounds a square inch. Thus the plumbing does not have to be of high quality except for valve #1 and the float valve of the water holdup tank, if the rain water supply is under higher pressure.

Sometimes special chlorinators are required; in which case when hypochlorinators are ordered, the following data should be furnished to the manufacturers:

If water is pumped:

1. Sketch of pumping installation
2. Number and type of pumps
3. Manual or automatic operation
4. Pumping rate (liters/second or gallons/minute) and total water pumped per day (cubic meters or gallons)
5. Electric current available (volts, phase, cycle)
6. Pressure on pump discharge (minimum and maximum)
7. Suction lift
8. Sizes of suction and discharge pipes
9. Other data (space available for installation, sizes of foot valves, check valves, etc.)

For gravity system:

1. Sketch of system, indicating source of water supply and distances
2. Size of main
3. Size of meter, if any, giving make and description
4. Pressure at meter or point of installation (minimum and maximum)
5. Rate of flow (minimum and maximum)
6. Average daily flow (cubic meters or gallons per day)
7. Fire flow, if any (liters/second or gallons/minute)
8. Allowable loss of pressure (m or ft)
9. Other data (space available for installation, etc.)

Boiler for Potable Water

Sometimes it is easier to boil drinking water than to disinfect. The following design can provide enough safe water for a small community with a distribution system, since it would require a lot of fuel to boil enough water for the system.

Tools and Materials

1 - 55 Gallon drum
1 - 3/4" Pipe Nipple 2" long. Quantity of bricks for two layers of bricks to support drum.
1 - bag of cement plus sand for mortar and base of fireplace.
1 - large funnel and filter medium for filling.
1 - metal plate to control draft in front of firebox.
1 - 3/4" valve, preferably all metal such as a gate valve to withstand heat.

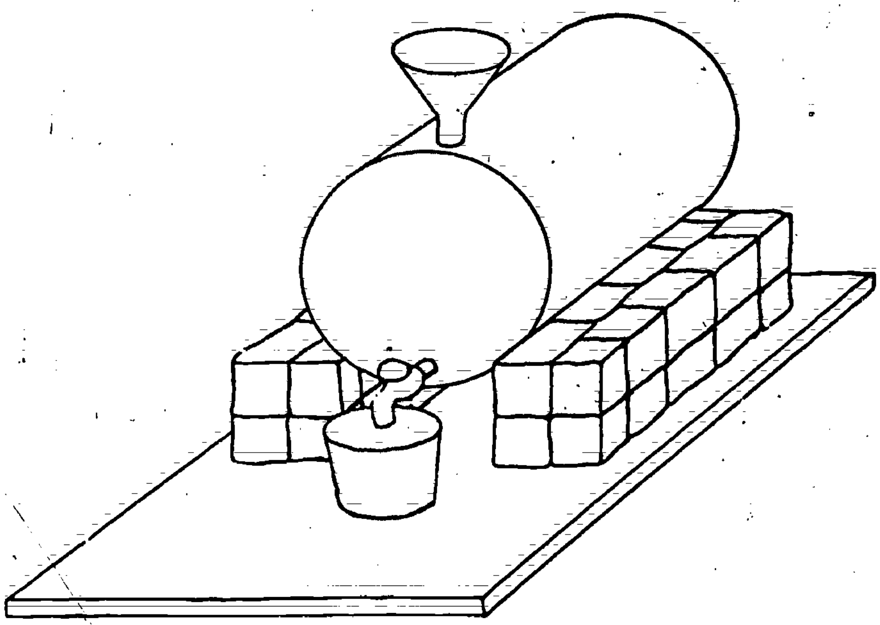


Fig. 56 Boiler for Potable Water

This drum for boiling of drinking water is intended for use in your residence to provide a convenient method for preparation and storage of sterile water. The fireplace is simple, oriented so that the prevailing wind or draft goes from front to back of the drum between the bricks. A chimney can be provided but is not necessary.

The unit has been tested in many Friend's workcamps in Mexico and elsewhere. A 55 gallon drum would normally last a 20 person camp group for an entire week, and certainly would provide adequate safe water supply for two or three individuals for a much longer time. Water must boil at least 15 minutes with steam escaping around the completely loosened filler plug. Be sure that the water in the pipe nipple and valve reach boiling temperatures by purging about two liters of water out through the valve while the drum is at a full boil.

## CONSTRUCTION ON SUPPLY LINE

Pipe trenches must slope uniformly to avoid pressure variations in the pipes. Whenever a pipe has to pass over a gap in the trench, structures should be installed to support the pipes, especially at the joints. Once laid, the pipes should be coated, and accurately recorded in the systems map.

Different joints are used for different connections. The choice of a joint depends on the number of branches desired at a point. Positions of joints with many branches should be marked and protected as it is usually the main source of trouble.

The diagrams attached illustrate the various joints used in distribution systems. The supplier should provide simple guides for joining pipes. If not available, a plumber's manual should be obtained. This should not prove necessary however, since this often involves only screwing parts together.

### VALVES

Valves are used for specific purposes:

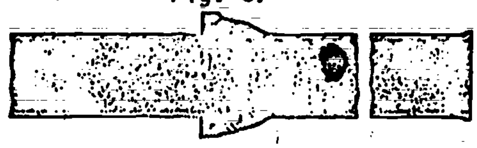
a. Gate valves - control the flow of water. Should be placed in junctions so that sectional repairs can be carried out without interruption of service. Should have manholes and be easily accessible.
b. Check valves - allows one directional flow only. Used between pumps and pipe lines.
c. Air-Valves - allows air to escape from high points in the pipelines
d. Pressure-reducing valves - to reduce water pressure in pipes of any desired value.

METERS are not essential in rural water supply systems.

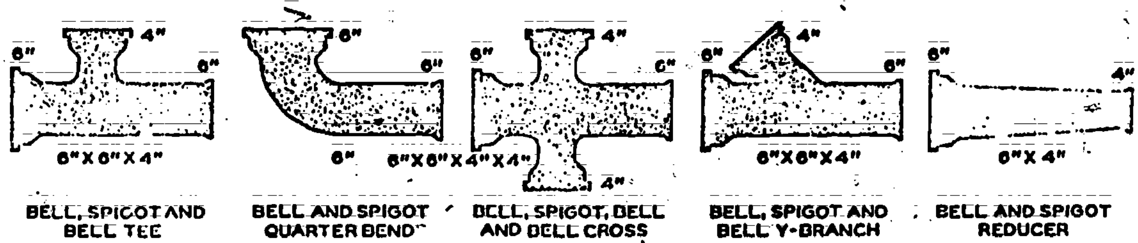
HYDRANTS - Where fire protection is provided, these should be designed to provide connections for 2 1/2 inch diameter fire hoses.

SERVICE PIPE -Connects street distribution pipe to the houses plumbing system. Should be rigidly connected to the street pipe.

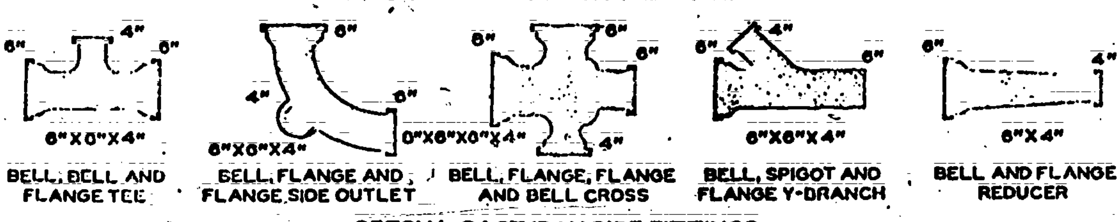
Fig. 57



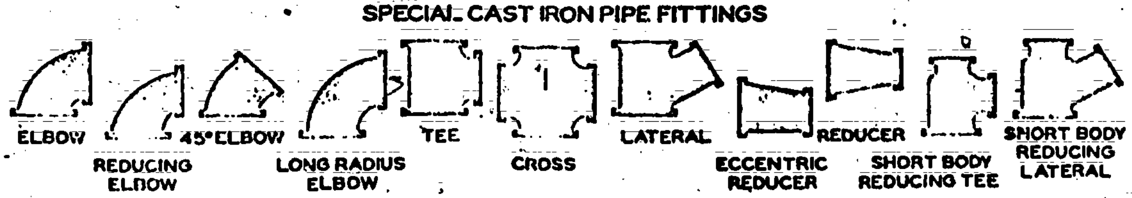
STANDARD BELL AND SPIGOT JOINT FOR CAST IRON PIPE




STANDARD CAST IRON PIPE FITTINGS




SPECIAL CAST IRON PIPE FITTINGS




AMERICAN STANDARD CAST IRON FLANGED FITTINGS

# CONSTRUCTION TECHNIQUES

## LESSON NO. 1

LESSON OBJECTIVE: To build an intake site and install pumping facilities.

| TOPIC | INSTRUCTIONAL PROCEDURE | SUPPLEMENTAL MATE[RIALS] RELATED READIN[G] |
|---|---|---|
| Intake Structures | Discuss need for and effectiveness of, various types of intake structures. | WHO Monograph Serie[s] Chapter 5. |
| | Take field trip to an open source with a visible intake structure | Intake Structure. |
| Designing Intake Structures | Divide class in small groups. Let each design (and construct) a simple intake structure. | Models of materials in constructing an structure. |
| | Draw conclusions indicating when to use an intake structure. | |
| Pump Selection | Discuss in class what sort of lift pump is required. | Section 3 on Pump Selection. |
| Concrete in Construction Work | Introduce concrete in construction work - its structure. | Concrete blocks. Raw ingredients for making concrete. |
| | Demonstrate how to determine the amount of each ingredient. | |
| | Demonstrate how to mix concrete properly. | |
| | Let students determine the required amount of each ingredient using the chart. | |
| Testing Concrete | Demonstrate the test for strength. | Slump Tester. |
| | Discuss in class the need for reinforcing concrete. | Concrete pipes: a) reinforced b) not reinforce[d] |
| | Test reinforced concrete and one not reinforced. | Strain-Stress Testi[ng] Machine. |
| [Buil]ding a Pump House | Discuss when a pump house is necessary. | |
| | In the field demonstrate how to build a pump house. (If not possible, the students should be given chance to work with a building crew). | Building Materials. |

CONSTRUCTION TECHNIQUES

LESSON NO. 2

LESSON OBJECTIVE: To test water obtained from a source for drinking water standards.

| TOPIC | INSTRUCTIONAL PROCEDURE | SUPPLEMENTAL MATERIALS RELATED READING |
|---|---|---|
| Testing Water Samples | Ask students to recall the characteristics of water that should be tested.<br><br>In the laboratory (or in the field) demonstrate how to use the various kits commonly used in the field. | WHO Monograph #42, pp. 46-54.<br><br>Portable water laborat field kit. Microfilt tester. |
| Exercise on Water Tests | Divide class into convenient groups and let each group test for a different pollutant.<br><br>Verify each result. | |

CONSTRUCTION TECHNIQUES

LESSON NO. 3

LESSON OBJECTIVE: To construct a treatment system appropriate for simple water purification.

| TOPIC | INSTRUCTIONAL PROCEDURE | SUPPLEMENTAL MATERIALS / RELATED READING |
|---|---|---|
| Assembling Treatment Systems | Ask students to recall the functions of component parts of various treatment processes.<br><br>Divide students in working groups.<br><br>Let each assemble a most complete purification system.<br><br>Test the efficiency of the constructed treatment systems. | Sand filters, chlorinators, aerators, settlement basins, chemicals, measuring vessels.<br><br>Section 4 on the functions of component parts of various treatment processes. |

CONSTRUCTION TECHNIQUES

LESSON NO. 4

LESSON OBJECTIVE: To install a storage tank and distribution pipes properly suited to the local environment.

| TOPIC | INSTRUCTIONAL PROCEDURE | SUPPLEMENTAL MATERIA RELATED READING |
|---|---|---|
| Building a Distribution Reservoir | Take a field trip to storage sites. | Section 4 on storag tanks. Central disti bution system. |
| | Using model designs, let each student assemble a distribution reservoir. | Plans and model block instruction manuals on assemblage. |
| | Stress the importance of outlet, inlet and overflow pipe screens. | Paint and brush (or spray). |
| | In a field inspection of local systems, let each student trace a distribution line from reservoir to a house. | |
| Pipe Laying | As field exercise, take the whole class to dig a trench and lay 50 ft. of pipe. | Short pipes of differ ent diameters, pipe joints, welding torch Rivets. |

# SECTION 6

## OPERATION AND MAINTENANCE

OVERVIEW:

A good water source, a well planned treatment and distribution system and good construction practices do not ensure a safe and continuing supply to consumers. If the system is not operated correctly, and if it is not maintained, the system will soon be unsafe and may be unusable even if the water remains safe. The correct operation and maintenance of the system is of prime importance.

This section covers the operation and maintenance of a distribution and treatment system. It also covers the training of local workers to assist and eventually operate and maintain the system. This training must be effective, or the system will deteriorate rapidly after the PCV's stay has ended.

SECTION 6: OPERATION AND MAINTENANCE

OBJECTIVE: Prepare an instruction manual for the operation and maintenance necessary to keep the above established system going. This should act as a reference for trained personnel, or as a training manual for the unskilled. The manufacturer's recommendations for the operation and maintenance procedures must be simplified and/or translated as situation demands so as to be easily followed by the operator or maintenance man (or trainee)

TASKS:

1. Write a guide to water inspection at the source
2. Devise laws safeguarding the source from trespassers who can either cause mechanical damage to machines or contaminate water at source by indiscriminate use of it, e.g., swimming or washing at an open reservoir.
3. Write down safety and sanitary precautions that must be observed by the operator or maintenance men, e.g., where to store chemicals, or where to wash their hands, etc.
4. Draw large scale picture of the pump or engine, labeling all operating switches (in local language if necessary); include a corresponding chart of directions to be followed in starting and closing.
5. On the large-scale picture and the machine itself, indicate with arrows where grease, oil, or fuel is applied and how often this should be done.
6. For a new component, set the limit of repairs the local operator can do, and write down to whom the need for major repairs should be reported.
7. Draw a flow chart of the treatment plant, and write down at each stage:
   a. The purification procedures to be carried out and how, e.g., at chlorinator add 1 1/2 cup HTH to a gallon of water and stir thoroughly, etc.
   b. The cleaning of the parts, e.g., backwashing the filter, etc.
8. Draw large-scale maps of distribution system showing the inspection valves, identifying marks.
9. Draw up a record-keeping chart which must be used to record what repairs have been done and when, by whom, etc.

OPERATION AND MAINTENANCE (cont.)

10. Write down directions for cleaning of water sources and pipes.

11. Lay down rules regarding the installation of new service connections to ensure that there is no unchecked connection to the mains; such connections can reduce the pressure in the mains.

12. Design a system of building up a stock of spare parts over the years from the very beginning. Te These must be the parts which often need regular replacements.

13. Design a rack for tools so they can be easily reached when needed.

14. Devise fire drills which must be used to train the operators and servicement so they can fight small fires at the pump or engine house.

15. Build an inventory of parts which can be used in case of emergency.

16. Recommend tools according to the scope of the work the operator or serviceman is capable of doing.

17. Set the limit of motor repair works that can be done locally, and when to call for an experienced repairman.

18. Simplify (or translate) the producer's motor repairs and maintenance manual so it can be followed by the serviceman.

19. Prepare a financial statement procedure.

FUNCTIONAL SKILLS:

1. Decide what points of the source are to be inspected.

2. Recognize the risk of unrestricted public access to source and pumphouse premises.

3. Recall sanitary standards to be maintained during the operation and repair of water system.

4. Recognize harmful characteristics of chemicals, fuels and oils used.

5. Simplify or translate producer's operation and maintenance instructions.

OPERATION AND MAINTENANCE (cont.)

6. Draw plans of machines.

7. Assess the capability of serviceman or operator as regards to his job.

8. Recall the various treatment processes in the plant.

9. Draw maps of distribution systems.

10. Recognize conditions indicating that pipes, sources or storage tanks need washing.

11. Recall the relationship between the available head and the required head at the service connection.

12. Recognize parts of equipment which most often need replacement.

13. Make simple designs for tool racks on walls.

14. Decide what extinguishing materials should be used for fires of different origins, e.g., electric fires, etc.

15. Recognize the vital parts of the system which must have spares in the inventory to be used in case of emergency.

16. Compare the operator's capability with the structure of the engine, pump or motor he is to work on.

17. Recognize fault in the functioning of the motor.

18. Follow and/or translate the producer's manual on operation and maintenance.

TERMINAL PERFORMANCE TESTS:

1. Given an operating water source, list the points that must be inspected during periodic maintenance checks.

2. Write down laws which should be posted as public notice prohibiting trespassing on the system premises.

3. List the precautions to be taken when cleaning the source and pumping house.

4. Given an electrically powered pump, draw its diagram and indicate the power connection.

OPERATION AND MAINTENANCE (cont.)

5. Given a motor and its diagram, identify the corresponding parts labeled on the diagram.

6. From a detailed report on the capability of two operators, set the limit of repairs each can carry out on a given pump and engine.

7. For a given treatment system, draw a flow chart of the different stages.

8. In a field exercise, follow the pipeline and draw a large-scale map of the system, showing the locations of all inspection valves.

9. Draw a chart for record keeping for the maintenance of a given system section.

10. Write the steps to be followed in cleaning a supply pipe and storage tank.

11. For a given available head, determine where new service connections can be installed without too much reduction of pressure in the mains.

12. In order of priority, list the spare parts of a given system which should be inventoried.

13. Given a list of tools available at a pumping station design a rack to hang the tools in an easily accessible place.

14. Design a drill for fighting:

    a. An electrically caused fire
    b. Gas fire

15. List the recommended minimum requirement of spares in emergency operation.

16. For a given motor and serviceman, determine the limit of repairs he can do.

17. Simplify a given manual on engine operation and maintenance.

## WATER SOURCE MAINTENANCE AND INSPECTION

### QUALITY OF WATER AT SOURCE

After water has been purified, cleanliness of all handling facilities is of utmost importance. All stations and men who maintain them must maintain the sanitary quality of the water.

### WELFARE OF PERSONNEL:

Persons suffering from communicable diseases must be prevented from coming into contact with the water supply. This includes grass-cutters in the premises of the pump-house, attendents who clean the filters and storage plants, etc. All personnel should be medically examined at least once a year, preferably just before the annual cleaning operation.

### PROTECTION OF FACILITIES

1. No unauthorized persons to enter pumping stations, treatment works, etc.
2. Open reservoirs should be fenced and the gate locked wherever possible. A guard should always be on duty to stop trespassers from washing or swimming in the reservoirs.
3. Install drinking fountains in a proper place, and a place for workmen to wash their hands.
4. Latrines should be built in the vicinity, but at a safe distance from the source.
5. Pump-house must be locked whenever the attendant is cut of it.
6. Trespassers should be handed over to the local authorities for punishment.
7. Chemicals and fuels must be stored at their designated places at all times.
8. Inspection of water quality and quantity at the source must be carried out regularly and recommendations made whenever applicable.

### INSPECTION REQUIREMENTS

1. Check all exposed joints for possible leaks.
2. Check possible growth of micro-organisms (e.g. algae) in the system.
3. Metal surfaces which come into contact with purified water (e.g. pipes) should be checked for possible emission of chemical solutions into the system.
4. Accidental cross-connections of pipes often occur, and the inspector must make sure there are no such mistakes.
5. Where applicable, pressure in the system must be maintained at the desired level at all times.

### OPERATION AND MAINTENANCE OF AUTOMATIC FACILITIES

Once a system has been installed, it is essential that maximum attention be paid to its maintenance and smooth operation. Experience points out that it is not often possible to find men with necessary skills to operate the system. Most often than not, such men have to be trained from the scratch.

PERSONNEL TRAINING

1. Select possible employees for administrative and operative jobs early during the construction period. During this time, the men have an opportunity to learn how the system has been put together and works.

2. Where many such projects are run, a period of training personnel in key responsibilities is strongly recommended. This should be devoted to instilling into them the concept that the project is theirs and therefore must be treated as personal property.

3. Manufacturers' recommendations as to operation and maintenance procedures should be simplified (or translated) so that the men may scrupulously observe. This is especially important with regard to pumping machinery.

4. Draw large scale picture of the equipment in question and draw arrows indicating where and what to do.

5. On the equipment itself, wherever possible, large labels should show where to apply grease, fuel, etc.

6. Supervision should ensure that procedures and schedules are followed.

EXAMPLE OF A SIMPLIFIED TECHNICAL PROCEDURE:

A flow chart of a treatment system is shown below:

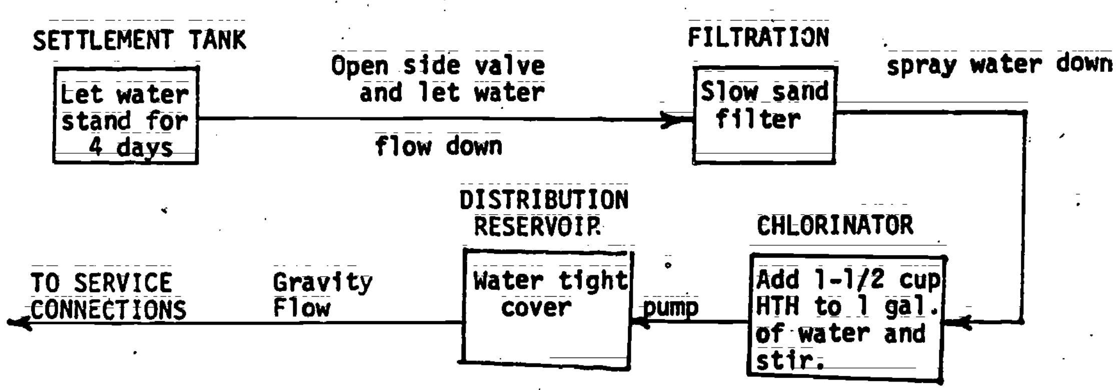



Fig. 58 Treatment System Flow Chart

## RECORDING REPAIRS

Common causes to major system breakdowns:

1. Operators unable to recognize signs which portend failures and breakdowns.
2. Operators with no skill to pinpoint and repair minor breakdowns, but try at random to tighten a nut or screw. This often results in greater breakdowns.
3. Operators using equipment and materials under conditions for which they were not designed.

Record Chart - The illustration below can be modified to suit the occasion.

TABLE 8 REPAIR RECORD CHART

| Description of Breakdown | Classification Minor | Classification Major | Operator | Consultant |
|---|---|---|---|---|
| At Source | | | | |
| 1. Cracked well-cover | x | | x | |
| 2. Decrease in well yield | | x | | x |
| Pump | | | | |
| 3. Broken pump belt | x | | x | |
| 4. Clogged plugs | x | | x | |
| 5. Broken cup leathers (washers) | x | | x | |
| 6. Faulty fuel and air filters and cooling fans | x | | x | |
| 7. Faulty injectors in diesel engines | | x | | x |
| Distribution System | | | | |
| 8. Leaky reservoirs | x | | x | |
| 9. Leaky pipe joints and valves | x | | x | |
| 10. Broken inspection covers | x | | x | |
| 11. Faulty meters | | x | | x |
| Purification system | | | | |
| 12. Faulty chemical dispenser | x | | x | |

The above suggestions should be expanded to suit the scope of the system and the capability of the operators and maintenance men. See **Table 9** as an example for the maintenance of a G.M. Diesel 71.

TABLE 9 MAINTENANCE CHART OF A G.M. DIESEL 71

| Item Operation | Time Interval Daily | 8 Hours 240 Miles | 50 Hours 1,500 Miles | 100 Hours 3,000 Miles | 200 Hours 6,000 Miles | 300 Hours 9,000 Miles | 500 Hours 15,000 Miles | 1,000 Hours 30,000 Miles | 2,000 Hours 60,000 Miles |
|---|---|---|---|---|---|---|---|---|---|
| 1. Engine Oil | X | | | | | | | | |
| 2. Oil Filter | | | | | | | | | |
| 3. Coolant and Filter | X | | | | | | X | X | |
| 4. Belts and Fan Bearings | | | | | | | X | X | X |
| 5. Heat Exchanger Electrodes and Core | | | | | | | X | X | |
| 6. Hoses | | | | | | | X | | |
| 7. Raw Water Pump | X | | | | | | | | |
| 8. Radiator | | | | | | | | | X |
| 9. Fuel Tank | X | | | | | | X | | |
| 10. Fuel Strainer and Filter | X | | | | | X | | | |
| 11. Air Cleaner | | X | | | | | | | |
| 12. Blower Screen | | | | | | | | X | |
| 13. Air Box Drains | | | | | X | | X | | |
| 14. Crankcase Ventilation | | | | | | | | X | |
| 15. Starting Motor | | | | | | | | | |
| 16. Battery-Charging Generators | | | | X | X | | X | | X |
| 17. Battery | | | | X | | | | | |
| 18. Tachometer Drive | | | | X | | | | | |
| 19. Throttle Controls | | | | | X | | | | |
| 20. Tune-Up | | | | | | | | X | |
| 21. Power Take-Off | | X | X | | | | X | | |
| 22. Reduction Gear (Single Engine Unit) | | X | X | | | | X | X | |
| 23. Torqmatic Marine Gear | X | | | | X | | | | |
| 24. Paragon Marine Gear | X | | | | X | | | | |
| 25. Torqmatic Converter* | X | | | | | | | X | |
| 26. Reduction Gear (Multiple Engine Industrial Units) | X | X | | | | | | X | |
| 27. Reduction Gear (Multiple Engine Marine Units) | X | | | | X | | | | |
| 28. Turbocharger | X | | | | | | | X | |
| 29. Overspeed Governor | | | | | | | X | | |
| 30. Power Generator | | | | X | | X | | | |
| 31. Transmission (Railcar) | X | | | | | | | X | |
| 32. Oil Filter (Railcar) | | | | | | | | | |
| 33. Hydrostarter | | | | | | | | X | X |

* Single and Multiple Engine Units

RECORD KEEPING

The operation and maintenance of a distribution system require the establishment of system maps and records.

Requirements of the Systems Map

1. Large scale; no less than 1:10,000
2. Show all Streets and their names
3. Locations of mains and their sizes should be shown
4. Valves (and hydrants) must be labelled and numbered appropriately.
5. Sources, reservoirs and pump-houses should be included in the map.
6. A wall-size map of the whole system should be supplied for office use. Copies of the map should be divided into sections and bound for easy handling in the field.

REGULATIONS FOR INSTALLING NEW SERVICE CONNECTIONS OR EXTENSIONS TO EXISTING SYSTEM.

1. New connections should be made only with the full acknowledgement of the designer, who should know hether there will be enough pressure for that branch. In this way the problem of maintaining adequate pressure in the system can be eliminated.

2. Financial agreements (where applicable) should be reached before such a connection is amde.

3. The connection must be made by a regular installer in the system.

4. In small water-supply schemes, these connections should be rigidly connected to the street pipe, and the addition included in the systems maps for up-to-date record.

5. New pipes must be disinfected before inclusion in the system.

6. Open ends should be covered during construction period.

REGULATIONS FOR CLEANING THE DISTRIBUTIONS SYSTEM

1. Dead-end branches must be completely flushed regularly.

2. Other systems should have a thorough cleaning at least once a year.

3. During the general cleaning the systems should also be inspected for possible deformities.

INVENTORYING FOR OPERATION IN EMERGENCIES

Building up a stock of spare parts, if started from the befinning will spread the expense of their purchase over the first ten years. Minimum requirement of spare parts stock;

PARTS

1. For gasoline engines - sets of plugs, gaskets, gasket-
pound, spare magneto, gasoline-feed pipe, air and oil
carburetor float, spare washers for gasoline-feed pipe
timing chain.

2. For diesel engines;- sets of injectors, gaskets, gaske
pound, washers, filter elements, fuel pipe, timing cha

3. For electric motors - sets of fuses, brushes, insulati

4. For pumps - cup washers, valve rubbers or leathers, be
fasteners, grease nipples.

5. For mains and distribution systems - minimum of half-
for each diameter, joints, tees and bends, odd valve,
and hydrant for each size.

FUEL

In order to estimate the required quantity to store, there
guide:

Small diesel engine consumes .06 gallons of diesel fuel pe
each horsepower.

Small gasoline engine consumes .08 gallons of gasoline per
each horsepower.

Lubricating oil for engines += 1/15 of fuel consumption.

STORAGE

1. Protection against dangers of fire and theft.

2. Underground tanks recommended for large systems. A ha
pump can be installed.

3. For small systems the fuel drums should be kept in fi
store. The drums should be kept almost horizontal, on
at a convenient height above floor to allow measuring
stand below the tap on the end of the drum.

4. Allowance should be made for 2% loss of gasoline, 1%
fuel in the tropics.

5. Accurate record of fuel consumption should be kept.

6. "No Smoking" signs should be posted and the rule enfo

7. In case of electrically powered systems all personnel
and observe the safety regulations. No unqualified pe
try to wire or repair anything on the system.

CHEMICALS

1. Most commonly used chemicals are bleaching-powder and high test hypochlorite (HTH)

2. Bleaching Powder - must be stored in dry, cool place.

3. Minimum stock must be specified depending on the capacity of the system.

4. Persons who get into contact with these chemicals should wash them off immediately.

TOOLS

Where there is no skilled fitter or mechanic in charge, a minimum n number of tools should be kept in order to keep to a minimum repairs that might be attempted by the inexperienced repairman. However, the following should be available:

1. Plug spanner, a pair of spanners to fit the fuel-pipe lines, hammer, screw driver, and pliers for belt fixing.

2. Oil can, grease-gun, fuel and oil measures, watering-can and bucket, head pan, chemical measures.

3. Shovels

Tool Rack

1. Should be designed and built on the walls. Systemmatic labelling of such tools should show at a glance which tool is missing.

2. Should be within easy reach from the floor.

FIRE PROTECTION

Full protection should be provided against fire. Fire-fighting equipment may consist of:

1. Buckets containing sand or water

2. Chemical extinguishers

3. Asbestos blankets.

Regulations

1. Fire-drills should be organized to make sure the men can use the equipment effectively.

2. Fire buckets should be painted red and labelled "Fire". Strict rules must be enforced for proper use of such buckets.

3. Where water stands in a bucket it must be renewed once a week to prevent mosquitoes breeding in the pump-house.

FIRST AID KIT

A first aid kit should be in every pump-house or treatment house. The men should be trained on the proper use of each item in the box. It must be pointed out that these are for the immediate personnel, not relatives. If not checked, this could prove expensive for the water management.

MAINTAINING CONSTANT INVENTORY

1. Whenever an item is used it must be replaced immediately.
2. Spares must be kept in locked cupboards or boxes with proper labels
3. A list of all available spares in the box must be included, a copy of which should be filed.

## TYPES OF FINANCIAL STATEMENTS FOR SMALL WATERWORKS

DETAILED COST BREAKDOWN

A detailed cost breakdown is calculated for the total yearly production of water.

Production Costs

Water pumping labor
Water pumping electricity (or other fuel)
Other production expense
Depreciation
Insurance
Interest
Allocated administrative expense

Total production costs

Distribution costs

Operating expense
Maintenance
Depreciation
Insurance
Interest
Stores expense

Total distribution costs

Other operating costs

Customer accounting and collecting
Administrative and general

Total other operating costs

Total all costs

Total water revenue

Net income to surplus

Administrative and general expense

Sales promotion expense
Sales: general, officers and executives
Other general office salaries
General office supplies and expense
Special services
Legal services
Insurance
Miscellaneous general expense
Maintenance of general property
Rent
Rent on office equipment
Stores expense

Total

STATEMENT OF OPERATING EXPENSES

The following operating expenses are tabulated for both monthly periods and the year to date.

Production expense

Operation supervision
City water pumping labor
Miscellaneous station labor
City water pumping, electricity, and fuel
Station expenses
Maintenance of structures and improvements
Maintenance of city wells
Employees' welfare and expense plant
Treatment labor
Treatment supplies and expense
Maintenance of structures and improvements
Maintenance of treatment equipment

Total

Distribution expense

Operation supervision and engineering
Operation of lines
Services on custo mer premises
Street repairs, labor and material
Maintenance of mains
Maintenance of valves and equipment
Maintenance of services
Maintenance of meters
Employees' welfare and expense--district

Total

Customers' accounts and collecting

Customers' contracts, meter reading
Customers' billing and accounting

Total

PROFIT OR LOSS STATEMENT

The profit or loss statement features, in addition to the following items figures on the number of customers served by the utility, and the amount of water pumped, sold, and lost. The number of customers for that month is compared to the number for the same month in the previous year. The amount of water pumped, sold and lost is tabulated for that month, for the year to date, and for the 12 previous months to date. The net profit or loss is drawn up for that month and the year to date.

Operating revenue

Water sales
Water for city
Interdepartmental sales--plant use

Total

Water taps
Service charges
Miscellaneous revenue

Total operating revenue less charges for water for city

Net operating revenue

Operating expense

Production expense
Distribution expense
Customer collection and accounting
Administrative and general

Total

Depreciation

Total operating expense
Net operating profit

Other expense

Bond interest expense
Interest on contracts

Services to city

Labor and material--fire hydrants
Other services to city

Total

# OPERATION AND MAINTENANCE

## LESSON NO. 1

LESSON OBJECTIVE: To outline rules that must be observed by operators and maintenance men and devise laws safeguard facilities from trespassers.

| TOPIC | INSTRUCTIONAL PROCEDURE | SUPPLEMENTAL MATER RELATED READING |
|---|---|---|
| Rules for efficient maintenance and operation of water works facilities | Discuss need for water inspection. | Nearby water supply system. |
| | Tour nearby pumping stations, treatment and storage facilities. | |
| | Discuss in class how the stations you toured meet these standards. | Section on sanitary standards of water at the source. |
| Protection of facilities from trespassers | Discuss in class the possible (and probable) risks of unrestricted public access to supply facilities. | |

# OPERATION AND MAINTENANCE

## LESSON NO. 2

LESSON OBJECTIVE: To simplify operational and service instructions so that efficient job be done by a relatively inexperienced man.

| TOPIC | INSTRUCTIONAL PROCEDURE | SUPPLEMENTAL MATERIALS / RELATED READING |
|---|---|---|
| Need for simplifying technical instructions. | Discuss in class the difficulty of finding skilled labor in developing countries. | WHO Monograph, Series #42 Chapter 9. |
| How to simplify technical instructions. | Lecture on how to simplify technical materials.<br><br>Demonstrate how to label instructional procedures on a machine. | |
| Exercise | For exercise, give out a sample of manufacturers' instructions to operation of a pump.<br><br>Let students simplify it. | Copies of operators' manual for hand-pump installation if available (relevant substitutes if necessary). |

OPERATION AND MAINTENANCE

LESSON NO. 3

LESSON OBJECTIVE: To prepare a record keeping chart for repairs, set limits to repairs that can be done by the operator and recommend who to contact for major repairs.

| TOPIC | INSTRUCTIONAL PROCEDURE | SUPPLEMENTAL MATERIAL RELATED READING |
|---|---|---|
| Capability of the operator. | Discuss in class how to determine the capability of an operator by serviceman.<br><br>Ask students to draw up criteria for assessing the operators' capability with respect to the structure of the system. | |
| | | |

OPERATION AND MAINTENANCE

LESSON NO. 4

LESSON OBJECTIVE: To draw a detailed map of the distribution systems, specifying regulations for installing new service connections and cleaning procedures.

| TOPIC | INSTRUCTIONAL PROCEDURE | SUPPLEMENTAL MATERIALS / RELATED READING |
|---|---|---|
| Record Keeping | Discuss in class the frustrations of "lost" systems. | Water Supply for Rural Areas and Small Communities, pp. 247-5 (WHO Monograph Series No. 42. Geneva 1959.) |
| | Review section on residual pressure in service connections. | |
| Extension of Distribution Systems | Review the characteristics of dead-end systems.<br>Relate them to the importance of regular flushing of the systems. | Annex 9, p. 316 in same book above. |

OPERATION AND MAINTENANCE

LESSON NO. 5

LESSON OBJECTIVE: To design a system of building up an inventory and emergency precautions.

| TOPIC | INSTRUCTIONAL PROCEDURE | SUPPLEMENTAL MATERIA RELATED READING |
|---|---|---|
| Inventorying | Discuss in class the advantages of long term planning in building up a stock of inventory. | |
| Minimum Required Stock of Spares | Ask students to name what parts of engines require regular replacements. | |
| | Draw up the minimum required stock of spares. | |
| Exercise | For exercise let students determine the minimum stocks for fuels (diesel or petrol) to be recommended for small engines. | Specify engine capac for each student; e. 1 hp., 10 hp., etc. |
| Tool Rack | Demonstrate how to design a good tool rack suitable for use in small pump houses. | |
| Fire-fighting | In the field demonstrate how to use various fire extinguishers and conduct a fire-fighting drill. | |
| First Aid | Demonstrate how to use first-aid kit. | |

OPERATION AND MAINTENANCE

LESSON NO. 6

LESSON OBJECTIVE: To prepare a procedure for systemmatic records of financial transactions.

| TOPIC | INSTRUCTIONAL PROCEDURE | SUPPLEMENTAL MATERIALS / RELATED READING |
|---|---|---|
| Financial Report | Discuss in class the importance of proper financial report as a vital part of good management. | |
| | | |

SECTION 7

## SCOPE OF DISPOSAL SYSTEM PROJECTS IN HOST COMMUNITIES

OVERVIEW:

The primary reason for construction of a disposal project is the improvement of public health standards. Therefore the trainee must learn the characteristics of an adequate system, how disease is carried from excreta and how the excreta may pollute the nearby water supply. To adequately ensure the improvement of the health standards, the community must be taught the importance of using the new facilities.

This section covers these general requirements of a disposal project. The trainee will learn the important characteristics of an adequate system. He will also learn to recognize the human factors that must be considered to ensure the use of the facilities and therefore the effectiveness of the project.

## DISPOSAL SYSTEMS

### SCOPE OF DISPOSAL SYSTEM PROJECTS IN HOST COMMUNITIES

OBJECTIVE: Identify the factors that must be considered in planning an economically feasible village or rural disposal system.

TASKS:

1. Define an adequate sewage disposal system that meets the basic needs of a rural or village environment.

2. Identify the types of appropriate sanitary measures that can usually improve existing rural or village disposal systems.

3. Identify the situations in which cesspools, seepage pits, and septic tanks are potential sources of contamination of the various water supply sources, irrigation systems, or the surface soil.

4. Recognize the significance of community attitudes and habits about sanitation and personal hygiene as they affect the planning and construction of disposal facilities.

5. Identify the situations in which cesspools, seepage pits, and septic tanks are inadequate or not feasible.

FUNCTIONAL SKILLS:

1. List the environmental conditions that are necessary for the transmission of disease from excreta.

2. Identify the agents and avenues of transmission of disease from excreta.

3. Identify the sanitary measures possible within the scope of a rural or village disposal system that will block the transmission of disease from excreta.

4. Identify the types of water supply sources.

5. List how far (vertically and horizontally) faecal borne diseases can be transmitted in a variety of soil and rock types.

6. Alter privy exteriors to be compatible with the attitudes and practices of hygiene in a village or rural community without changing its fundamental characteristics and efficiency.

SCOPE OF DISPOSAL SYSTEM
PROJECTS IN HOST COMMUNITIES (cont.)

7. Calculate the total amount of excreta per day per community.

8. Recognize the benefits to be derived from a well-planned and implemented village disposal system.

9. List the factors that affect the extent of digestion in a pit privy.

10. List the relative costs of septic tanks, cesspools, and seepage pits.

TERMINAL PERFORMANCE TESTS:

1. On a written examination, list the channels of transmission of disease from excreta and identify what sanitary measures can be employed to block these channels.

2. Correctly identify the various types of water supply sources.

3. Given a variety of soil and rock types, correctly list opposite each one how far faecal borne disease can be carried in it.

4. Given an essay describing the personal hygiene habits of several community members, design privy exteriors that are compatible with their practices of personal hygiene.

5. Given the population of a community, calculate the total amount of excreta per day for that community.

6. Correctly recall the probable extent of digestion in a pit privy, list the factors that affect this amount, and list the extent of influence each one of these factors has.

7. Correctly list the relative costs of septic tanks, cesspools, and sewage pits.

# DISPOSAL SYSTEMS

## SCOPE OF DISPOSAL SYSTEM PROJECTS IN HOST COMMUNITIES

### PUBLIC HEALTH IMPORTANCE OF EXCRETA DISPOSAL

The inadequate and insanitary disposal of infected human faeces the contamination of the ground and of water supply sources. It attracts certain species of flies to lay their eggs, to breed, t the exposed material, and to carry infection. It also attracts animals and rodents and other vermin which spread the faeces; an times creates intolerable nuisances.

Poor excreta disposal is often associated with the lack of adequ supplies and of other sanitation facilities and with a low econo or the rural population. These conditions, all affect the healt being of the people in a community.

When proper disposal systems exist, it is known that the inciden large group of diseases is reduced. This group of diseases incl era, typhoid and paratyphoid fevers, the dysenteries, infant dia hookworm disease, ascariasis, bilharziasis, and other similar in infections and parasitic infestations. These diseases lay a hea infants, whose immunity is low and whose vigor is often not grea cope with an infection after it becomes established.

Proper practices of excreta disposal can result in increased life healthier and strong people more effectively able to cope with th ronment, and opportunities for improved local living conditions.

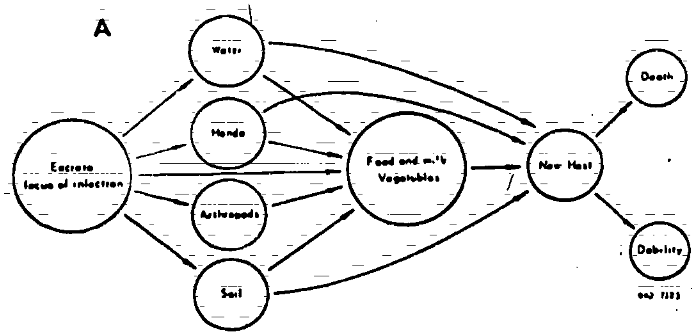
### HOW DISEASE IS CARRIED FROM EXCRETA

Man is the reservoir of most of the diseases that destroy or inca him. The faecal-borne infectious and infestations already mentio the cause of tremendous losses in death and debility. It is inte to note that all these diseases are controllable through good sa especially through sanitary excreta disposal.

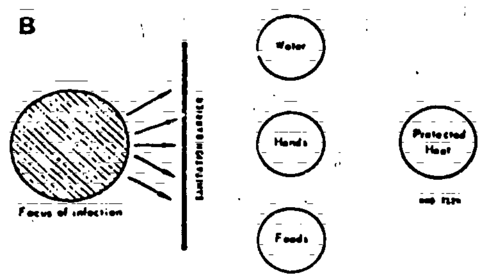
In the transmission of these diseases from the sick, or from car disease, to the healthy, the chain of events, as shown in Fig.59 lar to that for many communicable diseases. In order to transmi the following factors are necessary:

1. causative agent;
2. reservoir or source of infection of the causitive agent;
3. mode of escape from the reservoir;
4. mode of transmission from the reservoir to the potential
5. mode of entry into the new host;
6. susceptible host.

Fig. 59 Transmission of Disease from Excreta




Channels of Transmission of Disease from Excreta




Stopping the Transmission of Faecal-borne Diseases
by Means of Sanitation

The absence of a single one of these six conditions makes the spread of disease impossible. As may be seen from the diagram in Fig. 59, there are many ways in which the causative agent of enteric disease reaches a new host. In different parts of the world, different modes of tr   nission may assume various degrees of importance: in some areas, water,   , and milk may be most important; in others, flies and other insects; and in still others, direct contact may assume a major role. What is most probable is a combination of all, and the sanitary worker must assume that this is the case and guard against all modes of transmission.

THE CHARACTERISTICS OF AN ADEQUATE SYSTEM

The health objective of sanitary excreta disposal is to isolate faeces so that the infectious agents in them cannot possibly get to a new host. Fig. 28 shows the place where a sanitation officer might choose to erect a barrier to break the chain of disease transmission from excreta.

Any adequate disposal system must satisfy the following four conditions:

1. The surface soil should not be contaminated.
2. There should be no contamination of ground water that may enter springs or wells.
3. There should be no contamination of surface water.
4. Excreta should not be accessible to flies or animals.

In addition it is highly desirable that

1. there should be no handling of fresh excreta; or, when this is indispensible, it should be ke-t to a strict minimum.
2. there should be freedom from    s or unsightly conditions.
3. he method used should be sim    and inexpensive in construction and operation.

POSSIBLE SANITARY MEASURES IN RURAL AREAS

It should be noted that, in many countries, more than 80% of the popul tion live in rural areas and small communities and, as a general rule, have a low income. In most cases, all the elements or rural sanitation are absent and indiscriminate fouling of the soil with human excrement is common. Such conditions are also found in rural areas near towns, and aggravate the urban sanitation problems. The menace of inadequate excreta disposal is present so long as sanitary privies are lacking in a community

Rural methods of excreta disposal include privy systems and water-carried sewage systems. Of the privy systems, only the pit privy and sanitary latrines need be considered. Water-carried sewage systems include cesspools, seepage pits, and septic tanks.

## THE PRIVY METHOD

### The Pit Privy

The pit privy is used almost exclusively throughout the Western hemisphere and Europe and is common in parts of Africa and the Middle East. With a minimum of attention to location and construction, there will be no soil pollution and no surface or groundwater contamination. The excreta will not be accessible to flies if the hole is kept covered; but, even when the hole is left open, the fly problem will not be very great since flies are not attracted to dark holes and surfaces. A good super-structure helps to keep the sun's rays and light from shining into the pit. There is no handling of the material. Odors are negligible, and faeces are normally out of sight. The pit privy is simple in design and easy to use, and does not require operation. Its life span will vary from five to fifteen years, depending upon the capacity of the pit and the use and abuse to which it is put. Its chief advantage is that it can be built cheaply, in any part of the world, by the family with little or no outside help and from locally available materials. It has few disadvantages, and it can play a major role in the prevention of filth-borne diseases.

### Water Sealed Latrines

Mention may be made here of the water-seal slab which gives its name to a latrine called "water-seal" or sometimes "pour flush" latrine. The water-seal slab may be installed over a pit (such as that of a pit privy). With proper operation and maintenance, the water seal will keep both flies and odors away. For this reason it may be installed as a part of the dwelling, preferably near the back of the house and with an outside entrance. The water-seal slab is extensively used in South East Asia.

## WATER-CARRIED SEWAGE SYSTEMS

Experience has shown that, when running water is available, the water-carried system of excreta collection and disposal is most satisfactory and convenient under both urban and rural conditions. It fulfills all sanitary and aesthetic criteria. In particular, contamination of the soil and of surface water is avoided; potentially dangerous wastes are rendered inaccessible to flies, rodents, and domestic animals; and the mechanical transmission of faecal-borne diseases to man is prevented.

One serious disadvantage, however, is the difficulty of disposing of the large volume of wastes resulting from the addition of water. While in cities the liquid wastes are usually carried away by means of sewers, in most rural areas of the world sewerage systems do not exist, and liquid wastes are conveniently discharged into the ground. Since in such areas ground water is often tapped as a source of domestic water-supply, there is an obvious need for proper location and construction of the excreta disposal system, with a full understanding of the hazards involved.

Various methods may be used in rural areas to dispose of liquid wastes. They include the use of cesspools and seepage pits, and the septic-tank systems, which involve settling tanks with single or multiple compartments followed by subsurface irrigation fields, filter trenches or sand or trickling filters. Selection of methods will depend primarily upon the degree of sewage treatment to be provided, upon the location of the system and other local factors, and, finally, upon costs. Local factors which bear upon the selection and design of the disposal installation include the nature of soil formations, the presence and levels of ground water and the direction of flow, topography, the proximity of sources of water supply, the quantity of sewage, and the area available for the disposal works.

### The Cesspool

A cesspool is essentially a covered pit which receives raw sewage. It may be of the water-tight or of the leaching type. In some cases, especially in Europe, it is made water-tight and is designed to hold the liquid wastes which must be removed periodically, about every six months. The leaching cesspool, on the contrary, is dug into pervious soils in order to allow the liquid portion of the waste to seep off into the ground. The solids then accumulate in the pit and gradually seal the pores of the ground.

Water-tight cesspools are usually designed for a capacity of 15 gal. per person per month or 90 gal. per person when they are emptied every six months. Leaching cesspools have diameters of 36 in. or more, and are provided with an open-joint lining below the inlet level (see Fig. 60). The top part of the lining, which is within 2-3 ft. of ground level, should be impervious and laid with mortar. Covers with inspection manholes are usually provided. After the pores of the ground become clogged and the pit fills, an outlet tee and an overflow pipe lead the supernatant liquid to a seepage pit.

A cesspool should be located downhill from a well; in any case, a distance of 50 ft. will prevent bacterial pollution of the well. To prevent chemical pollution, too, the distance between a well and a cesspool placed directly uphill from it should be not less than 150 ft. Cesspools of the leaching type should be located at least 20 ft. away from dwelling foundations. Their construction is not permitted by health authorities in densely inhabited communities where wells are used as sources of drinking-water supply.

The Seepage Pit

The seepage oit receives the effluent from aqua privies, cesspools, and septic tanks and allows it to percolate away into the ground. It is sometimes used for the disposal of laundry, bathroom, and kitchen wastes. In the latter case, a grease trap may be necessary on the house sewer-line. The seepage pit may also be built at the lower ends of subsurface disposal tile lines in order to catch the septic-tank effluent which may have gone through without percolating away.

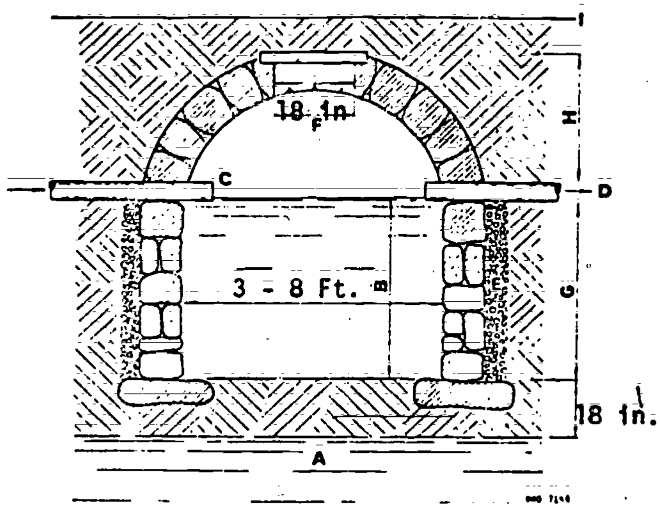
As shown in Fig. 3, the seepage pit consists merely of a round hole in the ground dug deep enough to penetrate 6 ft. or more into a porous layer of the earth. Diameters of 39-100 in. and depths of 7-16 ft. are common. The side walls are lined with bricks or stones laid without mortar below the level of the inlet pipe. The hole may be filled with stones, in which case a lining is not required. The seepage pit should be closed with a tight cover which will prevent access to mosquitos and flies and to surface water as well.

If the soil through which the pit has been dug is not sufficiently porous, the effluent will slowly accumulate and will ultimately overflow. Even in porous soils such a situation is common, as the pores of the earth walls become choked by the deposit of the finely divided matter carried by the effluent and by the solids built up by the life activities of zoogloeal organisms which thrive on the grains of the soil in contact with this effluent. These phenomena, in fact, govern the life span of a seepage pit, which should normally last for several years (perhaps 6-10 years) if the effluent is only slightly turbid as a result of efficient primary treatment of the raw sewage.

When a seepage pit ceases to operate, a new one should be dug several meters away. In order to increase the life span of the disposal system, it is possible to dig two or three seepage pits and to connect them at the top. The distance between any two pits should be at least three times the diameter of the larger pit.

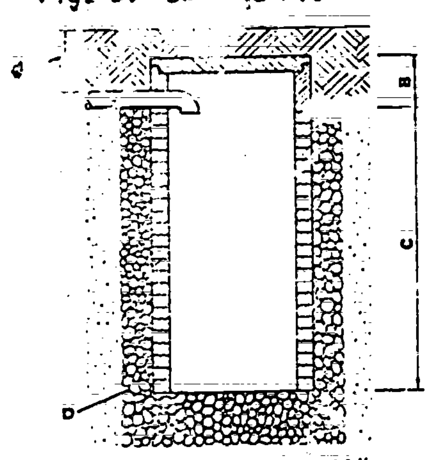
The obvious disadvantage of seepage pits is the danger of pollution of ground water. For this reason they should be carefully located. Seepage pits should preferably be located downhill and, in any case, at least 50 ft. away from drinking-water sources and wells. As in the case of cesspools, the construction of seepage pits is not usually permitted by health authorities in closely built communities where ground water is used for domestic purposes.

Fig. 60 Cesspool Lined with Large Stones




A = Ground Water
B = Depth 7 ft. or more to pervious soil
C = Inlet Pipe
D = Outlet pipe to another cesspool This pipe serves only when first cesspool is clogged and stops working
E = 6-in. layer of coarse gravel
F = Inspection manhole, (20in. x 20in.)
G = Stones laid without mortar
H = Stones laid with mortar
I = Ground Level

Fig. 61 Seepage Pit

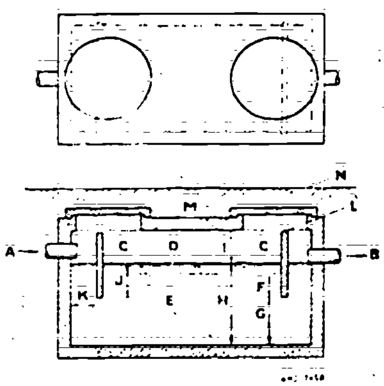



A = Variable depth of soil
B = Cement Joints
C = Open Joints
D = Rock Fill, 6 in. or more

THE SEPTIC TANK

The septic tank is the most useful and satisfactory unit among all water-carried systems of disposal of excreta and other liquid wastes from individual dwellings, small groups of houses, or institutions located in rural areas out of reach of sewer systems. It consists of a covered settling tank into which the raw sewage is led by the building sewer (See Fig. 62,63). The processes which take place inside the septic tank constitute the "primary treatment" of the raw sewage, and those which occur in the disposal field form the "secondary treatment". All liquid wastes, including those from bathrooms and kitchens, may be sent to the septic tank without endangering its normal operation.

Fig. 62 Typical Household Septic Tank




A = Inlet
B = Outlet
C = Baffle
D = Floating scum
E = Sludge
F = Scum-clear space
G = Sludge-clear space
H = Depth of water in tank
I = Clearance
J = Depth of penetration of baffle
K = Distance of baffle to wall, (8-12 in.)
L = Top of baffle 1 in. below roof for ventilation purposes
M = Tank covers, preferably r[illegible]
N = Ground level, less than [illegible] above tank (if less, ra[illegible] tank covers to ground su[illegible]

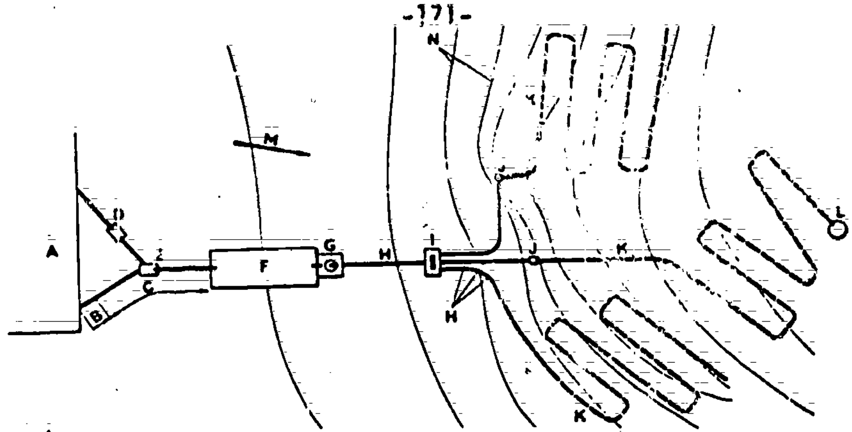
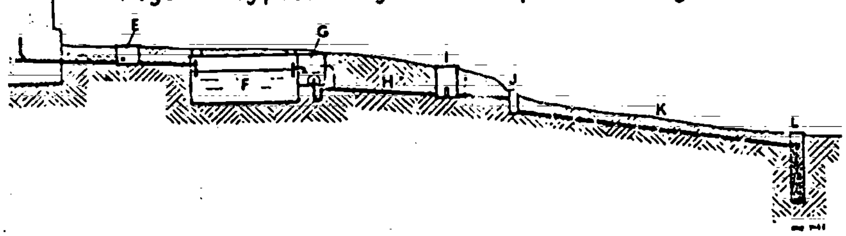


Fig. 63 Typical Layout of Septic-Tank System



A — Private house or public institution
B — House sewer
C — Building sewer
D — Grease interceptor on pipe line from kitchen
E — Manhole
F — Septic tank
G — Dosing chamber and siphon
H — Pipes laid with tight joints
I — Distribution box
J — Drop-boxes or terracotta L's
K — Absorption tile lines
L — Seepage pit, when required
M — Slope of ground surface
N — Topographic contour lines

SOIL AND GROUND-WATER POLLUTION

Knowing how soil and water are polluted by excreta provides useful information concerning the design of disposal facilities, especially their location with respect to sources of drinking--water supplies. After excreta are deposited on the ground or in pits, the bacteria, unable to move much by themselves, may be transported horizontally and downward into the ground by leaching liquids or urine, or by rain water. The distance of travel of bacteria in this way varies with several factors, the most important of which is the porosity of the soil. Their horizontal travel through soil in this manner is usually less than 3 ft. and the downward travel less than 10 ft. in pits open to heavy rains, and not more than 2 ft. normally in porous soils. There is relatively little migration of chemical and bacterial substances. Where the contamination does not enter the ground water, there is practically no danger of contaminating water supplies.

On the surface of the ground, only the earth immediately surrounding the faeces is likely to be contaminated, unless it is carried further by surface water such as rain and irrigation water, blown away by the wind, or picked up by the hair and feet of flies or other insects and animals.

Depending upon conditions of humidity and temperature, pathogenic bacteria and ova of parasitic worms will survive varying lengths of time in the ground. Pathogenic bacteria do not usually find soil a suitable environment for their multiplication, and will die within a few days. On the other hand, hookworm eggs will survive as many as five months in sewage. Hookworm disease is transmitted through contact of the skin, usually bare feet, with soil containing hookworm larvae. Other parasitic diseases are also transmitted when fresh faeces or sewage is used, during the growing season, to fertilize vegetable crops which are eaten raw.

If ground water is located near a source of infection within the distances mentioned above, it may become contaminated by harmful bacteria and by putrid chemical substances originating in faecal decomposition.

From the point of view of sanitation, the interest is in the maximum migrations and the fact that the direction of migration is always that of the flow of ground water. In locating wells, it must be remembered that the water within the circle of influence of the well flows towards the well. No ~~part of the~~ area of chemical or bacterial contamination may be within reach of the circle of influence of the well.

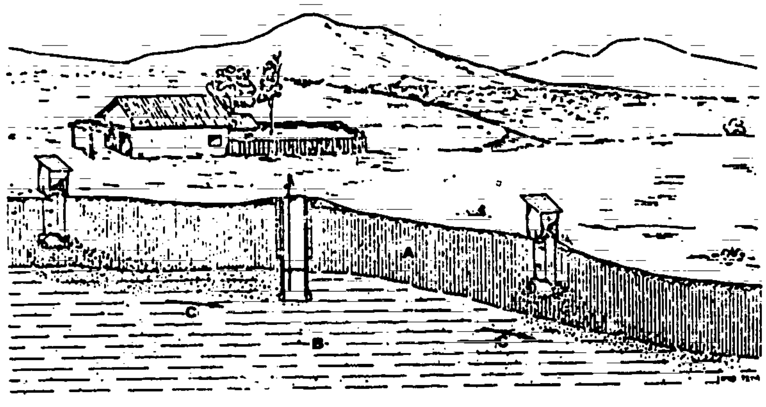



Fig. 64 Movement of Pollution in Underground Water

## LOCATION OF LATRINES AND OTHER EXCRETA DISPOSAL FACILITIES

There can be no standard rule governing the distance that is necessary for safety between the privy and a source of water supply. Many factors, such as slope and level of ground water and soil-permeability, affect the removal of bacteria in ground water. It is of the greatest importance to locate the privy or cesspool downhill, or at least on some level piece of land, and to avoid, if possible, placing it directly uphill from a well. Where uphill locations cannot be avoided, a distance of 50 ft. will prevent bacterial pollution of well. Setting the privy off to either the right or the left would considerably lessen the possibility of contaminating the ground water reaching the well. In sandy soil a privy may be located as close as 25 ft. from a properly constructed household well if it is impossible to place it at a greater distance. In the case of a higher-yielding well, not less than 50 ft. should separate the well from a latrine.

In homogeneous soils the chance of ground-water pollution is virtually nil if the bottom of a latrine is more than 5 ft. above the ground-water table. The same may be said if the bottom of a cesspool is more than 10 ft. above the level of the ground water.

A careful investigation should be made before building pit privies, bored-hole latrines, cesspools, and seepage pits in areas containing fissured rocks or limestone formations, since pollution may be carried directly through solution channels and without natural filtration to distant well or other sources of drinking-water supplies

Regarding the location of latrines with respect to dwellings, the distance between the two is an important consideration in the acceptability of the sanitary facilities. The location of latrines, private or communal, at a considerable distance or away and uphill from dwellings, will often cause local people to avoid their regular use and proper maintenance. A latrine will more likely be kept clean if it is close to the house or other building which it serves.

Other considerations are as follows:

(1) The site should be dry, well drained, and above flood level.

(2) The immediate surrounding of the latrine-i.e., an area 6.5 ft. wide around the structure--should be cleared of all vegetation, wastes, and other debris. This recommendation may be ignored, however, in the initial stages of sanitary development of rural areas where it is necessary, for example, in order to secure acceptability of the latrine by the local population, to avoid disturbing the natural bush-type surroundings which were previously used for defaecation.

SLUDGE ACCUMULATION AND THE LIFE OF A PIT PRIVY

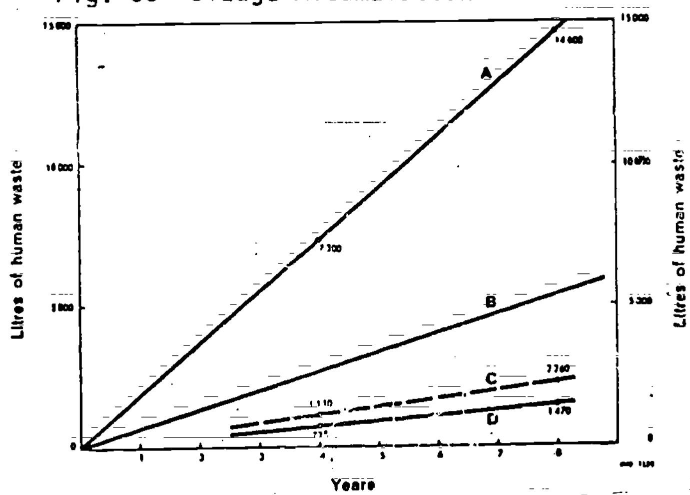
The life of a pit privy is directly proportional to the time required for a pit to fill. This time is determined by the rate of digestion in the privy. The factors that influence the rate of digestion in a pit are:

(1) the efficiency of bacteriological decomposition.
(2) the degree of abuse to which the pit is subjected (i.e. the stones, sticks, garbage, mud balls thrown into it).
(3) the method of anal cleansing.

The rate of accumulation of digested sludge and of partially digested excreta is not directly proportional to the amount of excreta added each year. This phenomenon is illustrated graphically in Fig. 65. From this graph it will be noted that, after the digestion process has been well established, the actual volume of material in a wet pit might be reduced in time to approximately 10% of the total waste (faeces and urine) deposited. This graph is very approximate, however, and may need to be substantially modified for different areas.

In wet pits, assuming that the daily production of one quart of excrement contains 3.5 oz. of dry solids and that digestion for one year under wet-pit conditions will reduce this mass by 30%, a total of 0.7 oz. of dry solids will remain. Further assuming an 80% moisture content in the digested sludge, one arrives at the figure of 3.5 oz. of wet sludge after one-year digestion period.

Fig. 65 Sludge Accumulation in Pit Latrines




A — Human waste (liquid and solid) deposited in pit by a family of five (at the rate of one litre, or quart, per person per day)
B — Corresponding amounts of solid wastes alone (approximately)
C — Rate of accumulation of sludge, by volume, in dry pit
D — Rate of accumulation of sludge, by volume, in wet pit

This amounts to 1.3 cu. ft. per person per year. Thus, a family of five would require sludge-storage space of 6.5 cu. ft. per year.

It is recommended that for the design of the effective capacity of wet-pit latrines a provision of 1.3 cu. ft. per person per year should be allowed. If cleansing materials such as grass, stones, mud balls, coconut husks, or similar solids are used, it is recommended that this figure be increased by 50% to a total of 2.0 cu. ft. per person per year.

Digestion of solids is about 50% less rapid and less complete in dry-pit latrines than in wet-pit latrines. In designing dry-pit latrines, a provision of 2 cu. ft. per person per year is recommended, to be increased resulting economic loss. Therefore, between these two extremes a solution should be found that will give the most in health protection and, at the same time, will be within the economic possibilities of the people to construct and maintain. Every sanitation worker should carefully consider this aspect of the problem, not only as it applies to privies, but also as it relates to every other type of sanitary improvement. It is relatively easy to decide on a privy campaign for a rural area from a health department office situated far away in the state or provincial capital simply by choosing a design that appears to be satisfactory because it has been used somewhere in the world. This is the kind of privy program which has resulted in empty, abandoned, and unused installations in so many places.

COMMUNITY PARTICIPATION

A program of rural sanitation cannot be successful without the participation of the local community. To be truly effective, environmental sanitation needs the understanding, the support and the active participation of the people concerned. Mere technical improvement of the environment without public education in hygiene and sanitation, based on local customs, traditions, and beliefs, has again and again proved futile.

One measure of the success of a rural sanitation program is its power to sustain itself and grow. In order to achieve this success, it is necessary to find ways of gaining popular support and of overcoming popular objection. In both, health education of the public plays a major role. In the former instance, attention must be given to the structure and organization of a program which will fit into the local social and economic system. More important still is the desirability of bringing the people into the program as partners. In the pursuit of the second objective, the assistance of a competent health educator may be required. It is very likely that, even before reaching the stage of overcoming popular objection, you may have to undertake the task of disturbing the age-old apathy and inertia which grip the people. For example, the fact that a community is without adequate excreta disposal facilities immediately suggests to a health worker the need for providing latrines. However, the community may not be ready for, or interested in, such facilities, or may even be hostile to them. To insist upon the immediate introduction of latrines into a community under such circumstances is not a wise move. Always guard against doing things to people and for people before you have fostered individual and local initiative, responsibility, and self-reliance on a well-informed basis.

This health education stage can be the most difficult hurdle to clear. Once it is successfully passed, the program will move at a faster rate. For example, in the rural areas of several Latin American countries where community health programs have been going on for some time, privies are constructed almost exclusively by the families, with the health department supplying the necessary guidance and the concrete privy slab either at cost or gratis. In many places the demand for slabs is always greater than the supply.

Experience shows that the most important factor in getting the community to participate is to bring members from all its segments into the program. The people must, however, understand what the program is all about. This may be achieved by working th[illegible]h the village council, if one exists, and if not, through a village committee set up at the planning stage and comprising prominent and respected leaders of the community. Further progress will come from the assimilation and use of scientific excreta disposal principles by the villagers themselves, and this can be realized only if they take part in the survey, planning, and conduct of the program. One should expect that initial progress will be rather slow and that it may be necessary to plan the program in successive stages stretched over a period of time.

The practical application of these principles is essential for lasting progress in rural sanitation. In addition, a specific local project or activity in sanitation initiated in response to a local demand can serve as a very practical basis for stimulating local interest and participation in attacking other basic problems, and thus act [illegible] important spearhead for the promotion of community development.

FAMILY PARTICIPATION

Since one of the ultimate objectives of a sanitation program in a community is to get the family to solve its own excreta disposal problems (within reason, of course), it is important that each family unit participate in some way in its execution. Whatever the nature of the sanitation needs and related health problems, you can gain the interest of people by a sympathetic and practical approach to their problems. People who come to a health center or dispensary (mobile or stationary) seeking treatment of intestinal disorders are usually receptive to suggestions as to how to avoid dysentery and diarrhoea. Full advantage should be taken of such opportunities to help make the people aware of the measures which can be applied at home and in the community to prevent these conditions. Practical demonstrations and discussions of latrine construction, aided by the use of visual media based on local situations-e.g., photographs, slides, posters, film strips, film exhibits, and others-may be particularly helpful.

Once the family is willing to participate in the scheme and to learn a new habit, you must be ready to offer a solution which is acceptable and as simple and economical as possible. When sanitation and personal hygiene become habits, the health program will have made tremendous progress.

The sanitation work cannot be considered completed, however, after the construction of the first privy or latrine: in fact, it has just begun. You must remain continuously in touch with the family to stimulate and educate its members into using and maintaining this facility, which often has been constructed after hard and time-consuming labor. Th[illegible] educational process involved requires the co-operation of th[illegible]h staff, in your area. Success has been achieved only when the [illegible] accepted the privy as a part of its way of life, and is willing [illegible]tain it, to rebuild it, and to move it to a new location, as necessity demands, and even to become a disciple in teaching the neighbors.

Mention has been made of simple and economical solutions to the family's excreta disposal problems. Finding reasonable solutions considered to be one of the keys to active family participation. These are not always to find. Undoubtedly there are places where nature, aided perhaps by makes it very difficult, if not impossible, to devise simple and econ facilities. In these situations, ingenuity and ability are taxed to limit. You must be resourceful in making use of available materials in organizing the people of the community for the difficult tasks at In some instances extra technical and financial assistance may be req from the local government health department. The family cannot be ex to perform difficult and complicated construction operations. You sh strive to propose and design solutions that are within the means and of the people to operate, maintain, and replace. This is true of a family privy, a village well, a public water-supply system, or large and sewage-treatment works.

As to actual modes of obtaining family participation, the best method those in which initial work and expenses are shared by the family and health authorities or other agencies. Family contribution either may financial or may take the form of labor and materials. Although fina contribution by the villagers, is highly desirable, it will be found tageous in the early stages of a program to secure the actual partici of the people in the work, which is being executed for their own bene People are more likely to put into daily practice those learning expe in which self-initiative and self-help are considerable, even if the of the self-help is limited to the provision of manpower and locally able material.

In an effort to give proper importance to the construction of privies has been made in Latin America, with remarkable success, of simple co between the health department and the head of the family. The contra state in simple direct terms the obligations of each party, so that understanding can arise. This impresses on the family the importance both parties attach to the privy as a vital element in household heal The application of this technique depends on a patient and enthusiast volunteer, for it takes time to talk to each family and explain over over the need for a sanitary privy and the benefits which can be deri from its daily use.

Another technique used with success in some countries in South-East A consists of "selling" the program to respected leaders of the communi and helping them, first, to install their latrines. The possession o sanitary latrine thus becomes associated with a position of prestige the community.

ROLE OF HEALTH DEPARTMENT AND OTHER AGENCIES

The health department (if one exists) should be approached for assist in organizing demonstration or pilot schemes of excreta disposal. Su demonstrations should be carried out first in health and welfare cent in schools, and in residences of local health and sanitation officials A demonstration plot of land suitably located and provided with sanit excreta disposal units in various stages of completion is a desirable in a planned sanitation improvement and training program. The health partment should help to make available to the people and their leader leaflets and manuals covering the design, construction, and operation of excreta disposal facilities that fit the conditions encountered in the areas concerned.

Wherever bad construction, poor ventilation and lighting, lack of washing facilities, insanitary toilets, or similar deficiencies exist [in schools], children will be absorbing wrong ideas and learning harmful habits which may never be eradicated...Similarly, a well-built and well-kept latrine may be far safer as well as of greater fundamental education value than a porcelain and tile toilet which is allowed to become dirty and a nuisance.

Mere classroom teaching of sanitation, unaccompanied by actual demonstration, will have little-if any-effect on children. It is well known that children learn by doing and through example, two facts which can be used to advantage in leading school children into the practice of a sanitary way of living. It goes without saying that you should lead the way and give the proper example to the people by living and working in sanitary surroundings.

Under certain circumstances, the role of the health department should be increased scope and importance. Such situations would arise, for example, in areas where crowding of houses or hard ground conditions make it necessary to put in some kind of collective sanitation facility, deep-bored holes inside houses, precast hand-flush installations in houses, or other types of excreta disposal systems which, because of physical circumstances, cannot be erected by the families themselves. In these cases a government, through its health department, may need to set up and maintain an efficient organization to carry out excreta disposal construction work. Here also the active participation and contribution of the local populations in the form of labor, materials, and money are absolutely required for the ultimate success of the excreta disposal program. The people should never be led to rely entirely on the health department for the provision, maintenance, or renewel of their sanitary facilities. An alternative solution which may sometimes be used involves the formation of construction co-operatives by the people themselves under the sponsorship of the health department with your support.

PUBLIC VERSUS PRIVATE LATRINES

Public latrines, or "multiple unit" types, are usually constructed in markets, camps, schools, factories, slum districts, and similar localities. They are also useful in other places where large numbers of persons congregate occasionally, provided that permanent and close attention is available to ensure cleanliness and proper operation.

Except in unusual circumstances though, multiple units should never be substituted for the individual family latrine. True, it is cheaper and less troublesome to construct a few communal latrines in a community than to build a large number of individual latrines at the rate of one unit per family. In addition, a good solution to each family's excreta disposal problem is not always easy to find. For such reasons the construction of the communal type of excreta disposal facility was accepted in the past, even in urban communities. However, it was discovered after a few years' use that these public latrines were employed by only a portion of the population for which they were intended, the remaining group continuing the original practice of defaecating anywhere. It was then believed that two reasons for this situation were inadequate design and the lack of cleanliness. Attempts were made to improve these elements; but in most cases, communal latrines, irrespective of the type of design, proved to be failures.

It should be pointed out that the community is generally made responsible for the maintenance of public units. Usually communal administrations are notoriously poor and ineffective at maintaining even the utilities that offer great convenience, such as water works and electric light systems, let alone a communal privy which many do not consider essential in any case. This does not mean that the construction of public latrines should be disregarded; but keep their limitations in mind and remember that they will not be automatically and efficiently maintained by the community. The truth is that the communal authorities must be prodded on this important matter of maintenance as much as, or more than, the family. So long as the effort to ensure good maintenance must be made, it is decidedly better to spend it on the family, on whom there is hope of its eventually having the desired effect. Families will usually keep their own latrines clean and in proper operation with only occasional guidance from the public health inspector.

Public latrines, therefore, should be built only where absolutely necessary and should be designed to facilitate maintenance and constructed for permanence, as far as possible. They must be kept clean at all times, for, unless cleanliness is observed, they will not be used. Water and other materials must be available for use in keeping the latrines clean.

HUMAN FACTORS

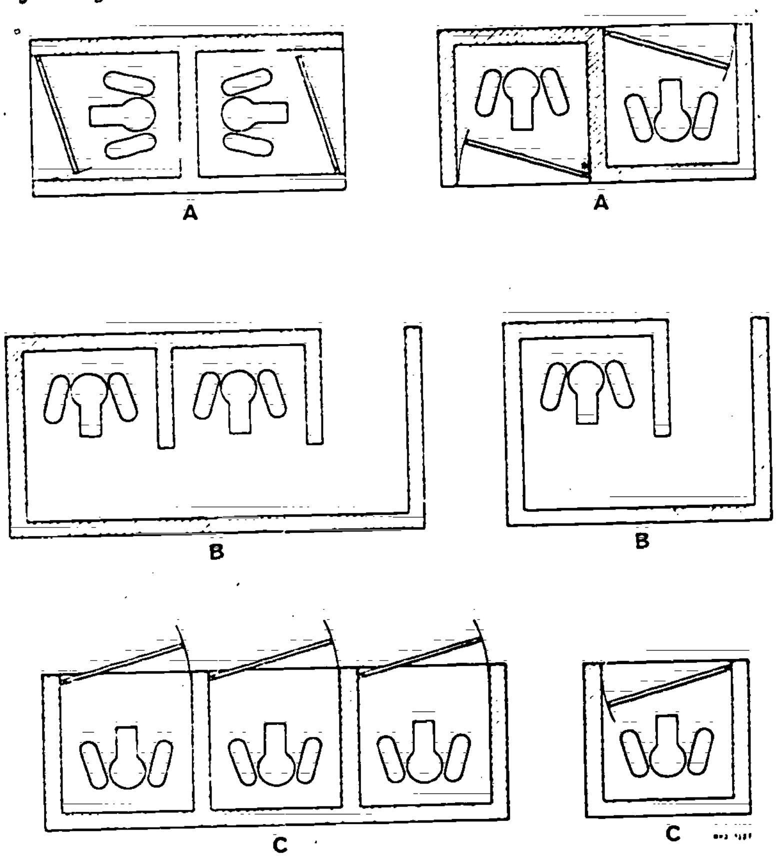
In all matters of excreta disposal, human factors are as important as technical features. People, especially inhabitants of rural areas, will not use a latrine of a type which they dislike, or which does not afford adequate privacy or, finally, which cannot be kept clean.

Regarding the type of latrine which should be selected, the preliminary sanitation and sociological survey will indicate the types of facilities, if any, in use in the area. The first step in design will therefore be to try to improve the existing system, retaining as many as possible of its 'sociological' features. Two examples may be cited to illustrate this important point. Water-flush-type latrines with risers and seats, though best from the sanitary standpoint, have not normally been found acceptable by people who are used to defaecating in the bush in a squatting position. In another instance, people readily accepted pit privies which were built within a thatch and bamboo enclosure without a roof, as they preferred to squat in the open air. Everywhere in the world people have certain taboos with respect to the collection and disposal of human faeces. While it is impossible to study them all, you should pay much attention to them and should avail yourself at all times of the assistance of experienced health educators, social anthropologists, or sociologists to discover the right approach to the solution of the excreta disposal problem of rural communities.

The next important human factors to be considered are the matters of privacy and of separation of the facilities provided for men and for women. Various systems have been designed to provide privacy; they are shown in Fig. 66 together with those for separating the sexes. It will be noted that latrine doors should preferably open inwards.

A latrine, whether of the family or communal type, the design of which does not allow easy cleaning will also not be acceptable to most people. In this respect, smooth, hard-surface floors of concrete, cement, brick, or similar material are best because it is easy to flush them with water.

A latrine which is designed for too large a number of people will probably get dirty quickly and remain so, with the result that late callers will prefer to go and defaecate around the latrine building or in a neighboring bush. A one-hole latrine is adequate for a family of five or six persons. For communal latrines in camps, markets, and similar places, one hole should be provided for every 15 persons; and in schools, one hole for every 15 girls and one hole plus a urinal for every 25 boys.




A – These two layouts ensure complete separation of the sexes.
B – Semi-private installation. Snail-type entrance. Defaecation may take place in corridor passage when latrine floor is dirty.
C – Preferred types, ensuring complete privacy.

Fig. 66 Privy Designs Ensuring Privacy and Separation of the Sexes

# SCOPE OF DISPOSAL SYSTEMS IN MOST COMMUNITIES

## LESSON NO. 1

LESSON OBJECTIVE: Define the characteristics of an adequate sewage disposal that meets the basic requirements of a village or rural environment.

| TOPIC | INSTRUCTIONAL PROCEDURE | SUPPLEMENTAL MATERIALS / RELATED READING |
|---|---|---|
| Disease Transmission | Illustrate<br>1) the environmental conditions<br>2) the agents and the avenues necessary for the transmission of disease from excreta. | Charts of Figure 7.1 |
| The Adequate System | Outline the characteristics of an adequate system. | |
| Methods of Rural Sanitation | List the methods available to block the avenues of disease transmission.<br><br>List which of the above is the most economically practical.<br><br>Discuss the character of<br>1) the pit privy<br>2) the water seal latrine<br>3) the cesspool<br>4) the seepage pit<br>5) the septic tank.<br><br>Organize students to estimate the relative cost of these systems from the list of components. | Rural Sanitation in the Tropics (inclusive) |

# SCOPE OF DISPOSAL SYSTEMS IN HOST COMMUNITIES

## LESSON NO. 2

LESSON OBJECTIVE: Discuss the factors that must be considered in locating sanitary facilities and the determination of the type of facility to be implemented.

| TOPIC | INSTRUCTIONAL PROCEDURE | SUPPLEMENTAL MATERIALS RELATED READING |
|---|---|---|
| The Movement of Pollution | Discuss the movement (vertical and horizontal) of faecal borne diseases and chemical pollution.<br><br>Recall the distances sanitary systems must be from water supply sources when located in homogeneous soils, fissured limestone formations and sandy soils. | Diagrams illustrating the underground movement of pollution. |
| Privy Location | Outline the parameters that must be considered in the location of excreta disposal facilities. | The Sanitary Code Article XI, p. 10-11 |
| Digestion of Excreta | List the most probable weight (wet and dry) of excreta produced per day per person<br><br>Recall the factors that influence this figure.<br><br>Outline the factors that affect the extent of digestion in a pit privy.<br><br>List the most probable rate of sludge build-up in wet and dry privies.<br><br>Discuss the factors that influence this figure.<br><br>Recall the service life for privies of various volumes. | A Chart of Figure 8. |
| System Requirements | Assemble students for an individual performance test in which they determine<br>1) the number of facilities required<br>2) the various volumes of these facilities (pit privies) for a community whose population and population distribution is given. | |
| General Factors in Privy Selection | Outline the general factors that must be considered in determining the type of facilities to be implemented. | |

SCOPE OF DISPOSAL SYSTEMS
IN HOST COMMUNITIES

LESSON NO. 3

LESSON OBJECTIVE: Discuss the sociological factors that must be considered in planning a rural or village disposal system.

| TOPIC | INSTRUCTIONAL PROCEDURE | SUPPLEMENTAL MATERIALS RELATED READING |
|---|---|---|
| Social Factors in Privy Selection | Outline the social factors that contribute to the success of an excreta disposal program. | WHO Monograph Series #39 p. 17-38 |
| Privy Exteriors | Demonstrate how to alter privy exteriors to be compatible with the attitudes and practices of hygiene. | |

## SECTION 8

## THE PRIVY METHOD OF EXCRETA DISPOSAL
## DESIGN FOR A VILLAGE

OVERVIEW:

A sanitary survey and a description of the area where a disposal system will be installed is necessary so the project will ensure the public health. This section covers the design and construction of disposal projects of the privy type. The trainees will learn to construct several types of privy and be able to make the proper selection for a given situation.

SECTION 8 THE PRIVY METHOD OF EXCRETA DISPOSAL
DESIGN FOR A VILLAGE

OBJECTIVE: Design, plan, and construct a privy system which extends the present system to provide minimum satisfactory service within the community's social and economic limits of acceptability.

TASKS:

1. Establish criteria that proposed system must meet.
2. Define the capacity of the present system.
3. Sketch the location of any disposal facilities with respect to any water supply sources, irrigation systems, and food supply areas.
4. Determine whether these facilities are potential sources of contamination of any of the above.
5. For each disposal facility that is a potential source of contamination, determine whether a feasible means for arresting this situation is available.
6. Estimate population and define the community's capacity requirements for a disposal system.
7. Determine whether the present system is adequate in terms of the community requirements and the design criteria established above.
8. Define the extent to which new installations are necessary.
9. Determine the attitude toward sanitation and the practices of personal hygiene in the community.
10. Determine which types of installations are most likely to be maintained by the community.
11. Determine where any new facilities should be located so that:
    a. They do not contaminate any of the existing water supply sources.
    b. They are dry, well drained, and above flood level.
    c. They are compatible with social attitudes in the community.
12. Identify the types of pit privy systems that satisfy the design criteria.

THE PRIVY METHOD OF EXCRETA DISPOSAL
DESIGN FOR A VILLAGE (cont.)

13. Determine what material and financial resources are available.

14. Prepare a plan to acquire public support toward and finances for the system.

15. Select the privy system that is most feasible.

16. Set up a program to construct this privy system.

17. Carry out this program.

FUNCTIONAL SKILLS:

1. Bore a test hole with a hand-held auger.

2. Determine how far faecal borne diseases can be carried in each of the strata or soils encountered in the test hole.

3. Conduct a survey to determine the population of the community.

4. Estimate the volume of pits, holes, and tanks.

5. Determine the practices of hygiene in the community.

6. Identify the components of various types of pit privies.

7. Dig a pit.

8. Mix concrete

9. Construct structures with brick, stone masonry, and rough cut logs.

10. Train local persons in the masonry and carpentry skills needed to build the system.

11. Provide instruction in the maintenance of the system.

TERMINAL PERFORMANCE TESTS:

1. With a hand-held auger, bore a hole, with horizontal dimensions of from 4 to 12 inches to a depth of 24 feet and determine how far faecal borne diseases can be carried in each of the strata or soils encountered in this test hole.

THE PRIVY METHOD OF EXCRETA DISPOSAL - DESIGN FOR A VILLAGE (cont.)

2. Determine the population of a designated community.

3. In a field exercise, determine the volume of any pits, holes, and tanks.

4. Determine the practices of personal hygiene in a designated community.

5. On a written examination, sketch three different designs for pit privies and list opposite each one of these the materials needed for construction.

6. Given the designs and materials needed to construct a pit privy, in a field exercise, construct this privy.

THE SANITARY SURVEY

In most rural areas, community sanitary surveys are usually necessary to obtain first-hand information concerning local sanitary conditions and needs. Such surveys, undertaken with the participation of local leaders of the community, will be of immense help in program planning and evaluation. Such a survey should cover the following factors.

DESCRIPTION OF AREA

1. location, topography, climate, character, communications, maps;

2. geology and hydrology, with particular reference to nature of top and underground layers of the soil, its porosity, presence and abundance of ground water (if any), direction of flow, level of ground-water table, its appearance and potability, estimation of yields of springs, rivers, and so on;

3. population--number, constitution by age-groups and sex, density, growth;

4. industries and agriculture, with particular reference to irrigation, drainage, and soil fertilizing practices;

MEDICAL AND SANITARY DATA

1. general health of the population, with special emphasis on communicable diseases and on intestinal infections;

2. vital statistics, mortality and morbidity data;

3. health and sanitary administration, with reference to organization, personnel, budget, and activities of voluntary or other agencies in the field of sanitation;

4. existing sanitary conditions in the area, with reference to description of private and public latrines, their distribution and use; to wells, springs, and other systems of water supply (including such information as number of persons served by piped water-supplies, and by wells, the consumption and uses of water, number of dwellings with private water supply, etc); to wastes collection, disposal, and composting; to milk and food sanitation; to insects (flies, fleas, lice, mosquitos); to health aspects and standards of housing; and to school sanitation.

5. sociological and cultural patterns, with particular reference to community and family organization, leadership; customs, beliefs, and habits bearing on personal hygiene and community sanitation; present methods (if any) of health education of the public.

RESOURCES AVAILABLE

1. general economic level of the population; average income per worker;

2. co-operation expected from agricultural, educational, and other agencies or groups for training and health education of the public;

3. housing and vehicle transport for program, vehicle and equipment repair and maintenance facilities; sources or power (electricity, fuel);

4. local construction materials and their costs;

5. local craftsmen and wages;

6. potential resources for self-help;

This information has an important bearing on the project andmakes it possible to make a reasonably accurate cost estimate. Such a survey is a useful educational tool and also serves to acquaint the PCV with the families and with their customs, beliefs, interests, and attitudes. In short, it helps to prepare a "social map" of the community.

## THE PIT PRIVY

### DESCRIPTION

The pit privy consists of a hand-dug hole in the ground covered with either a squatting plate or a slab provided with riser and seat. A superstructure or house is then built around it.

### DESIGN AND FUNCTION OF ITS PARTS

#### The Pit

The function of the pit is to isolate and store human excreta in such a way that no harmful bacteria can be carried there from to a new host. The pit is usually round or square for the individual family installation and rectangular for the public latrine. Its dimensions vary from 36 in. to 48 in. in diameter or square. Common figures for family latrines are 36 in. diameter or 42 in. square. For public installations, the pit will be 36 in. to 40 in. wide; its length will depend upon the number of holes provided. The depth is usually about 8 ft. but may vary from 6 ft. to 16 ft. In Iran, and elsewhere, some pits have been dug to a depth of 23-26 ft. in soils which are very stable.

##### Lining of the Pit

It is often necessary to provide a pit lining to prevent the sides from caving in. This is true especially in rainy seasons where privies are dug in fine-grained alluvial soils, sandy soils, and similar formations, or when they penetrate deeply into ground water. Even in stable soil formations, it is desirable to line the top 16-24 in. of the pit in order to consolidate it and to prevent it from caving in under the weight of the floor and the superstructure.

Materials commonly used for this purpose include bricks, stones, concrete blocks, laterite blocks, adobe materials, lumber rough-hewn logs, split cane, and bamboo. When the first five materials mentioned above are used, they are laid with open joints over most of the walls' height and with mortar near the top of the walls, the reason being that with these material the lining also serves usefully as a base for the floor. Brick linings should preferably be round, not square, as they then develop arch action and are much stronger for the same wall thickness. Wooden logs and bamboo should be used exclusively to support the walls of the pit, not as a foundation for the floor. Rough-hewn logs will of course, last longer than bamboo linings. If possible both logs and bamboo should be tarred in order to increase their useful life. The use of rot-and termite-resistant woods is recommended wherever possible.

Where a lining is necessary, it is often given to the family by the health department, along with the floor or slab.

The Base

The base serves as a solid, impervious foundation upon which the floor can rest. It also helps to prevent the movement of hookworm larvae. Properly made of a hard, durable material, it helps to prevent the entrance of burrowing rodents and of surface water into the pit. Pit lining in most cases will serve as a base although it may need to be strengthened at the ground surface.

The foundation should be at least 4in. wide on top in order to provide a good surface for the floor to rest upon, and 6 in. or more at the bottom in order to give a stable contact with the ground. Its shape will be that which will fit the pit. The base should be high enough to raise the floor 6 in. above the level of the surrounding ground, thus, with the mound, protecting the pit from flooding.

The following materials may be used in the construction of the base:

a. plain or reinforced pre-cast concrete--same mix as floors;
b. soil cement--5%-6% cement mixed with sandy clay soil and tamped at optimum moisture content;
c. clay--tight clay, well tamped at optimum moisture content;
d. brick--mud-dried, burned, adobe, etc.
e. stone masonry;
f. rough-cut logs--hardwood, termite-resistant.

The Floor

The floor supports the user and covers the pit. It should be constructed so as to fit tightly on the base, with a minimum of small cracks and openings between the surfaces. The squat-type plate or slab for pit privies is the most suitable for rural conditions in most parts of the world. However, in many countries a slab provided with a riser and seat may be found to be more acceptable. This aspect of slab design requires careful consideration. An eminent health educator and social anthropologist has stated that customary posture in defaecating is perhaps the single most important fact bearing on the acceptance or rejection of privies.

The floor or slab should normally extend to the superstructure walls, as a peripheral earth strip might be soiled and become a medium for hookworm infestation. It should be made of a durable impervious material with a hard surface which will facilitate cleaning. Materials commonly employed include:

a. reinforced concrete;
b. reinforced concrete with brick filler;
c. wood;
d. built-up floor of small-diameter wooden poles with chinks filled by mud or soil-cement mixture.

The consensus of opinion is that concrete is, in the long run, the most practicable, most acceptable, and cheapest material for the privy floor. Wooden floors come next in the line of preference. "Built-up" floors, are less desirable because they are difficult to keep clean and, as they get soiled (especially by children), are likely to spread hookworm.

Latrine slabs or floors may be round, square, or rectangular. When slabs are to be made or cast at a central shop, it is advantageous to adopt a standard shape and size in order to facilitate production. The size of concrete slabs, which influences to a certain degree the cross-sectional area of the pit and the size of the superstructure, is governed by their weight and by the difficulty of transportation (where this applies).

All factors considered, appropriate dimensions for concrete slabs may be 39 x 39 in. in over-all size. Such a slab will weigh approximately 300 lb. if the average thickness is 2.5 in. Smaller slabs, 3 x 3ft. have been built where it is easy to complete the floor at the site with a cement surface. Round slabs, 3 ft. in diameter, have also been used. Their advantage is that they may be rolled to the latrine site instead of being transported.

The thickness of slabs also varies a great deal in practice. In order to reduce weight, the tendency, of course, has been to reduce the thickness to a minimum consistent with safety. In this respect, however, much depends on the quality of the concrete and the reinforcement available. When these factors are satisfactory the slab may be 2.5 in. - 3in. thick on its edges and 2 in. thick at its center. A slab 1 yd. square will then weigh approximately 286 lb. The surface of the slab will slope towards the hole, which is an advantage in Asian countries where water is used for anal cleansing. Where solid cleansing materials are used; the slab may be of uniform thickness throughout, but not less than 2.5 in. thick.

Where it is not possible to cast concrete slabs in place and where the problem of transportation is serious, the possibility of casting the slab in four parts may be considered.

With respect to the shape and size of squatting plates, the following are important considerations:

1. The opening should be large enough and shaped so as to minimize-or better, prevent--soiling of the floor. An opening having an effective length of about 15 in. preferably more, will satisfy this requirement.

2. It should not be so large that small children may fall into the pit. An opening having an effective width or diameter of 7 in. or less will satisfy this requirement.

In communal installations, the number of openings will depend on the number of people to be served. It is good practice to provide one hole for not more than 15 users, preferably one for each 10-12 persons.

It is often recommended that squatting plates should be provided with slanting foot-rests to minimize the possibility of soiling the floor. Foot-rests usually form an integral part of the squatting plate and should be designed to be used by both adults and children. When foot-rests are not properly built--for instance, when they join the floor at a sharp angle or are excessively long, etc.--they make it difficult to clean and scrub the floor.

Another factor affecting the acceptance or rejection of a privy by the users is the free distance from the opening to the back wall of the latrine. When this distance is too small, the back of the user will rest against the wall, which may not at all times be very clean and free from ants or other insects. Also, there is a chance that excreta may soil the upper portion of the pit wall. Yet this distance should not be too large; otherwise there is a likelihood that the back part of the floor will be soiled. The minimum distance between the rear edge of the opening and the superstructure wall should be no less than 4 in. preferably 6 in. and maximum of 7 in.

The Mound

The function of the mound is to protect the pit and base from surface run-off which otherwise might enter and destroy the pit. It should be built up to the level of the floor and be very well tamped. It should extend 20 in. beyond the base on all sides. In exceptional cases in flood plains and tidal areas, the mound may be built up considerably above the ground for protection against tides and flood waters. It will normally be built with the earth excavated from the pit or surrounding area, and may be consolidated with a stone facing to prevent it from being washed away by heavy rains. In front of the entrance door, it may be preferable to supplement the mound with a masonry or brick-built step. This helps to keep the latrine floor clean .

In the Phillippines, where the dwelling is often built above the ground on piles, the latrine floor is also elevated; and a drop-pipe leads the excreta downward to the covered pit below. This is called the "antipole" system.

The House or Superstructure

The house affords privacy and protects the user and the in tallation from the weather. Fig. 67 shows various types of houses, and a typical wooden house frame for use in rural areas. From the sanitary viewpoint, the house is less important than the pit or the floor. For this reason, when latrine programs are undertaken on a campaign basis, the house is often left for the people to erect in the manner which is most satisfactory to them with only general advice being offered by you. Standardized superstructures are desirable, however, from many standpoints, among which economy of construction and durability are most important.

A properly built superstructure should conform to certain rules, the most significant of which are:

1. Size. It should preferably fit the dimensions of the floor or slab and should never be too large, lest people be tempted to defaecate on any part of the floor at times when the area around the opening has been soiled by previous users. The height of the roof over the slab near the entrance door should be 6.5 ft. or more.

2. Ventilation of superstructure. It is desirable to provide openings 4-6in. wide at the top of the house's walls to facilitate constant ventilation.

3. Lighting. Natural light should be available wherever possible. However, the superstructure should provide sufficient shade over an uncovered seat or hole in order not to attract flies.

4. Cleanliness. A superstructure which is left dirty and in a constant state of disrepair will soon be abandoned and unused as a latrine. It is therefore extremely important that the house be kept clean at all times, both inside and outside, and that no poultry or animals be housed in it. White or colored washings of the superstructure should be encouraged, and the vegetation immediately surrounding it should be trimmed. The roof should cover the house completely and have a large overhang, to protect the mound and the walls from rain and roof drainage. One of the duties of the health department staff, especially the sanitarians and health educators, is to provide constant advice to the family regarding the cleanliness and the proper use of the latrine.

Example Privy Shelters

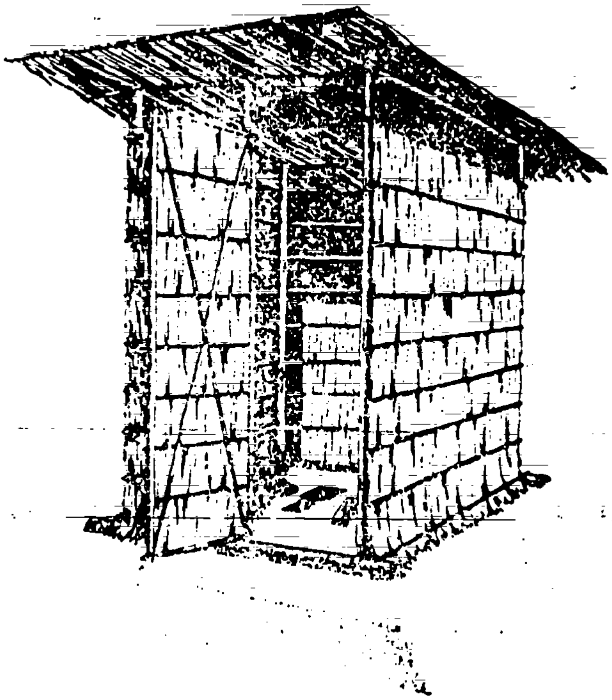
Drawings of several designs are provided on the next page. The structures shown have been found satisfactory in many parts of the world.

Tools and Materials needed for construction include:

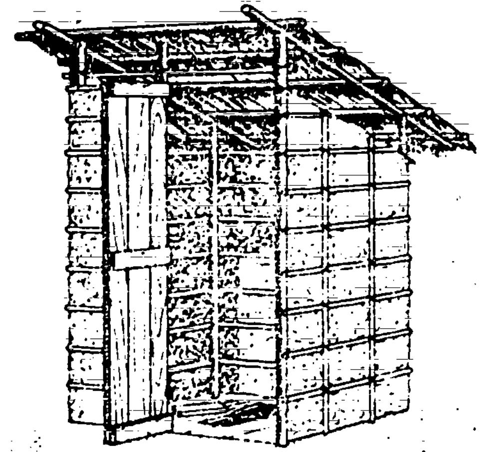
A sheet of corrugated sheet metal roofing, 4 ft. x 4 ft. or larger
Wooden posts 2in. x 2 in., 66 feet long
Boards, 8 in. wide, 3/4 in. thick, 132 feet long.
Nails, handtools, paint (2 quarts)

## Fig. 67 Types of Privy Shelters

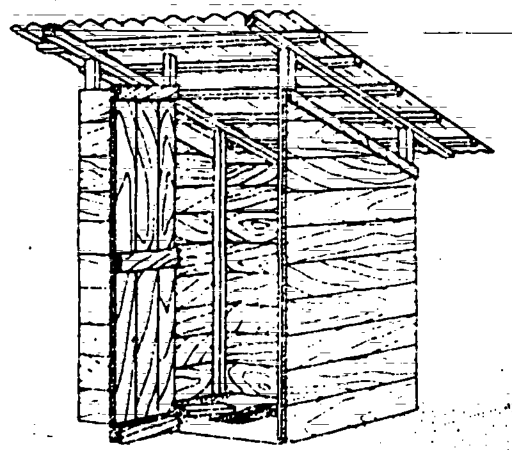
COMPLETED PRIVY, SHOWING PALM THATCH WALL AND ROOF COVERING



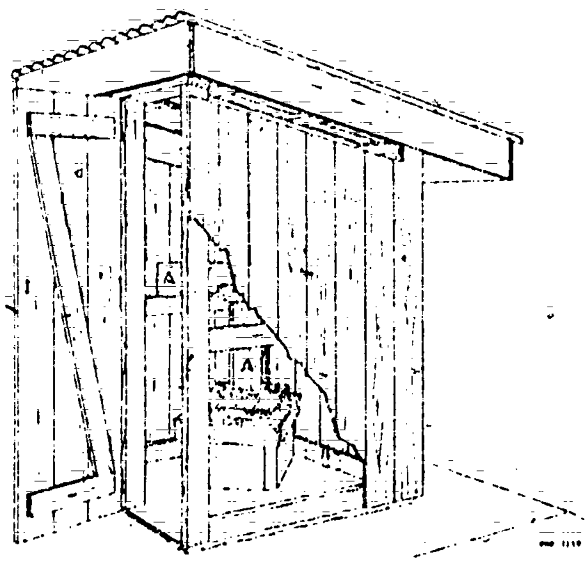
WATTLE HOUSE WITH PALM THATCH ROOF



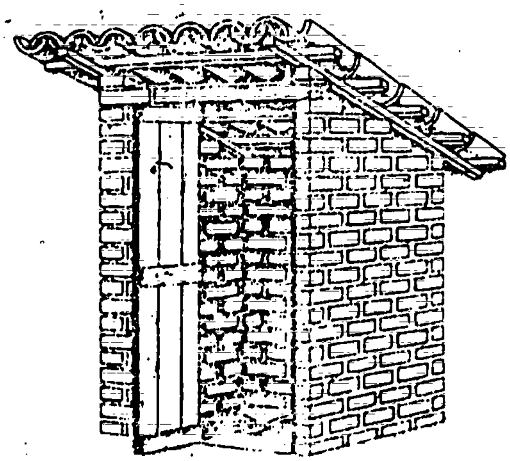
HOUSE OF CUT LUMBER WITH CORRUGATED METAL OR ASBESTOS CEMENT ROOF



...E OF SUPERSTRUCTURE RECOMMENDED BY US PUBLIC HEALTH SERVICE



HOUSE OF BRICK WITH TILE ROOF



Adapted, by permission, from United States Public Health Service (1943) The sanitary privy, Washington, D.C. (Revised type No. IV of Publ. Hlth Rep. (Wash.), Suppl. 105)

## EXAMPLE PRIVY DESIGNS

### PIT PRIVY

This is the simplest recommended latrine or privy, having a hand dug hole, properly mounted slab and a shelter. This is the most widespread and satisfactory type of latrine, when properly designed, built, and located.

#### Tools and Materials

Materials for building the shelter
Handtools for digging the pit, concrete construction and building the shelter.

#### Details

The pit is round or square, about 3.5 feet in diameter or for each side and usually 3.3 to 10 feet deep. The pit may have to be lined, to prevent caving, with brick, wood, bamboo, etc., even in hard soil. It is good to line the top 3.5 feet of the hole so as to make a solid base for the slab and shelter. 19.5 inches of the top of the hole can be lined with mortar for this purpose.

The following table will help you to estimate the depth of hole to make. The top part of the table is for a wet-pit privy, where the hole penetrates the water table and the contents are usually quite wet.

Table 10 PIT PRIVY CAPACITY FOR A FAMILY OF FIVE

| Pit Type | Years of Service | Estimated volume and depth* for hole with 10ft² area — Personal Cleansing Material: Water — volume ft³ and | depth ft | Solid — volume ft³ and | FT depth |
|---|---|---|---|---|---|
| WET | 4 | 26 | 2.6 | 40 | 4.0 |
| | 8 | 52 | 5.2 | 80 | 8.0 |
| | 15 | 97 | 9.7 | 150 | 15.0 |
| DRY | 4 | 40 | 4.0 | 60 | 6.0 |
| | 8 | 80 | 8.0 | 120 | 12.0 |
| | 15 | 150 | 15.0 | - | -- |

One and a half feet have been added to the depth since the pit is considered full when material is that distant from the slab.

The base serves as a solid, waterproof support for the floor. It also helps to prevent hookworm larvae from entering. Properly made of a hard, strong material, it helps stop the entrance of by 50% in cases where the types of personal cleansing materials normally employed might indicate that such an allowance is necessary.

It is further recommended that, where practicable, wet-pits should have a minimum depth of 10 ft. With regard to pit storage capacity, it is desirable to design for as long a period as possible, i.e., for 10-15 years. However, it is recognized that, from the standpoint of cost, or because of difficulties in supporting pit walls in unstable soil formations, it might sometimes be impossible to attain this objective. Nevertheless, it is strongly recommended that pits should be designed for a life of at least four years.

TABLE II

Volume & Depth For Rural Latrine With Cross-Sectional Area of 9 Sq. Ft. (For family of five)

| Wet Pit<br>Service life | Personal cleansing material | | | |
|---|---|---|---|---|
| | water | | solid | |
| | volume (cu. ft) | depth (ft) | volume (cu. ft) | depth (ft) |
| 4 years (minimum) | 26 | 3 | 40 | 4.8 |
| 8 years | 52 | 5.8 | 80 | 9 |
| 15 years (maximum) | 97 | 11.8 | 150 | 16.6 |

| Dry Pit<br>Service life | Personal cleansing material | | | |
|---|---|---|---|---|
| | water | | solid | |
| | volume (cu. ft) | depth (ft) | volume (cu. ft) | depth (ft) |
| 4 years (minimum) | 40 | 4.5 | 60 | 6.7 |
| 8 years | 80 | 9 | 120 | 13.3 |
| 15 years (maximum) | 150 | 16.6 | — | — |

* Depth given is effective pit depth, and 1-2 ft (30-60 cm) are usually added to obtain overall depth of pit.

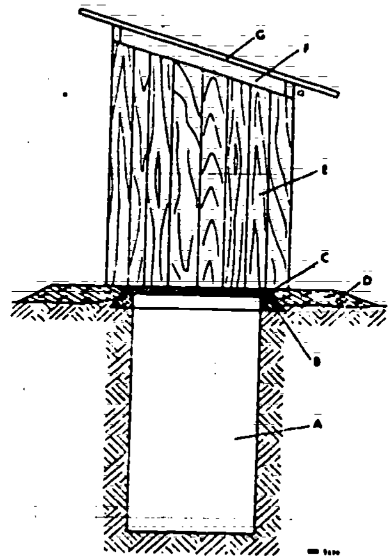
Table I shows the pit volume and dimensions for household latrines for families and gives varying periods of service life based on wet-pit conditions. Table II presents similar data for dry-pit conditions.

These tables show that, where there is little possibility of maintaining water in pits or holes, a pit privy with the largest possible volume is best. From the economic standpoint, the deep pit, although higher in initial cost, will prove to be a profitable investment.

Finally, one factor that also influences the cross-sectional area of the pit, although to a lesser extent, is the size of the floor that covers it. The size of the floor slab depends much on the type of material from which it is built. This matter is discussed in a later section.

The selection of the type of installation best suited to local needs must take into account the element of cost. Water-carried sewerage systems with flush toilets are very expensive and far beyond the economic possibilities of most rural areas. At the other extreme, it is possible for everyone to relieve himself in the most primitive manner at no cost whatsoever; but this method is disastrous in terms of sickness and death and burrowing rodents and of surface water into the pit. The pit lining in most cases will serve as a base although it may need to be strengthed at the ground surface.

Fig. 68 Various Parts of a Sanitary Privy




A – Pit
B – Base
C – Floor
D – Mound
E – House, including door
F – Ventilation
G – Roof

A concrete water-seal slab is best and is economical but means added labor and construction. A concrete open-hole slab is the next best, while a wooden floor is adequate. A built-up floor of wood and compacted soil is sometimes used but is difficult to keep clean as it gets soiled and is likely to spread hookworm.

The concrete should not be weaker than 1 part cement to 6 parts of aggregate with a minimum of water. It should be reinforced with strips of bamboo about 1 inch wide and with the weaker fibers stripped away. Soak the bamboo in water overnight before use.

The slabs are cast upside down in one operation. The footrests are shaped by removing part of the wooden form so as to make two separate indentations in the wood. Sheet metal is placed around the form so that the metal extends above the wood to the thickness of the slab. Side walls of the hole and foot-rests are made with a slight slope so as to come out easily. The form for the open hole is removed when the concrete first sets. Slabs are removed from the forms in about 40 hours and should be stored under water for 10 days or more.

Round slabs can be rolled some distance when carrying is difficult.

The mound protects the pit and base from surface run-off which otherwise might enter and destroy the pit. It should be built up to the level of the floor and be very well tamped. It should extend 20 inches beyond the base on all sides. In unusual cases, such as flood plains and tidal areas, the mound may be built much higher than the ground as a protection against flood and high tides. It will normally be built with the earth removed in digging the pit and soil from the surrounding area. A stone facing will help stop it from being washed away by heavy rains. In front of the entrance door, a masonry or brick step can be built to help keep the floor clean.

Fig.69 TYPICAL ROUND AND SQUARE BASES (BUILT WITH SOIL-CEMENT OR CLAY)

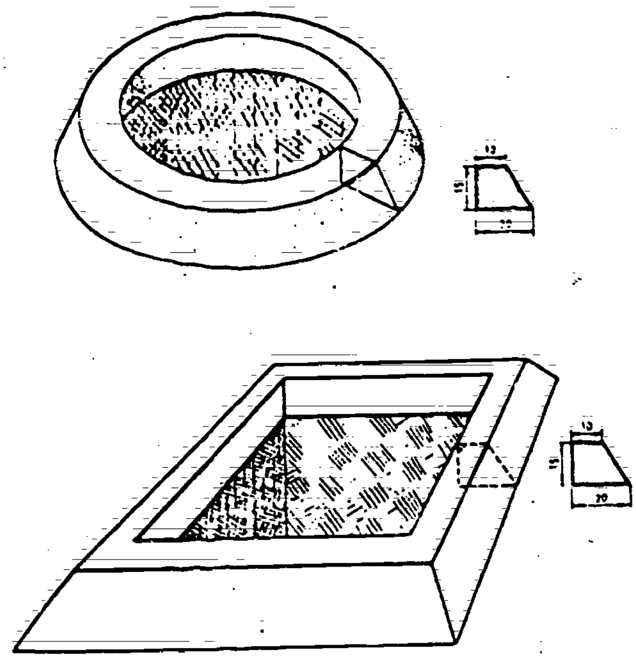
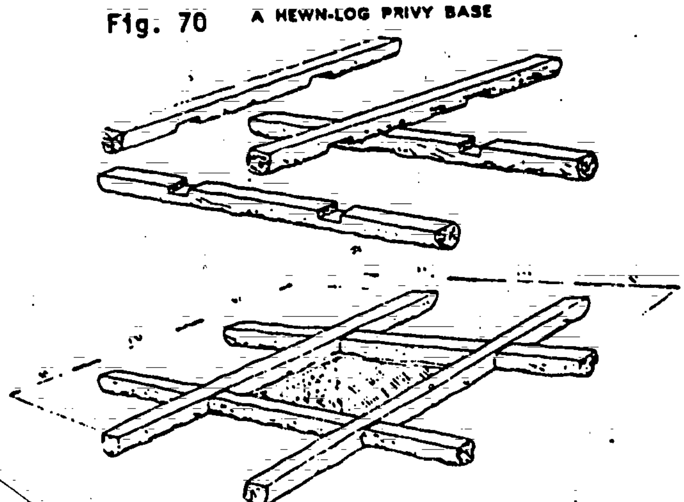
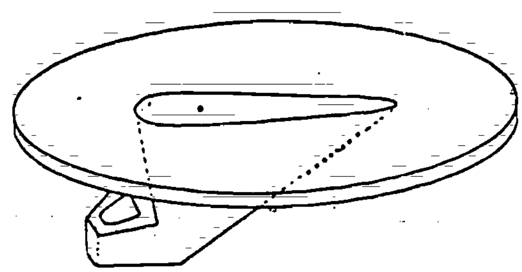


Fig. 70 A HEWN-LOG PRIVY BASE



## LATRINE FOR VILLAGE USE

Fig. 71 Latrine for Village Use



This low cost water seal latrine slab is a single concrete casting. It requires very little space, is sanitary, odorless, easy to install and maintain, and can be used to produce nightsoil fertilizer

Tools and Materials

Foot plate form - See Fig. and
Steel strap iron 2" wide, 1'7" long
3/8" bolts 5" long for air vents
Outer form - made of wood detailed on Fig.
Inner form - made of wood detailed on Fig.
Clay to make water seal form
Cement, sand, stone aggregate up to 1" maximum

Details

In villages where space is a premium and the soil can absorb the flushing water, this latrine may be worth serious consideration. A 30" diameter hole eight feet deep is covered with a slab. Most soils have sufficient stability to support the slab. Very loose or sandy soils may require some type of lining. Any type of simple superstructure can be fitted over it for privacy. If the nightsoil must be used for fertilizer, this method can be used. After the first six months, a new hole is dug, and the slab moved. The first pit is covered with two feet of dirt. Six months later the nightsoil in the first pit has been converted to essentially non-pathogenic fertilizer and may be used with reasonable safety. Do not use any nightsoil fertilizer that has not been composted at least three months. The slab is moved back to the first hole and the second covered with two feet of dirt.

The latrine can be cleaned with only 1/2 gallon of water. When this is done, there is no odor nor any flies and it stays quite clean. Thus it is easy to use. Villagers must be urged to provide for a sufficient supply of water to be brought and stored at the latrine in a large container (eg. a 4 gallon kerosene tin). A quart container should also be provided. Instructions should be given in the proper method of flushing the latrine. If this is done improperly a large quantity of water will be wasted. Two quarts of water are sufficient to clear the latrine if the water is thrown with a fair amount of force from the narrow end of the latrine.

Installation is so simple that the untrained villager can do it easily. The round one piece construction facilitates moving the slab by rolling it. It is simple to make once the forms and methods are practiced. The materials cost about $1 for a latrine. One trained villager can make three slabs per day, using three forms. The wooden forms cost about $8 each.

A convex foot-plate form about 38" in diameter is made of wood, metal, or concrete. It must be 1" higher in the center than at the edge. See Fig.

Fig. 72 shows the steel ring and inner form in place on the base. The ring is formed of two inch wide strap iron and fastened with a bolt for easy removal from the concrete slab. The collapsible wooden inner form is detailed in Figure 73 .

The inner form has three pieces Fig. shows the outline of the two side pieces of the form. These must be cut from wood 2 1/4" thick. The 18 1/8" sides and 3 3/4" sides stay nearly in contact. A wedge shaped piece of wood shown in Fig. holds corner G of the sides one inch apart. The wedge fits along the 9" side. The spring holds the form closed tight against the separation bars while the wedge is inserted and the inner form placed on the base. The dimensions shown for the inner form should only be used as a guide since some inconsistencies have been observed.

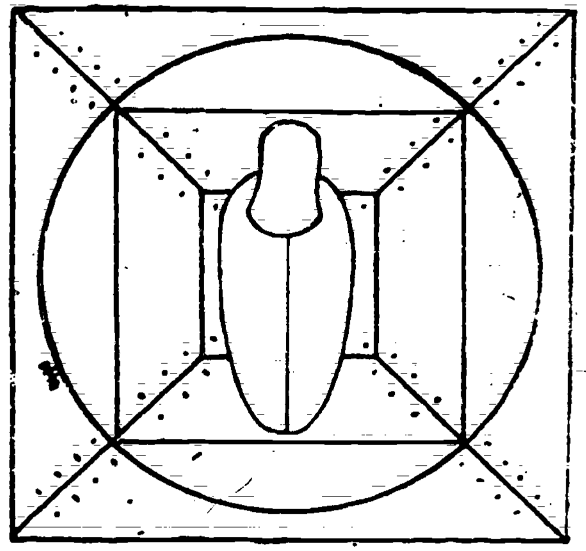


Fig. 72 Inner Form of Latrine (Top View)

Two inches of well mixed concrete (cement 1, sand 2, stone chips 3) is placed in the ring and tamped will to compact it. Next the wooden outer form is set up around the inner liner. See Figs 72 and 73. There should be a clearance of not less than 1/2" between the inner liner and the wooden outer forms. A cement sand mixture (cement 1, sand 2) of plastic consistency is placed in this inner space and compacted. A 3/8" bolt through the outer wood form and into the inner form provides an antisyphon vent and helps to hold the inner form in place. See Figs. and .

After 48 hours the casting may be placed on blocks. The clay siphon and wooden inner form removed, and a finish of cement plaster added to cover any imperfections. When this is set a final coat of pure cement is put on. If there is any defect in the seal it may easily be repaired by putting a little cement slurry (cement and water in creamy consistency) over the defect and adding at once cement plaster to fill the defect.

Fig. 73 Inner form and steel rim in place on base.

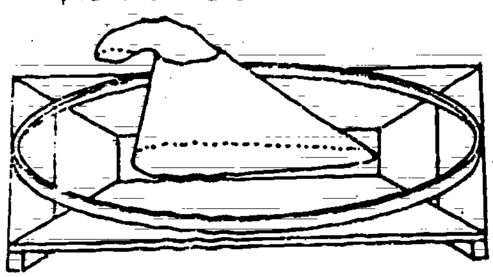


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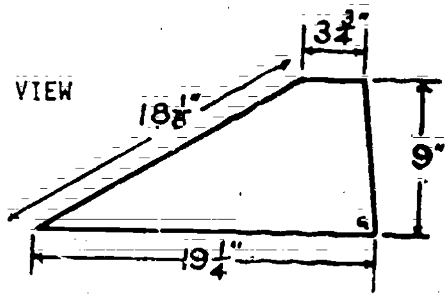
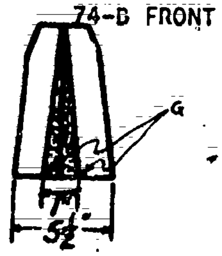
Fig. 74 LATRINE BOWL MOLD

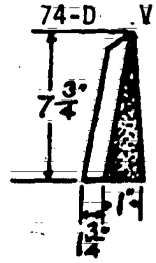
74-A
SIDE VIEW



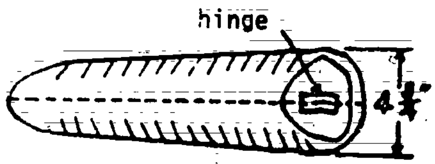

74-B FRONT VIEW



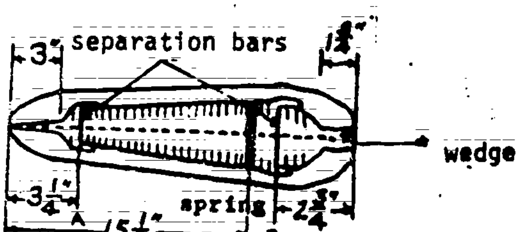

74-D VIEW OF WEDGE




74-C TOP VIEW




74-E BOTTOM VIEW

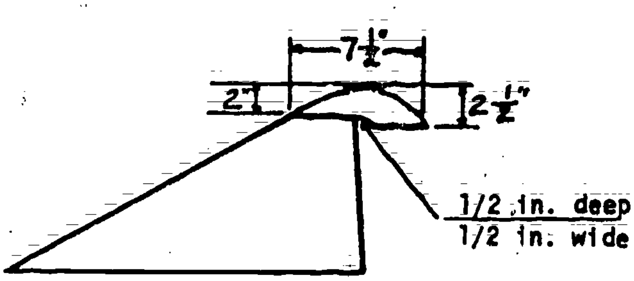



* is a wooden wedge, used to hold form tight. to remove form from concrete latrine, one knocks out wedge, then removes separation bars; the bottom of the form then contracts.

If the wood is not hard and smooth, a tim outer coating may be hammered on to wooden form.

Width of mold a A & B are 4-1/4 and 5-1/2 in. respectively. The separation bars at A & B are 2-1/2 & 4 in. long respectively.

Finished bowl-seal form, ready for placing on wooden base. The water-seal form has been molded from clay, by hand, and placed on top of the wooden bowl form. The size and configuration of the water-seal form must be shaped carefully, as shown. This is not difficult.




74-F

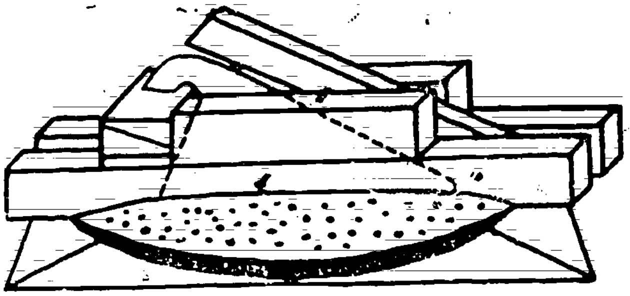


Fig. 75 Concrete slab has been poured; part of the exterior sectional mold has been placed in its position.

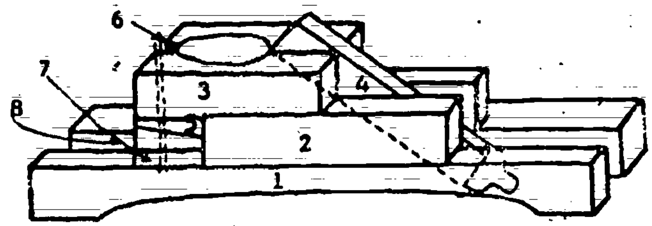



Fig. 76 Rough exterior knock-apart mold made to fit around the clay core with a clearance of 1/2 in. to 3/4 in.

Wooden constituents of above mold:

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 1. | 4" | x | 4" | x | 36" | - | 2 pieces |
| 2. | 3" | x | 4" | x | 16" | - | 2 pieces |
| 3. | 3" | x | 4" | x | 16" | - | 2 pieces |
| 4. | 3" | x | 3" | x | 21" | - | 1 pieces |
| 5. | 2" | x | 5" | x | 13" | - | 1 pieces |
| 6. | 4" | x | 4" | x | 1" | - | 1 pieces |
| 7. | 5" | x | 13" | x | 1" | - | 1 piece |
| 8. | 3" | x | 4" | x | 4" | - | 1 piece |

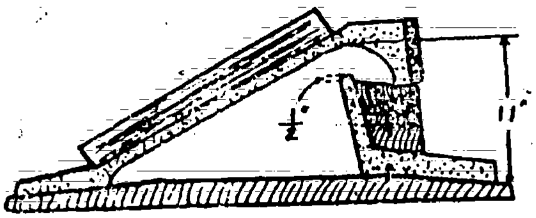



Fig. 77 Sectional view after pouring the cement in bowl and trap. Note the concave shape of the base plate.

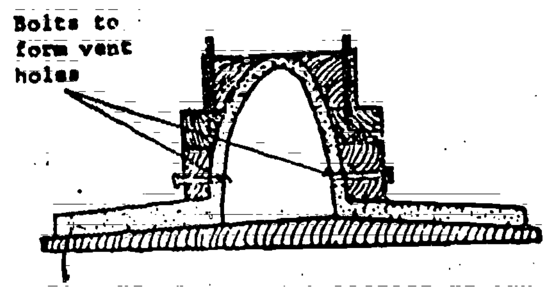



Fig. 78 Transverse section of the casting with forms in place.

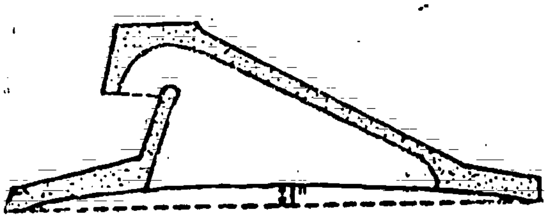



Fig. 79 Section of the casting after removal of the forms.

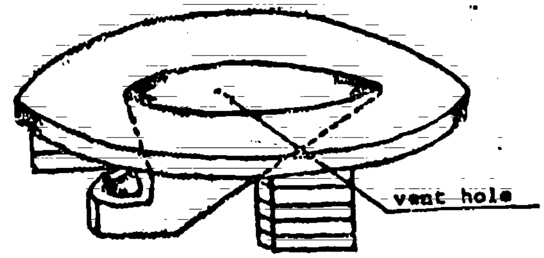
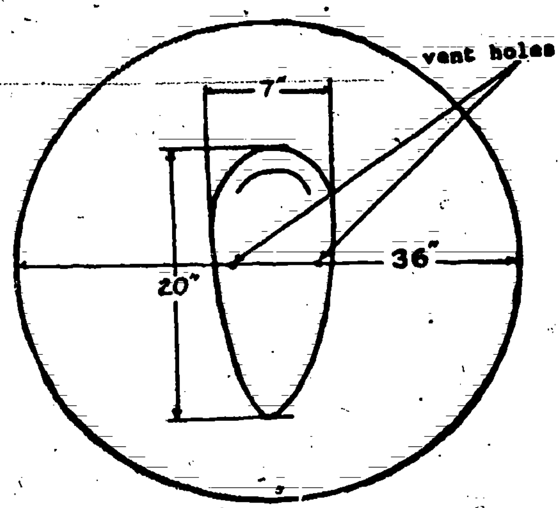



Fig. 80 Completed casting set up on bricks where the wooden inner form is removed and clay siphon lining dug out. The final finish of cement plaster and neat cement polish is applied.

Fig. 81 The completed casting from above showing the dimensions.



## THAILAND WATER-SEAL PRIVY

This concrete water-seal slab is most useful for widescale privy programs. It is used to cover an ordinary pit privy. This method represents the collected experience of a long established privy program in Thailand. The general method should be applicable to other water-seal slab designs.

### Tools and Materials

Master molds - Can be purchased from Village Health and Sanitation Project, Ministry of Public Health, Department of Health, Bangkok, Thailand. This aluminum master mold weighs 24 pounds and costs $7.50 plus shipping charges.

Concrete making materials
Wood for platform forms
Reinforcing rod and wire
Clay
Crankcase oil
Beeswax and kerosene (optional)
3/4" x 3/4" x 5" steel bars

The basic method used for making these water-seal slabs is to cast the slab, bowl, and water-seal trap using three forms:

1. A wooden form for shaping the slab.
2. A concrete bowl core for shaping the inside of the bowl.
3. A concrete core for shaping the inside of the water-seal trap.

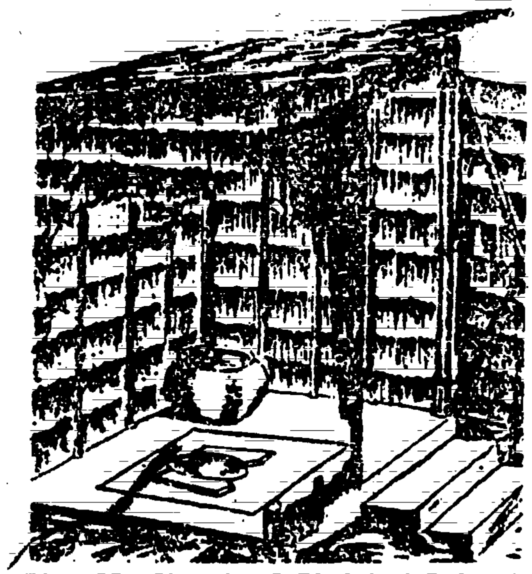


Fig. 82 Sketch of Finished Privy

Since the three parts of the slab are all cast at one time, the finished privy slab is quite strong. The water-seal trap is curved back under the bowl as shown in Fig. 83 A.

This makes flushing more difficult but prevents erosion of the back of the pit on loose soil. The same general method could be used to make a forward flushing trap, Fig. 83 B.

The forms used when making a slab must stay in place till the concrete has gained enough strength to allow their removal. This is usually 24 hours. For this reason, many sets of forms are necessary if a reasonable number of slabs are to be cast every day. Here is where the master molds are needed. One is used to cast the bowl core, and two are needed to cast the trap core.

Casting the Bowl Core

1. Oil the inside of the master bowl mold and insert a 3/4" x 3/4" x 5" steel bar into the bottom.

2. Add a fairly loose mixture of cement and water, called neat cement, to a depth of about 6". Then fill to brim with a 1:1 cement sand mixture. The 1:1 should be firm, not runny, and should be laid into the loose neat cement without stirring to insure a smooth finish on the bowl core.

3. After the bowl core has become firm enough, scoop a depression into the surface to install the two steel hooks made from the reinforcing rod. They should be about 9" apart, and should not protrude above the surface of the concrete. See Fig.

4. Allow the concrete to set at least 24 hours before removing the bowl core from the master mold. The bowl core can be used to make another master mole and vice versa.

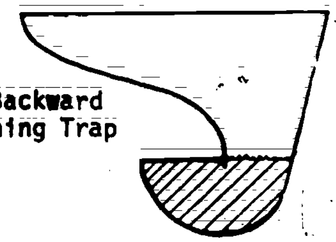


Fig. 83A Backward Flushing Trap

Casting the Trap Core

Make the trap core using the pair of master molds, which consist of the trap master mold and the insert mold.

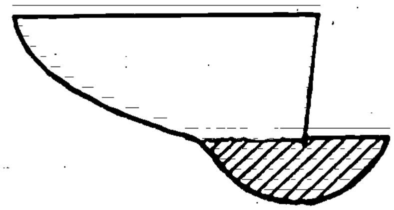


Fig. 83B Forward Flushing Trap

1. Add about 1" of 1:1 cement sand mix to the oiled trap master mold and put in some wire for reinforcing. Then fill it with 1:1 almost to the brim.

2. Put the oiled insert mold into place and scrape off excess.

3. After 45 minutes remove the insert and add a square sheet metal pipe 3/4" high made by wrapping sheet metal around a 3/4" x 3/4" steel bar.

4. Remove the finished trap core by gently tapping the master mold with a wooden block

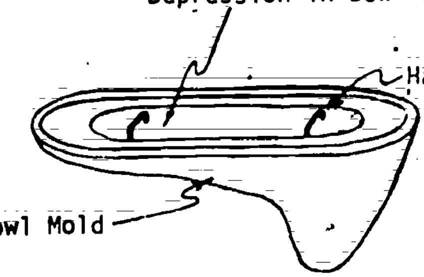



Fig. 84 Bowl Core Handles

Construction of the Wooden Slab Form

1. Make a frame of 1 1/2" x 1 1/2" wood with an inside diameter of 80 cm x 80 cm. A notch and single nail on each corner works well. See Fig. 86 .

2. Make a wooden platform 90 cm x 90 cm out of 1" thick planks. Gouge 1/2" deep footrests if these are desired. See the outline in Fig. .

Casting the Slab

With these three forms finished you are ready to cast the first water-seal slab.

1. Use a paint brush to coat the bowl core and the trap core with a layer of wax about 1/8" thick. Prepare the wax by dissolving 1 kilogram of melted beeswax in 1/2 liter of kerosene. The wax coating will last 5 or 6 castings adding 1¢ to the cost of each slab. Wax makes removing the cores much easier, but isn't absolutely necessary.

2. Place the bowl core on the wooden slab form and fill all cracks with clay.

3. Oil the bowl, platform and frame.

4. Apply a 1/4" thick coat of pasty cement and water mixture to the bowl core and platform. (Many Thai people prefer to spend 25¢ more for an attractive polished slab. To do this, instead of using a mixture of cement and water, use a mix of 5 cement : 5 color : 1 granite chips. After the forms are removed, polish with a carborundum stone and plenty of water).

5. Cover the bowl core with a mixture of 1 cement : 2 sand, to total thickness of 1/2". Notice the smooth lip made on the cement 3/8" from the top of the bowl core. This lip is your water-seal. Use fairly dry cement and allow it to set for 15 minutes before cutting this lip.

6. Place the trap core on the bowl core and seal the crack with clay. Also add a little clay on each side of the form to prevent cement from getting to the front lip.

7. Cover with 1 : 2 cement sand mixture to a thickness of 1/2". Do not exceed the 1/2" thickness below the trap core or you will not be able to remove this core.

8. Fill the slab form with a mixture of 1 cement : 2 sand : 3 clean gravel or crushed rock almost to the top. In preparing the concrete, first mix cement and sand, then add gravel and water. Use water conservatively. The looser the mixture, the weaker the concrete will be.

9. Press in 4 pieces of 1/4" steel rod reinforcing.

10. Fill to top of frame and smooth. Allow at least 24 hours for setting.

11. Remove the frame by tapping lightly with hammer.

12. Turn the slab form over on a wooden stand and use simple levers to remove the bowl core. You must remove the bowl core before the trap core.

13. Tap the trap core gently and slip it out. Add a little water and check to see if your seal is 3/8".

14. Keep the slab damp and covered for a minimum of 3 days and preferably a week to gain strength.

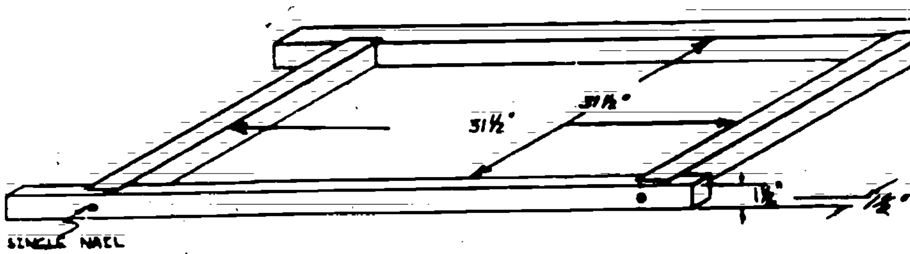



Fig. 85 Privy Frame

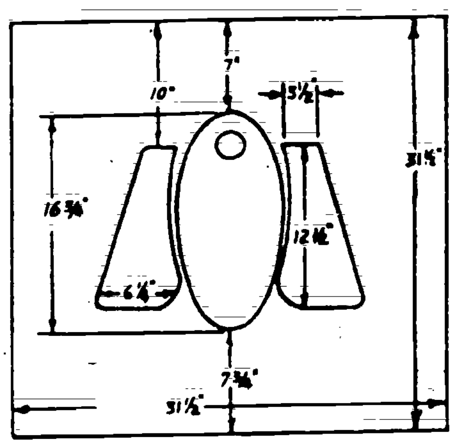



Fig. 86 Privy Slab Outline

THE PRIVY METHOD OF EXCRETA DISPOSAL

DESIGN FOR A VILLAGE

LESSON NO. 1

LESSON OBJECTIVE: Outline the factors that must be considered in designing a village privy system.

| TOPIC | INSTRUCTIONAL PROCEDURE | SUPPLEMENTAL MATERIALS / RELATED READING |
|---|---|---|
| Sanitary Survey | Recall the need for a sanitary survey.<br><br>Outline the essential elements of this survey.<br><br>Demonstrate estimating the volume of pits, holes and tanks. | WHO Monograph Series #39 p. 158-159. |
| The Pit Privy | Discuss the function of the basic components of a pit privy.<br><br>Illustrate the designs and components for three types of pit privies. | WHO Monograph Series #39 p. 43-76. |
| Sanitary Survey | Discuss how to determine the adequacy of the present system.<br><br>Assemble students to conduct a survey of a rural area. This survey must<br>1) designate the population and its distribution<br>2) determine the practice of hygiene in this area indicated from the present type(s) of facilities implemented<br>3) state where present facilities are improperly located, poorly maintained and not used<br>4) estimate the health of the community from records of communicable diseases, intestinal infections (diseases caused by worms) and acute conjunctivitus in infacts (inflammation of the mucus membrane around the eyeball) and cite the death and debility statistics.<br>5) identify what type(s) of privies are presently used (public or private; distribution and use) and determine the location of these facilities with respect to water supply systems. | See Section 7 |

THE PRIVY METHOD OF EXCRETA DISPOSAL
DESIGN FOR A VILLAGE
(Continued)

6) designate the number of new installations needed and where they should be located
7) define the average income of the community members
8) estimate the cooperation available from agencies or groups for training and health education of the public
9) determine what materials are available locally, their costs, whether potential resources for self-help are available and if the needed craftsmen are available locally and their wages
10) state what type(s) of privies would be the most economically feasible.

Assemble students for discussion of survey findings.

# THE PRIVY METHOD OF EXCRETA DISPOSAL

## DESIGN FOR A VILLAGE

## LESSON NO. 2

ESSON OBJECTIVE: Set up and carry out a program to construct a privy system.

| TOPIC | INSTRUCTIONAL PROCEDURE | SUPPLEMENTAL MATERIALS / RELATED READING |
|---|---|---|
| lection of ivy System | Assemble students to visit the present facilities to determine the type(s) of facilities presently implemented.<br><br>Review the criteria to be used in the selection of a village privy system.<br><br>Select the most feasible privy designs.<br><br>Discuss how to prepare a plan toward the finances for the system. | |
| ruction niques | Outline the logical sequences of construction for the privy type selected.<br><br>Have students assemble the tools and materials for the construction of this privy type.<br><br>Set up a program (allocate construction tasks to the students) for the construction of a privy of the type selected.<br><br>Supervise students in the construction of this privy. | For construction techniques see Section IIC |

## SECTION 9

## WATER CARRIED SEWAGE SYSTEMS
## CONSTRUCTION AND MAINTENANCE

OVERVIEW:

The construction of the various water carried sewage systems is covered in this section. The trainees are instructed in the testing of sites for the water and sewage disposal and in the operation and maintenance of these systems. Again the health standards to be improved must be stressed so that the design and execution of the project will achieve these results.

SECTION 9: WATER-CARRIED SEWAGE SYSTEMS CONSTRUCTION AND MAINTENANCE

OBJECTIVE: Construct and maintain cesspools, seepage pits, and septic tanks.

TASKS:

1. Determine absorption area requirements.
2. Locate site of construction.
3. Set up a construction program.
4. Set up a maintenance program that identifies:
   a. How often the system must be cleaned.
   b. The number of personnel needed to clean the system.
   c. The equipment needed for maintenance.

FUNCTIONAL SKILLS:

1. Identify the components of various types of septic tanks, cesspools, and seepage pits.
2. Identify the logical sequence of operations involved in building septic tanks, cesspools, and seepage pits.
3. Conduct percolation tests.
4. Draw a map of the proposed system and the location of its components.
5. Identify the maintenance requirements of various types of water-carried sewage systems.
6. Identify the skills a person would need to maintain various types of water-carried sewage systems.

TERMINAL PERFORMANCE TESTS:

1. Design, locate and construct a water-carried sewage system that satisfies the requirements of Section Village Privy Design Criteria.
2. Prepare a manual on the maintenance of septic tanks, cesspools, and seepage pits.

## LOCATION AND SELECTION OF WATER-CARRIED DISPOSAL FACILITIES

### SPECIFICATIONS

There are minimum distances that different types of disposal facilities should be placed in relation to water sources and dwellings. These distances will increase in direct proportion to the porosity of the soil.

TABLE 12 DISTANCES FROM VARIOUS SOURCES TO DISPOSAL FACILITIES

| Component | Septic Tank | Leaching Field Seepage Pit and Cesspool | Building Sewer | Privy |
|---|---|---|---|---|
| | Feet | Feet | Feet | Feet |
| Well or suction line | 50 | 50* | (a) | 50* |
| Water supply line (pressure) | (b) | (b) | (b) | (b) |
| Property line | 10 | 10 | -- | 30 |
| Dwelling | 5 | 20 | -- | 30 |
| Surface water supplies or tributaries, including open and subsurface drains | 50* | 50* | 50* | |
| Watercourses, including streams, ponds, open and subsurface drains | 10 | 25 | | |
| Edge of fill | | 25 | | |

Table I. Sanitary Facilities Location Requirements

* 50 feet is a minimum acceptable distance.

(a) 10 feet if constructed of durable corrosion resistant material with watertight joints, or 50 feet if any other type of pipe is used.

(b) Disposal facilities should be installed as far as possible from water supply lines. Where sewer lines cross water supply lines, both pipes should be constructed of durable corrosion resistant materials with watertight joints.

### SUITABILITY OF THE SOIL

Along with the specifications mentioned above, the location and implementation of water-carried sewage depends on the suitability of the soil. The first step in the design of subsurface sewage disposal systems is to determine whether the soil is suitable for the absorption of septic tank effluent and, if so, how much area is required. The soil must have an acceptable percolation rate*, without interference from ground water or impervious strata below the level of the absorption system. In general, two conditions must be met:

1. The percolation time should be within the range of those specified in Table.

2. The maximum seasonal elevation of the ground water table should be at least 4-feet below the bottom of the trench or seepage pit. Rock formations or other impervious strata should be at a depth greater than 4-feet below the bottom of a cesspool or seepage pit. Unless these conditions can be satisfied, the site is unsuitable for a conventional subsurface sewage disposal system.

TABLE 13 REQUIRED ABSORPTION AREA FOR GIVEN PERCOLATION RATES

| Percolation rate (time required for water to fall one inch, in minutes | Required absorption area in sq. ft. per standard trench and seepage beds |
|---|---|
| 1 or less | 70 |
| 2 | 85 |
| 3 | 100 |
| 4 | 115 |
| 5 | 125 |
| 10 | 165 |
| 15 | 190 |
| 30 | 250 |
| 45 | 300 |
| 60 | 330 |

* A percolation test is a test to determine the rate of flow of water through the interstices or pores of a soil.

The soil should be considered unsuitable for seepage pits if the percolation rate is over thirty and unsuitable for any subsurface disposal system if this rate is over 60.

PERCOLATION TESTS

Subsurface explorations are necessary to determine subsurface formations in a given area. An auger with an extension handle, is often used for making the investigation. Wells and well drillers' logs can also be used to obtain information on ground water and subsurface conditions. In some areas, subsoil strata vary widely in short distances, and borings must be made at the site of the system. If the subsoil appears suitable, as judged by other characteristics described in section 2 below, percolation tests should be made at points and elevations selected as typical of the area in which the disposal field will be located.

The percolation tests help to determine the acceptability of the site and establish the design size of the subsurface disposal system. The length of time required for percolation tests will vary in different types of soil. The safest method is to make tests in holes which have been kept filled with water for at least 4 hours, preferably overnight. This is particularly desirable if the tests are to be made by an inexperienced person, and in some soils it is necessary even if the individual has had considerable experience ( as in soils which swell upon wetting). Percolation rates should be figured on the basis of the test data obtained after the soil has had opportunity to become wetted or saturated and has had opportunity to swell for at least 24 hours. Enough tests should be made in separate holes to assure that the results are valid.

The Procedure for a Percolation Test

This percolation test incorporates the principles cited above. Its use is particularly recommended when knowledge of soil types and structure is limited.

A. Number and location of tests:

Six or more tests shall be made in separate test holes spaced uniformly over the proposed absorption field site.

B. Type of Test Hole

Dig or bore a hole, with horizontal dimensions of from 4 to 12 inches and vertical sides to the depth of the proposed absorption trench. In order to save time, labor, and volume of water required per test, the holes can be bored with a 4 inch auger.

C. Preparation of Test Hole

Carefully scratch the bottom and sides of the hole with a knife blade or sharp-pointed instrument, in order to remove any smeared soil surfaces and to provide a natural soil interface into which water may percolate. Remove all loose material from the hole. Add 2 inches of coarse sand or fine gravel to protect the bottom from scouring and sediment.

D. Saturation and Swelling of the Soil

It is important to distinguish between saturation and swelling. Saturation means that the void spaces between soil particles are full of water. This can be accomplished in a short period of time. Swelling is caused by intrusion of water into the individual soil particle. This is a slow process, especially in clay-type soil, and is the reason for requiring a prolonged soaking period.

In the conduct of the test, carefully fill the hole with clear water to a minimum depth of 12 inches over the gravel. In most soils, it is necessary to refill the hole by supplying a surplus reservoir of water, possibly by means of an automatic syphon, to keep water in the hole for at least 4 hours and preferably overnight.

Determine the percolation rate 24 hours after water is first added to the hole. This procedure is to insure that the soil is given ample opportunity to swell and to approach the condition it will be in during the wettest season of the year. Thus, the test will give comparable results in the same soil, whether made in a dry or in a wet season. In sandy soils containing little or no clay, the swelling procedure is not essential, and the test may be made as described under item E 3 after the water from one filling of the hole has completely seeped away.

E. Percolation-rate measurement

With the exception of sandy soils, percolation-rate measurements shall be made on the day following the procedure described under item D above.

1. If the water remains in the test hole after the overnight swelling period, adjust the depth to approximately 6 inches over the gravel. From a fixed reference point, measure the drop in water level over a 30 minute period. This drop is used to calculate the percolation rate.

2. If no water remains in the hole after the overnight swelling period, add clear water to bring the depth of water in the hole to approximately 6 inches over the gravel. From a fixed reference point, measure the drop in water level at approximately 30 minute intervals for 4 hours, refilling 6 inches over the gravel as necessary. The drop that occurs during the final 30 minute period is used to calculate the percolation rate. The drops during prior periods provide information for possible modifications of the procedure to suit local circumstances.

3. In sandy soils (or other soils in which the first 6 inches of water seeps away in less than 30 minutes, after the overnight swelling period), the time interval between measurements shall be taken as 10 minutes and the test run for one hour. The drop that occurs during the final 10 minutes is used to calculate the percolation rate.

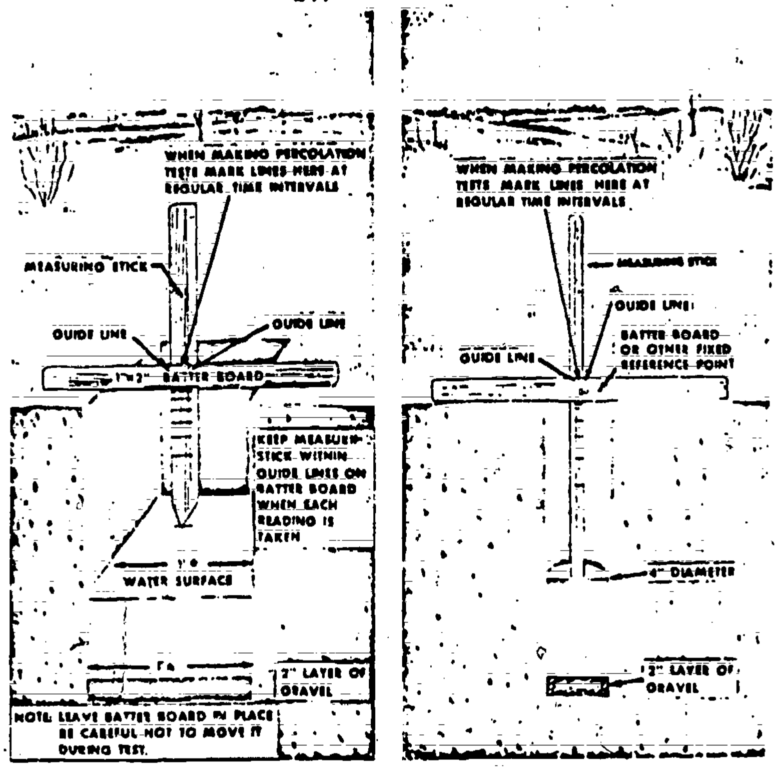



Fig. 87 Methods of making percolation tests

Guide For Estimating Soil Absorption Potential

A percolation test is the only known means for obtaining a quantitative appraisal of soil absorption capacity. However, observation and evaluation of soil characteristics provide useful clues to the relative capacity of a soil to absorb liquid. Most suitable and unsuitable soils can be identified without additional testing. When determined and evaluated by trained or experienced soil sceentists or soil engineers, soil characteristics may permit further categorizing of suitable soils. This has been done for some areas of the country and described in the soils reports mentioned below.

Soil Maps

The capacity of a soil to absorb and transmit water is an important problem in agriculare, particularly in relation to irrigation, dr drainage, and other land management practices. Through studies in these fields, a variety of aids have been developed for judging the absorption of water transmission properties of soils, which could be helpful in the sewage field. Considerable information has been accumulated by agricultural authorities on the relative absorption capacities of specific soils in many areas of the United States. Much of this information is included in Soil Survey Reports and Maps published by the United States Department of Agriculture in cooperation with the various State agricultural colleges. The general suitability of specific soils for effluent disposal may often be interpreted from these reports and maps.

## Clues to Absorption Capacity

Considerable information about relative absorption capacities of soils may also be obtained by a close visual inspection of the soil. The value of such an inspection depends upon some knowledge of the pertinent soil properties. The main properties indicative of absorption capacity are soil texture, structure, color, depth or thickness of permeable strata, and swelling characteristics.

### Texture

Soil texture, the relative proportion of sand, silt, and clay, is the most common clue to water absorption capacity. The size and distribution of particles govern the size and distribution of pores which, in turn, govern the absorption capacity. The larger the soil particles, the larger are the pores and the faster is the rate of absorption.

Texture can best be judged by the feel. The lighter or sandier soils have a gritty feel when rubbed between the thumb and forefinger; silty type soils have a "floury" feel and, when wetted, have no cohesion: heavier, clay type soils are dense and hard when dry, and have a slick greasy feel when wetted.

The use of texture as a clue to absorption qualities has its limitations; it is primarily reliable in the sandier soils. In the heavier type soils, including sandy soils containing appreciable amounts of silt or clay, one must look for additional clues, such as structure and soil color, as indicators of absorption capacity.

### Structure

Soil structure is characterized by the aggregation or grouping together of textural particles, forming secondary particles of larger size. Such secondary particles then tend to govern the size and distribution of pores and, in turn, the absorption properties. Structure can easily be recognized by the manner in which a clod or lump breaks apart. If a soil has structure, a clod will break with very little force, along well defined cleavage planes, into uniformly sized and shaped units. If a soil has no structure, a clod will require more force to break apart and will do so along irregular surfaces, with no uniformity in size and shape of particles.

In general, there are four fundamental structure types, named according to the shape of the aggregate particles: platy, prism-like, block-like, and spheroidal. A soil without structure is generally referred to as massive. Spheroidal structure tends to provide the most favorable absorption properties, and platy structure, the least. Although other factors, such as size and stability of aggregates to water, also influence the absorption capacity, recognition of the type of structure is probably sufficient for a general appraisal.

Color

One of the most important practical clues to water absorption is soil color. Most soils contain some iron compounds. This iron, like iron in a tool or piece of machinery, if alternately exposed to air and to water, oxidizes and takes on a reddish-brown to yellow oxidized color, it indicates that there has been free alternate movement of air and water in and through the soil. Such a soil has desirable absorption characteristics. At the other extreme are soils of a dull gray or mottled coloring, indicating lack of oxidizing conditions or very restricted movement of air and water. These soils have poor absorption characteristics.

Depth or Thickness of Permeable Strata

The quantity of water that may be absorbed is proportional to the thickness or volume of the absorbent stratum, when all other conditions are alike. In a soil having a foot or more of permeable material above tight clay, absorption capacity is far greater than that of the same kind of material lying within 3 inches of tight clay. When examining soils or studying soil descriptions, the depth and thickness, therefore, are important criteria of absorption capacity.

Swelling Characteristics

Most, but not all, clays swell upon the addition of moisture. There are many clays (in the tropics, in particular) that do not swell appreciably. There are also some soils in the United States which do not swell noticeably. On the other hand, some soils have a very high percentage of swelling, and these in particular must be suspect. Relative swelling of different soils is indicated by relative shrinkage when dry, as shown by the numbers and sizes of cracks that form. Those that shrink appreciably when dry are soils that may give trouble in a tile field when they are wet.

Information obtained through inspection or from soil maps and reports can be of particular value in preliminary appraisal of soils for sewage disposal. For instance, in many cases, unsuitable soils may be immediately rules out on the basis of such information; in other cases, selection of the best of several sites may be made on the basis of the inspection. Absorption capacity information obtained in this manner is relative. For quantitative information upon which to base specific design, we still must depend on some direct measurement, such as a water absorption rate as measured by a percolation test.

## THE SEPTIC TANK

### THE FUNCTION OF SEPTIC TANKS

When raw sewage enters the septic tank, it should quiscent for a period of one to three days depending on the tank capacity. During this period the heavier solids, including grease and fats, remain in the tank and form the scum over the water surface, while the rest is carried away by effluent into the final disposal system.

The solids which are retained in a septic tank undergo anaerobic decomposition through the activity of bacteria and fungi. The significant result of this process is a considerable reduction in the volume of sludge, which allows the tank to operate for periods of one to four years or more, depending on circumstances, before it needs to be cleaned. This decomposition involves not only the sludge, but also the dissolved and colloidal organic contents of the sewage.

In this manner the turbidity of the effluent is significantly reduced so that it may be more readily percolated into the subsoil of the ground. Thus, the most important function of a septic tank is to provide protection for the absorption ability of the subsoil

The three functions that take place in the tank, then, are:

Removal of Solids

Clogging of soil with tank effluent varies directly with the amount of suspended solids in the liquid. As sewage from a building sewer enters a septic tank, its rate of flow is reduced so that larger solids sink to the bottom or rise to the surface. These solids are retained in the tank, and the clarified effluent is discharged.

Biological Treatment

Solids and liquid in the tank are subjected to decomposition by bacterial and natural processes. Bacteria present are of a variety called anaerobic which thrive in the absence of free oxygen. This decomposition or treatment of sewage under anaerobic conditions is termed "septic," hence the name of the tank. Sewage which has been subjected to such treatment causes less clogging than untreated sewage containing the same amount of suspended solids.

Sludge and Scum Storage

Sludge is an accumulation of solids at the bottom of the tank, while scum is a partially submerged mat of floating solids that may form at the surface of the fluid in the tank. Sludge, and scum to a lesser degree, will be digested and compacted into a smaller volume. However, no matter how efficient the process is a residual of inert solid material will remain. Space must be provided in the tank to store this residue during the interval between cleanings; otherwise, sludge and scum will eventually be scoured from the tank and may clog the disposal field.

DESIGN

The design of the septic tank should promote and facilitate the separation and digestion of the sewage solids and provide for periodic inspection and occasional physical removal of accumulated sludge and scum.

The average daily flow of sewage depends on the average water consumption in the area under consideration. In rural areas and small communities the water consumption per person is likely to be lower than in municipalities. As a result, sewage flows of less than 26 US gal. per person per day may be expected in most rural areas of the world. However, experience indicates that such low figures cannot be used for the design of small septic tanks, which sould be provided with ample capacity since such tanks are seldom cleaned before trouble develops. It is therefore important that their capacity be ample to permit reasonably long periods of trouble-free service and to prevent frequent and progressive damage to the effluent absorption systems due to discharge of sludge by the tanks. For this reason the capacity of residential, single-chambered, septic tanks should not be less than 500 US gal. below water-level.

The liquid capacities of the septic tanks described in Tables 14 and 15 are based on a sewage contribution of:

50 US gal. per person daily in dwellings;
25 US gal. per person daily in cmaps;
17 US gal. per person daily in day schools.

TABLE 14 Required Capacities for Septic Tanks Serving Individual Dwellings

| Maximum number of persons served | Nominal liquid capacity of tank (US gal.) | Recommended dimensions | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | width | | length | | liquid depth | | total depth | |
| | | ft | in. | ft | in. | ft | in. | ft | in. |
| 4 | 500 | 3 | 0 | 8 | 0 | 4 | 0 | 5 | 0 |
| 6 | 600 | 3 | 0 | 7 | 0 | 4 | 0 | 5 | 0 |
| 8 | 750 | 3 | 6 | 7 | 6 | 4 | 0 | 5 | 0 |
| 10 | 900 | 3 | 6 | 8 | 6 | 4 | 6 | 5 | 6 |
| 12 | 1100 | 4 | 0 | 8 | 6 | 4 | 6 | 5 | 6 |
| 14 | 1300 | 4 | 0 | 10 | 0 | 4 | 6 | 5 | 6 |
| 16 | 1500 | 4 | 6 | 10 | 0 | 4 | 6 | 5 | 6 |

* Liquid capacity based on number of persons served in dwelling. The volume based on total depth includes air space above liquid level.

The capacities indicated in Table 14 should in most countries provide sufficient sludge-storage space for a period of two years or more, and an additional volume equal to the sewage flow for 24 hours.

TABLE 15 Required Capacities for Septic Tanks Serving Camps and Day Schools

| Maximum number of persons served | | Nominal liquid capacity of tank (US gal.) | Recommended dimensions | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| camps | day schools | | width | | length | | liquid depth | | total depth | |
| | | | ft | in. | ft | in. | ft | in. | ft | in. |
| 40 | 60 | 1000 | 4 | 0 | 8 | 6 | 4 | 0 | 5 | 0 |
| 80 | 120 | 2000 | 5 | 0 | 11 | [illegible] | 5 | 0 | 6 | 3 |
| 120 | 180 | 3000 | 6 | 0 | 13 | 6 | 5 | 0 | 6 | 3 |
| 160 | 240 | 4000 | 6 | 0 | 16 | 0 | 5 | 0 | 6 | 3 |
| 200 | 300 | 5000 | 7 | 6 | 16 | 0 | 5 | 0 | 6 | 6 |
| 240 | 360 | 6000 | 8 | 0 | 20 | 0 | 5 | 0 | 6 | 6 |
| 280 | 420 | 7000 | 8 | 6 | 20 | 0 | 5 | 6 | 7 | 0 |
| 320 | 480 | 8000 | 8 | 6 | 23 | 0 | 5 | 6 | 7 | 0 |

Note: Tanks with capacities in excess of 8000 gallons should be designed for the specific requirements involved; however, in such cases the necessity for a more complete type of treatment should receive consideration.

The capacities shown in Table 15 are based on a 24-hour flow of sewage without allowance for sludge-storage space, since it is expected that septic tanks serving camps and schools will receive regular inspection and maintenance, including more frequent cleaning than those for residences.

In the case of public institutions, such as rural hotels and hospitals, and groups of houses, such as housing projects, the figures given in Tables may not apply. It will first be necessary to secure the advice of a competent engineer whose duty it will be to determine the probable daily water consumption and sewage flow, both of which are likely to be much higher than the figures cited above. Most recent information indicates that:

1. For flows between 500 gal. and 1500 gal. per day, the capacity of the septic tank should be equal to at least 1 1/2 days' sewage flow.

2. For flows between 1500 gal. and 10,000 gal. per day, the minimum effective tank capacity should be 1125 gal. plus 75% of the daily sewage flow, or:

$$V = 1125 + 0.75\ Q, \text{ where}$$

V is the net volume of the tank in gallons, and Q is the daily sewage flow, also in gallons.

Tanks may be of either single- or multi-compartment design. The single compartment tank is satisfactory for a wide range of conditions and is simpler and less expensive to build and maintain. A two-compartment tank, with the first compartment equal to one-half to two-thirds of the total volume, provides an opportunity for removing more solids, which may be valuable under tight soil conditions. The compartments may be sections of one continuous shell separated by partitions, or separate units connected in series. Each compartment should be vented and provided with inlet and outlet fittings and access facilities for inspection and cleaning.

Whether a tank is rectangular, round, or oval has little effect on its performance, provided it has the necessary capacity and other features. Rectangular tanks are usually built with thelength two to three times the width. It is recommended, however, that the smallest horizontal dimension be at least 2 feet and that the liquid depth be between 30 and 60 inches. These dimensions should be observed in single compartment tanks. About 12 inches (or about one-fourth the liquid depth) is required above the flow line to allow space for scum accumulation and free passage of gases for venting.

Tank performance is affected by the type and arrangement of the inlet and outlet fittings. The inlet invert (flow line) should be at least 1 inch--preferably 3 inches--higher than the outlet invert to prevent backwater and stranding of solids in the house sewer. Use either tees or straight pipe and baffles, arranged as shown in fig. 86. Provide a vertical clearance of at least an inch for venting purposes between the tops of the fittings and the under side of the tank roof. Submerged entry in a downward direction tends to confine entrance disturbance and helps mix the incoming sewage with the more biologically active sewage and sludge already in the tank. The inlet tee or baffle should extend to at least 6 inches below the surface of the liquid, but not deeper than the outlet device. Depth of submergence of the outlet tee or baffle is a critical factor in the performance of the system. If too shallow, scum can pass out of the tank with the effluent. If too deep, sludge can scour out. In either case the particles of solids in the effluent can lead to early clogging of the soil in the absorption area. The ideal depth for the outlet is at a point of balance between the scum and sludge accumulations. This point has been found to be at a depth below the flow line of about 35 to 40 percent of the total liquid depth.

Siphons and dosing chambers are not necessary in ordinary farm installations. They are useful, however, in large installations where the combination of sewage volume and tight soil conditions calls for more than 500 linear feet of disposal tile in the absorption field. The siphon and chamber serve to accumulate a near-continuous, small flow of effluent and provide an intermittent discharge of a larger volume to the absorption field. This loads the field more uniformly and allows some time for rest and aeration between discharges. The frequency and volume of the discharge are controlled by the sizes of the siphon and the chamber. A 3- or 4-inch siphon is adequate. Capacity of the dosing chamber (volume of single discharge) should be about two-thirds the interior volume of the disposal tile. Installation should be inaccordance with the manufacturer's instructions.

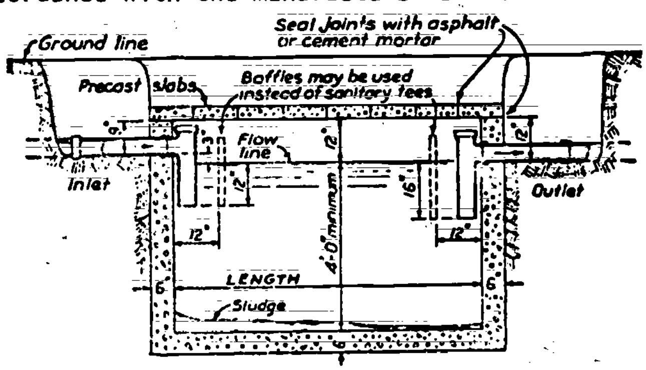


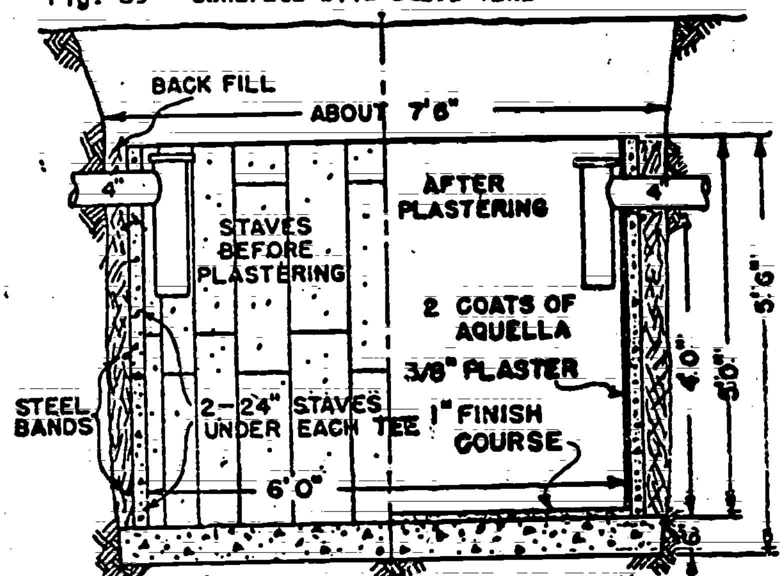

Fig. 88 Longitudinal section of single-compartment Concrete Septic Tank

## Construction Methods For Septic Tanks

Two construction methods for septic tanks have been developed by the Agricultural Engineering Department of the South Dakota State College Agricultural Experiment Station, Brookings, South Dakota.

The methods use readily available building materials. One method employs concrete silo staves, and the tank is built in the form of a vertical cylinder. The other uses standard concrete blocks for a rectangular tank.

Fig. 89 Concrete Silo Stave Tank




SECTION THRU CENTER OF TANK

## Concrete Silo Stave Tank

The construction of both tanks issimple and sizes can be adjusted to the needs of the family. One step in the building process has to be kept in mind as important. Both silo staves and concrete blocks are of relatively porous concrete, therefore the danger of ground water pollution is present unless careful waterproofing is provided.

This tank is in the form of a vertical cyclinder, 6 feet in inside diameter and 5 feet in depth, with a capacity below the outlet of 850 gallons (Fig. 89 ). It is suitable for a family of eight.

Materials:

- 12 6-inch concrete silo staves
- 14 24-inch concrete silo staves
- 34 30-inch concrete silo staves
- 9 sacks cement
- 1 cubic yard of sand
- 1 cubic yard of gravel
- 3 pieces of 1/2-inch round steel rod, 13 feet 8-inches long for hoops
- 3 pieces of 1/2-inch round steel rod, 10 feet 8-inches long for hoops
- 6 steel silo lugs, 12 nuts
- 120 feet (45 pounds) of 3/8-inch knobbed reinforcing rod
- 10 pounds or 1 gallon of waterproofing material
- 2 sewer tile tees, 4-inches in diameter

Excavation

The excavation should be 7 1/2 feet in diameter, with a depth of about 7 feet, depending on the depth at which the sewer from the house will enter. Dig the sides vertical and level the floor before pouring concrete.

Floor

The floor is poured in two courses. The first course, 4 inches thick, is of concrete mixed 1 part cement, 2 1/2 parts sand, 3 1/2 parts gravel. The first course of the floor should cover the whole bottom of the excavation. The concrete should be well worked and carefully levelled to provide a firm, smooth base for placing the staves. Covering the floor with paper or a tarpaulin will make it easier to keep it clean while working on the walls. The pouring of the second course is postponed until the walls are fully constructed, so that the second layer ties floor and wall closely together.

Walls

The walls are made of concrete silo staves 2 1/2 inches thick, 10 inches wide, in lengths of 30, 24, and 6 inches.

First mark a circle of 3-foot radius on the floor to serve as a guide in placing the staves. The staves are set with the inner edge just touching this mark, with 24-inch and 30-inch staves alternating. When this first tier of staves has been completed, a hoop is placed around the outside, 6 inches above the floor, and tightened. A tier of 30-inch staves is now placed upon the top of the 24-inch staves except where the inlet and outlet are to be where 24-inch staves should be used. A second hoop is placed 3 inches above the top of the 24-inch staves in the first tier and tighten the second hoop. Fill in the remaining spaces with 6-inch staves, leaving openings 12 inches high for the inlet and outlet fittings. Place the top hoop just below these openings, and tighten.

Inlet and Outlet Fittings

Cut forms to fit around sewer tile tees and place in position in the openings. The outlet tee should be placed at the bottom of the 12-inch opening left for it,the inlet tee 2 inches above the bottom of the opening. Fill in the space around the tees with a rather dry mortar, tamping it carefully make a watertight joint around the tee.

Plastering the walls

Apply a 3/8-inch coat of plaster of 1 part cement, 3 parts sand, and 1/4 part "Cem-mix" after thoroughly wetting the staves. Smooth the plaster as much as possible.

## Finishing The Floor

Make sure the floor is perfectly clean, dampen it to obtain a good bond, and pour a finish course of 1 part of cement to 3 parts of sand mortar 1 inch thick. Smooth and level this carefully, being sure to obtain a good joint with the plaster on the walls. Allow to cure for seven days or more.

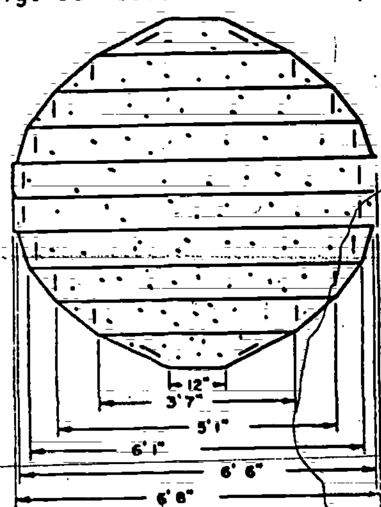
## Waterproofing

Apply two coats of a waterproofing material according to instructions on the package. Waterproofing is essential in order to prevent seepage through the porous staves.

## Cover

The cover is made of reinforced concrete slabs, 4 1/2 inches thick and 8 inches wide, of varying lengths as shown in Fig. 90.

Fig. 90 Cover slab for septic tank

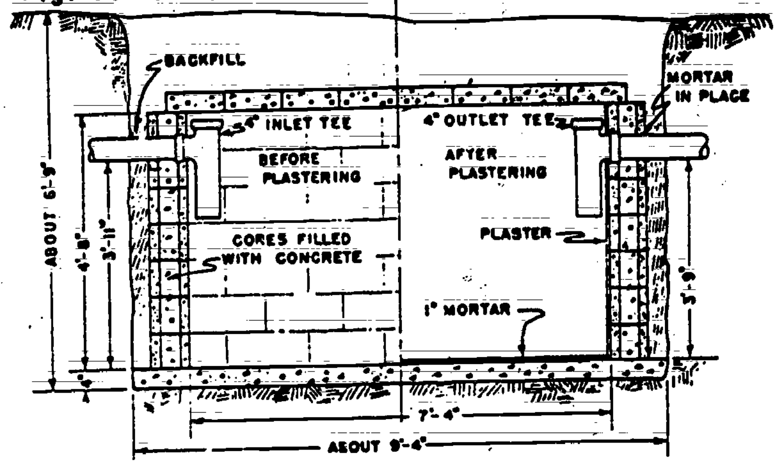



## Mixture for slabs

Mix 1 part cement, 2 1/2 parts of sand, and 3 1/2 parts of gravel or crushed stone to a smooth consistency in order to get a good bond between the concrete and the reinforcing rod. Each slab is reinforced with two 3/8-inch knobbed steel rods, spaced 1 inch from the bottom and 2 inches from the sides. The rods should be placed at both ends of the slab.

These slabs may be made in forms of 2-inch by 6-inch lumber, placed on asphalt paper on any flat surface. Keep the slabs moist and allow to cure for at least three days before moving them.

Fig. 91 Concrete Block Tank




## Concrete Block Tank

This tank is rectangular in shape, 7 feet 4 inches long, 2 feet 8 inches wide, and 4 feet 8 inches deep (inside measurements) with a fluid capacity of 550 gallons (Fig.91 ).

### Materials

- 119 standard concrete blocks (8 inches by 8 inches by 16 inches)
- 15 sacks of cement
- 1 1/2 cubic yards of sand
- 3 3/4 cubic yards of gravel
- 90 ft. of 3/8-inch reinforced rod
- 2 4-inch sewer tile tees
- 110 pounds or 1 gallon of waterproofing material

### Excavation

The excavation should be made 9 feet 4 inches long, 4 feet 8 inches wide, and about 6 feet 9 inches deep, depending on the level at which the sewer will enter. Dig the sides vertical, and level the bottom before pouring.

### Floor

The floor is poured in the same way as for the silo stave tank.

### Walls

The walls are built of standard concrete block laid up with mortar consisting of 1 part cement, 3 parts sand, and 1/4 part lime or "Cem-mix." The corners should be kept square and plumb by use of a straight edge or level.

To add strength to the walls, be sure the joints are staggered between adjacent courses, and fill the cores of the blocks with concrete (1:2 1/2: 4 mix). Cut openings in the block for inlet and outlet fittings.

Plastering and Waterproofing

Follow the instructions given for plastering and waterproofing the silo stave tank. Both silo staves and concrete blocks are of relatively porous concrete which will allow the passage of liquids and contaminating material. Proper waterproofing is essential to reduce the danger of ground water pollution.

Cover

Make precast slabs 4 feet long, 12 inches wide, and 4 1/2 inches thick, using two 3/8 inch reinforcing rods. Follow the instructions given for the silo stave tank. Eight slabs will be required.

Size of tanks

Both tanks may be made larger if required (see Table 16 below). Add more staves to the silo stave tank to increase the size. A larger excavation and longer rods will be required. The concrete block tank may be enlarged by using one more block in each course at the ends, resulting in a width of 4 feet inside, and a capacity of 845 gallons. A tank this size would be large enough for a family of eight, or a smaller family that has methods of construction would be the same, but more materials would be required, and the size of excavation, length of cover slabs, etc., would be increased.

Tanks should not be made smaller than described. ~~In the case of the stave tank, little~~ saving would result, whereas the 550 gallon concrete block tank is little larger than the recommended minimum of 500 gallons.

TABLE 16 CAPACITIES, DIMENSIONS AND MATERIALS FOR SEPTIC TANKS

BUILT OF CONCRETE SILO STAVES

| Number of Persons | Liquid Capacity, Gallons | Diameter (Inside) | Liquid Depth | Total Depth (Inside) | Number of Staves Required 6" | 24" | 30" | Rod Required |
|---|---|---|---|---|---|---|---|---|
| 8 or less | 850 | 6' 0" | 4' | 5' | 12 | 14 | 34 | 3-13' 8", 3-10' 8" |
| 10 | 1050 | 6' 10" | 4' | 5' | 13 | 15 | 37 | 3-13' 8", 3-12' 4" |
| 14 | 1220 | 7' 5" | 4' | 5' | 14 | 16 | 40 | 3-13' 8", 3-14' 0" |

BUILT OF CONCRETE BLOCK

| Number of Persons | Liquid Capacity Gallons | Length (Inside) | Width (Inside) | Liquid Depth | Total Depth (Inside) | Blocks Required |
|---|---|---|---|---|---|---|
| 4 or less | 550 | 7' 4" | 2' 8" | 3' 0" | 4' 8" | 110 |
| 6 | 680 | 7' 4" | 3' 4" | 3' 0" | 4' 8" | 120 |
| 8 | 810 | 7' 4" | 4' 0" | 3' 9" | 4' 8" | 133 |
| 10 | 950 | 7' 4" | 4' 0" | 4' 5" | 5' 4" | 152 |
| 12 | 1150 | 8' 8" | 4' 0" | 4' 5" | 5' 4" | 168 |

Note: A somewhat greater quantity of sand, cement, gravel and waterproofing material will be required for tanks larger than those described in the text.

Note: The foregoing material was digested from New Construction Methods for Septic Tanks and Cisterns, by T.R.C. Rokeby, Circular 99, March 1953, Agricultural Engineering Dept., Agricultural Experiment Station, South Dakota State College, Brookings, South Dakota

## OPERATION AND MAINTENANCE

A newly built septic tank should be filled with water up to the outlet level and then seeded with several buckets of ripe sludge. Although most design recommendations call for desludging about every two years, it is suggested that private installations be examined at least once a year and septic tanks serving public institutions be examined every six months. The inspection should be directed towards the determination of:

(a) the distance from the bottom of scum to bottom of outlet* (scum clear space)
(b) the depth of accumulation of sludge over tank bottom.

Sludge may be bailed out by means of a long-handled, dipper-type bucket, or pumped out by a specially equipped cesspool-emptying vehicle. It is important to recall that the scum and sludge removed from ordinary septic tanks will normally contain some portion which is still offensive and dangerous to health. It is, therefore, wise to compost these materials before using them as a crop fertilizer.

### THE DISPOSAL OF EFFLUENT

In rural areas and small communities, the choice of methods available for treating and disposing of the effluent is usually limited to dilution, seepage pits, subsurface irrigation, filter trenches, sand filters, or trickling filters. Here the discussion will be confined to subsurface irrigation systems and seepage pits.

### THE EFFLUENT SEWER

The effluent sewer conveys the effluent from the septic tank to the absorption or disposal area and may be constructed of the same materials and in the same manner as the house sewer. Joints should be tight and root-proof. A 4-inch line to a slope of 1/8 or 1/4 inch per foot is recommended.

### SUBSURFACE IRRIGATION SYSTEMS

#### Disposal Lines

The effluent is discharged to the soil through a system of open-jointed or perforated disposal tile or pipelines laid in absorption trenches or beds having a total bottom area as determined from table . Dividing this bottom area by the effective absorption area in square feet per lineal foot, from table gives the total length required, in feet. Lateral seepage is neglected.

Proper design and careful workmanship are important to successful operation of the system. Arrangement of the lines varies with the absorption area required and the topography of the available terrain.

* The scum-clear space should not be less than 3 in. and the total depth of scum and sludge accumulations should not be more than 20 in.

Four-inch open-jointed agricultural tile or perforated drain pipe is customarily used. Individual lines should not exceed 100 feet in length and should be laid on a flat grade, never sloping more than 6 inches per 100 feet. All lines should be about the same length.

The preferred depth for an absorption trench (allowing for a gravel bed) is from 24 to 30 inches. However, depths from 18 to 36 inches may be used if it is necessary to clear high ground-water, maintain grade, allow for an extra deep gravel bed, or to meet some other special condition. If it is necessary to go deeper than 36 inches, the deeper portions should be confined to short stretches totaling only a small percentage of the field as a whole. As previously stated, the trench bottom should be at least 4 feet above the highest seasonal ground-water level, the top of any rock formation, or impervious stratum.

Trench width should be from 18 to 24 inches, although widths up to 36 inches may be used in the deeper trenches. Wider trenches call for wider spacing between trenches, as indicated in table

Table 17 Absorption trench area and spacing

| Trench width (inches) | Effective absorption area | Minimum clear distance between trenches |
|---|---|---|
| | Square feet per lineal foot of trench | Feet |
| 18 | 1.5 | 6.0 |
| 24 | 2.0 | 6.5 |
| 30 | 2.5 | 7.0 |
| 36 | 3.0 | 7.5 |

The tile or pipe should be laid in a bed of clean gravel, crushed or broken stone, or similar material. The gravel bed should extend from at least 6 inches below the bottom of the line to at least 2 inches above the top. The bed material may range in size from 1/2 to 2 1/2 inches. Cinders, broken shells, slag, and similar materials are not recommended because they are usually too fine and may cause clogging. About 1/8 to 1/4 inch joint space should be allowed between sections if agricultural tile is used. The upper half of this joint space should be covered with tar paper or similar material to keep out fine material from above. A cover of untreated building paper, straw, hay, pine needles, or similar pervious material should be placed over the bed material to keep out particles of the earth backfill. Impervious material should not be used for this covering as it would interfere with the action of the trench.

Fig. 92 Closed or continuous tile system arrangement for level ground

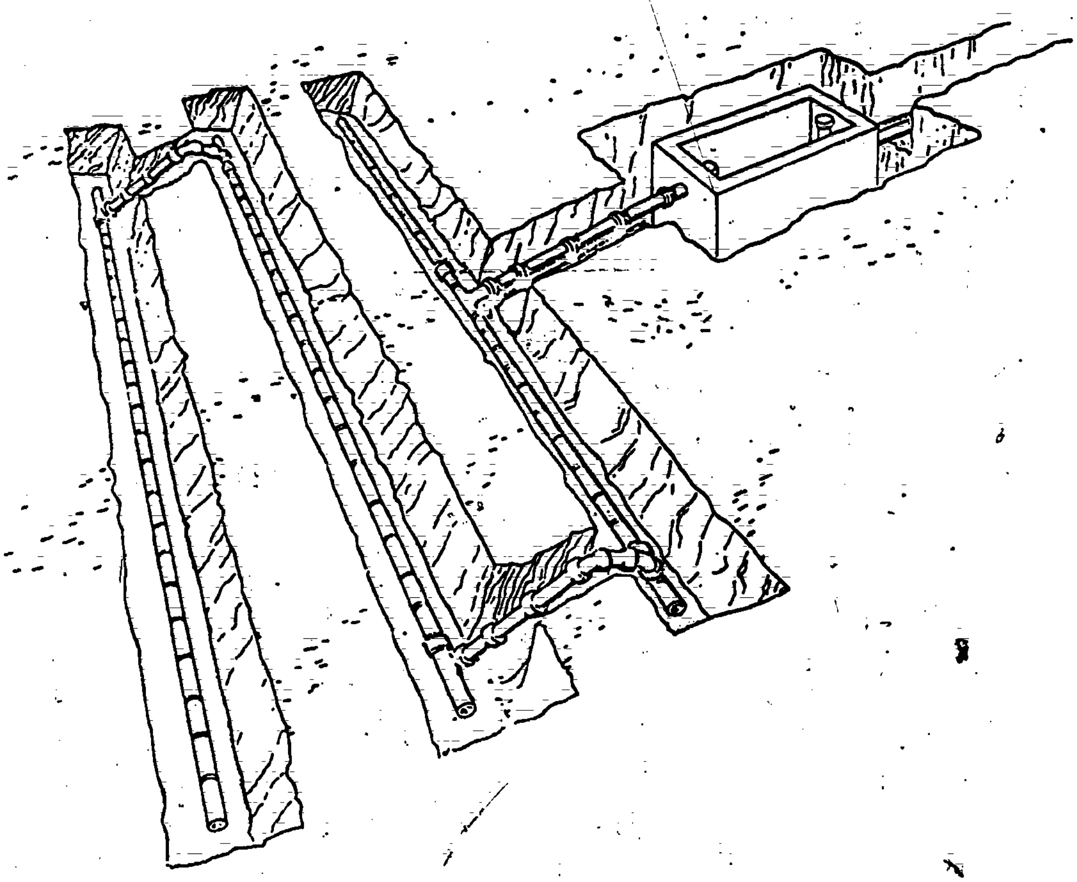
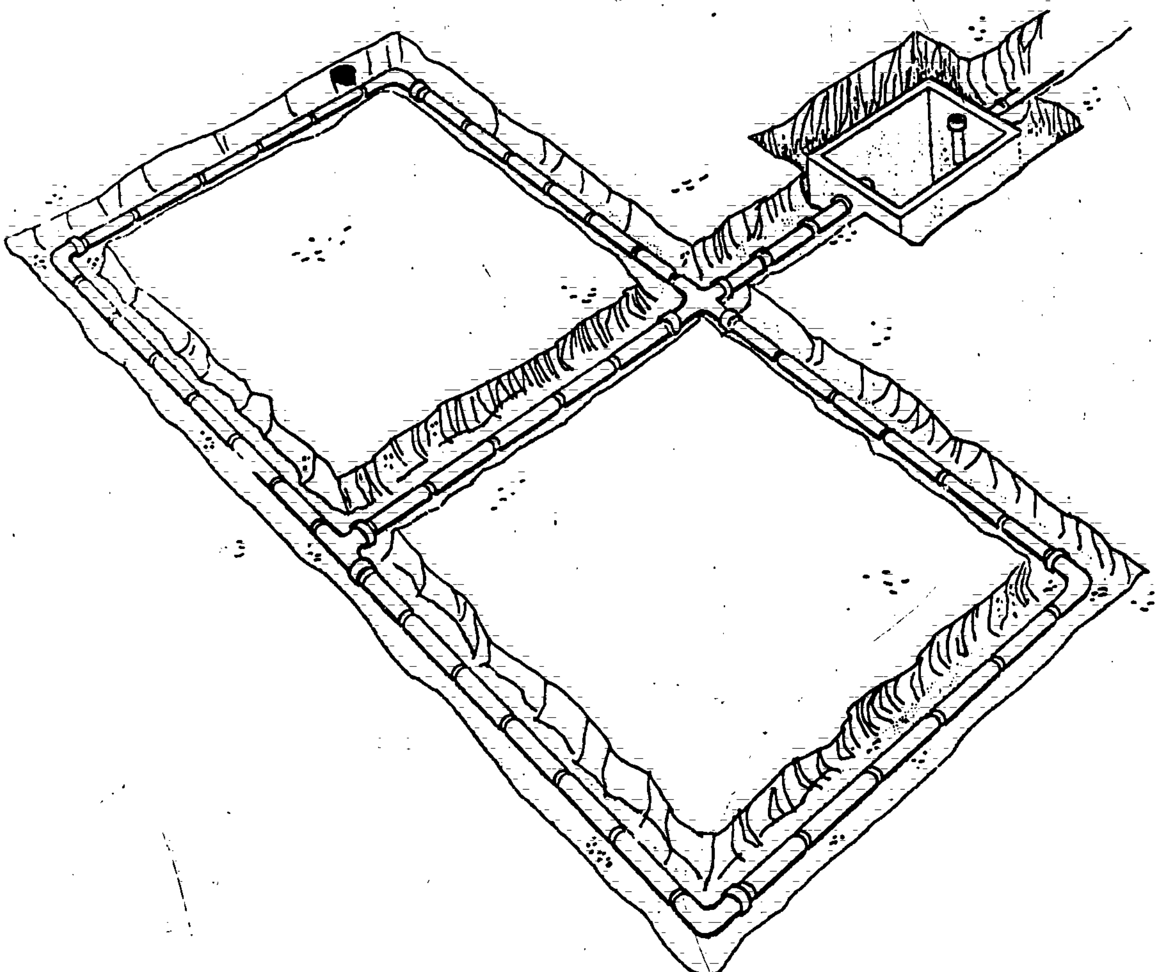


Fig. 93 Serial distribution system arrangement for sloping ground.



If it is necessary to locate a disposal line within reach of the roots of trees or shrubs, deepen the gravel bed in the affected area by about 12 to 18 inches, keeping the line itself level. This provides extra space between the moist trench bottom and the line and may keep the roots from entering the line.

Exercise care during construction to preserve the natural absorptive quality of the soil. Protect the trench from silt and debris while open. Avoid unnecessary walking in the trench. Place gravel or stone carefully and tamp backfill lightly with a hand tamper. Do not machine-tamp and do not use a hydraulic backfill. Overfill the trench about 4 to 6 inches to allow for settling.

Closed or Continuous System

In flat locations, where the slope of the ground surface does not exceed 6 inches in any direction within the area of the absorption field, the disposal lines may be arranged in a closed or continuous system as shown in figure 92 . In this system, open-jointed tile or perforated pipe is used throughout the field. It is laid on a flat grade and the entire trench length is counted in the effective absorption area. Because of the flat grade and interconnecting lines, the effluent will distribute satisfactorily without a distribution box.

Serial Distribution System

Serial distribution of effluent is recommended for practically all situations where soil conditions permit subsurface absorption and where the slope of the ground surface exceeds 6 inches in any direction within the confines of the absorption field. Excessively steep slopes that are subject to erosion should be avoided. In the serial distribution system, the individual trenches of the absorption field are arranged so that each trench is forced to pond to the full depth of the gravel fill before the effluent flows into the succeeding trench. (See Fig. 93 )

Advantages of this system are: (1) It minimizes the importance of variable absorption rates in different parts of the field by forcing each trench to absorb effluent until its ultimate capacity is utilized; (2) it causes each trench in the system to be used to full capacity before failure occurs; and (3) it eliminates the cost of a distribution box and the runs of tight-jointed pipe from the box to the absorption trenches.

The following design and construction features should be observed for satisfactory operation of this system:

1. Individual trench bottoms and disposal lines should be level, following contours to minimize variation in trench depth.

2. A minimum of 12 inches of earth should cover the gravel fill in the trenches.

3. A minimum of 6 feet of undisturbed earth should be allowed between adjacent trenches, and between the septic tank and the nearest trench.

4. Overflow lines should connect the trenches in such a manner that a trench will be filled with effluent to the depth of the gravel before the effluent flows to the next lower trench. This may be done as shown in figure , by having the invert of the overflow line at the top of the gravel fill.

5. The overflow lines should be 4-inch diameter tight-jointed sewers, connecting directly to the distribution lines in the trenches. The trench for an overflow line, at the point where it leaves an absorption trench, should be dug no deeper than the top of the gravel fill in the absorption trench.

6. The outlet (overflow) from a given absorption trench should be as far as practical from the inlet to that trench in order to prevent short-circuiting of the effluent.

7. The invert of the first overflow line should be at least 4 inches lower than the invert of the septic tank outlet.

8. All other features should match those for subsurface absorption fields generally.

Distribution Box

Experience has shown that distribution boxes and similar devices seldom achieve the uniform distribution of effluent that is expected of them. Effluent distribution by the continuous or serial distribution systems gives as good results or better, and generally at less cost.

If a distribution box is used, the following essential design features should be observed:

1. All outlets must be set at exactly the same level--about 4 to 5 inches above the bottom is recommended. This gives space for carryover sludge to accumulate and be detected by inspection. It also serves in lieu of a baffle to prevent short-circuiting and thus aid in obtaining equal distribution of the effluent.

2. A separate outlet is needed for each line of tile; adjacent outlets should be separated by at least a full pipe diameter.

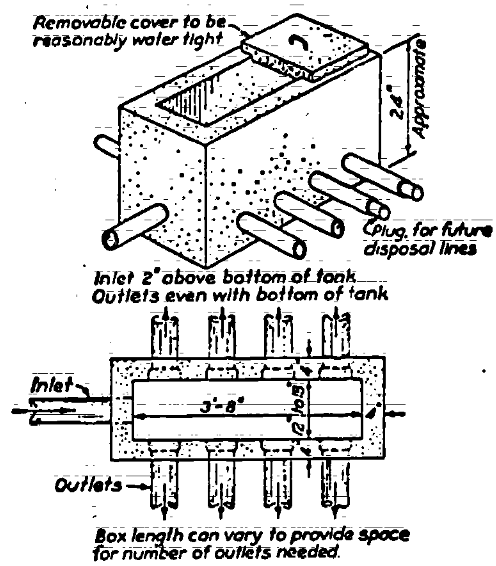
3. The inlet should be about 2 inches higher than the outlets.

4. A watertight, removable cover should be provided for access.

If a box is to serve an absorption field in which it is desired to "work" and "rest" certain lines alternately or in rotation, because of tight soil conditions or other reason, facilities should be provided in the box for opening and closing the corresponding outlets. Also, if there is prospect of future need for more lines from the box, additional outlets may be provided at the time of construction and fitted with plugs that can be readily removed when the need develops. More than one box may be used if the ground slope warrants.

Fig.94 illustrates a distribution box such as used on farms in the U.S.

Fig. 94 Typical Distribution Box



WATER-CARRIED SEWAGE SYSTEMS

CONSTRUCTION AND MAINTENANCE

LESSON NO. 2

LESSON OBJECTIVE: Outline the factors that must be considered in designing a water-carried sewage systems.

| TOPIC | INSTRUCTIONAL PROCEDURE | SUPPLEMENTAL MATERIALS RELATED READING |
|---|---|---|
| System Location | Outline the factors that must be considered in the location of water-carried sewage systems. | |
| The Percolation Test | Demonstrate digging a test hole with a hand held auger.<br><br>Supervise students in digging test holes for a percolation test.<br><br>Conduct a percolation test. | |
| Selection of Disposal System | Review the factors that must be considered in determining the type of facility to be implemented. | |

# WATER-CARRIED SEWAGE SYSTEMS

## CONSTRUCTION AND MAINTENANCE

## LESSON NO. 2

LESSON OBJECTIVE: Set up and carry out a program to construct a water-carried sewage system.

| TOPIC | INSTRUCTIONAL PROCEDURE | SUPPLEMENTAL MATERIALS RELATED READING |
|---|---|---|
| The Components of Water-Carried Disposal Systems | Discuss the functions of the fundamental components of the seepage pit, cesspool and septic tank | Diagrams of these systems<br>WHO Monograph Series #39 Chapter 3. |
| | Illustrate the [illegible] and components for these systems | Manual of Septic Tank Practice, p. 9-38. |
| | Outline the [illegible]e of construction for these sy[illegible] | Constructing a Concrete Septic Tank (Technical Digest Survey) |
| Sy[illegible] Selection | Assemble students to select the most feasible locations of these systems in a rural or village community. | |
| Construction Techniques | Outline construction methods for septic tanks. | |
| | Set up a program (allocate construction tasks to the students) for the construction of a septic tank. | |
| | Supervise students in the construction of this septic tank. | |

WATER-CARRIED SEWAGE SYSTEMS

CONSTRUCTION AND MAINTENANCE

LESSON NO. 3

LESSON OBJECTIVE: Define the need for and the methods of establishing a maintenance program for this system.

| TOPIC | INSTRUCTIONAL PROCEDURE | SUPPLEMENTAL MATERIALS RELATED READING |
|---|---|---|
| Rules for Efficient Operation and Maintenance of Septic Tank Systems | Discuss the need for septic tank inspection.<br><br>Recall how often inspection should be carried out and what it should establish.<br><br>Discuss how to maintain a septic tank.<br><br>Visit a site where a septic tank is being desludged. | |
| The Need for Simplifying Technical Materials | Discuss the difficulty of finding skilled labor in developing countries.<br><br>Outline how to simplify instructional materials. | WHO Monograph Series -- Chapter 9 |

# APPENDIX A

The chart converts pounds and oucces to kilograms and grams of vice versa. For weights greater than ten pounds, or more accurate results, the tables or conversion equations must be used.

Notice that there are sixteen divisions for each pound on the chart to represent ounces. There are only 100 divisions in the first kilogram, and each division represents ten grams. The chart is accurate to about plus or minus twenty grams.

EQUATIONS

1 oz. = 28.35 g.
1 lb. = 0.4536 kg.
1 g. = 0.03527 oz.
1 kg. = 2.205 lb.

KILOGRAMS INTO POUNDS
(1 kg. = 2.20463 lb.)

| kg. | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|---|
| 0 | lb. | 2.20 | 4.41 | 6.61 | 8.82 | 11.02 | 13.23 | 15.43 | 17.64 | 19.84 |
| 10 | 22.05 | 24.25 | 26.46 | 28.66 | 30.86 | 33.07 | 35.27 | 37.48 | 39.68 | 41.89 |
| 20 | 44.09 | 46.30 | 48.50 | 50.71 | 52.91 | 55.12 | 57.32 | 59.53 | 61.73 | 63.93 |
| 30 | 66.14 | 68.34 | 70.55 | 72.75 | 74.96 | 77.16 | 79.37 | 81.57 | 83.78 | 85.98 |
| 40 | 88.19 | 90.39 | 92.59 | 94.80 | 97.00 | 99.21 | 101.41 | 103.62 | 105.82 | 108.03 |
| 50 | 110.23 | 112.44 | 114.64 | 116.85 | 119.05 | 121.25 | 123.46 | 125.66 | 127.87 | 130.07 |
| 60 | 132.28 | 134.48 | 136.69 | 138.89 | 141.10 | 143.30 | 145.51 | 147.71 | 149.91 | 152.12 |
| 70 | 154.32 | 156.53 | 158.73 | 160.94 | 163.14 | 165.35 | 167.55 | 169.76 | 171.96 | 174.17 |
| 80 | 176.37 | 178.58 | 180.78 | 182.98 | 185.19 | 187.39 | 189.60 | 191.80 | 194.01 | 196.21 |
| 90 | 198.42 | 200.62 | 202.83 | 205.03 | 207.24 | 209.44 | 211.64 | 213.85 | 216.05 | 218.26 |

POUNDS INTO KILOGRAMS
(1 lb. = 0.45359 kg.)

| lb. | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|---|
| 0 | kg. | 0.454 | 0.907 | 1.361 | 1.814 | 2.268 | 2.722 | 3.175 | 3.629 | 4.082 |
| 10 | 4.536 | 4.990 | 5.443 | 5.897 | 6.350 | 6.804 | 7.257 | 7.711 | 8.165 | 8.618 |
| 20 | 9.072 | 9.525 | 9.979 | 10.433 | 10.886 | 11.340 | 11.793 | 12.247 | 12.701 | 13.154 |
| 30 | 13.608 | 14.061 | 14.515 | 14.969 | 15.422 | 15.876 | 16.329 | 16.783 | 17.237 | 17.690 |
| 40 | 18.144 | 18.597 | 19.051 | 19.504 | 19.958 | 20.412 | 20.865 | 21.319 | 21.772 | 22.226 |
| 50 | 22.680 | 23.133 | 23.587 | 24.040 | 24.494 | 24.948 | 25.401 | 25.855 | 26.308 | 26.762 |
| 60 | 27.216 | 27.669 | 28.123 | 28.576 | 29.030 | 29.484 | 29.937 | 30.391 | 30.844 | 31.298 |
| 70 | 31.751 | 32.205 | 32.659 | 33.112 | 33.566 | 34.019 | 34.473 | 34.927 | 35.380 | 35.834 |
| 80 | 36.287 | 36.741 | 37.195 | 37.648 | 38.102 | 38.555 | 39.009 | 39.463 | 39.916 | 40.370 |
| 90 | 40.823 | 41.277 | 41.730 | 42.184 | 42.638 | 43.091 | 43.545 | 43.998 | 44.452 | 44.906 |

## APPENDIX B

This foldout chart is useful for quick conversion from meters and centimeters to feet and inches or vice-versa. For distances greater than three meters, or more accurate results, the tables or conversions equations must be used.

The chart (page ) has metric division of one centimeter to three meters, and English graduations in inches and feet to ten feet. It is accurate to about plus or minus one centimeter. Folding out the chart makes a handy reference when studying other drawings in the Handbook.

For more accurate results the tables below!

An example may help explain how to use this type of table. Suppose you wish to find how many inches are equal to 66 cm. On the cm. to in. table look down the leftmost column to 60 cm., and then right to the column headed 6 cm. This gives the result, 25.984 inches.

**Inches into Centimeters**
(1 in. = 2.539977 cm.)

| inches | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|---|
| 0 | cm. | 2.54 | 5.08 | 7.62 | 10.16 | 12.70 | 15.24 | 17.78 | 20.32 | 22.86 |
| 10 | 25.40 | 27.94 | 30.48 | 33.02 | 35.56 | 38.10 | 40.64 | 43.18 | 45.72 | 48.26 |
| 20 | 50.80 | 53.34 | 55.88 | 58.42 | 60.96 | 63.50 | 66.04 | 68.58 | 71.12 | 73.66 |
| 30 | 76.20 | 78.74 | 81.28 | 83.82 | 86.36 | 88.90 | 91.44 | 93.98 | 96.52 | 99.06 |
| 40 | 101.60 | 104.14 | 106.68 | 109.22 | 111.76 | 114.30 | 116.84 | 119.38 | 121.92 | 124.46 |
| 50 | 127.00 | 129.54 | 132.08 | 134.62 | 137.16 | 139.70 | 142.24 | 144.78 | 147.32 | 149.86 |
| 60 | 152.40 | 154.94 | 157.48 | 160.02 | 162.56 | 165.10 | 167.64 | 170.18 | 172.72 | 175.26 |
| 70 | 177.80 | 180.34 | 182.88 | 185.42 | 187.96 | 190.50 | 193.04 | 195.58 | 198.12 | 200.66 |
| 80 | 203.20 | 205.74 | 208.28 | 210.82 | 213.36 | 215.90 | 218.44 | 220.98 | 223.52 | 226.06 |
| 90 | 228.60 | 231.14 | 233.68 | 236.22 | 238.76 | 241.30 | 243.84 | 246.38 | 248.92 | 251.46 |

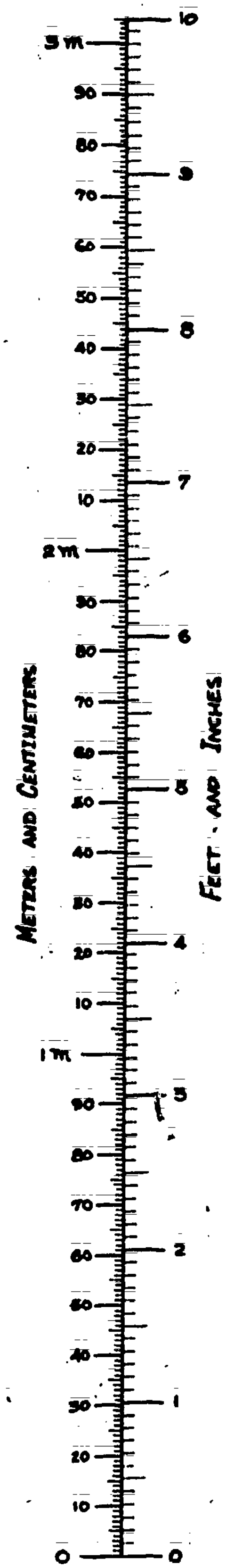
**Centimeters into Inches**
(1 cm. = 0.3937 in.)

| cm. | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|---|
| 0 | inches | 0.394 | 0.787 | 1.181 | 1.575 | 1.969 | 2.362 | 2.756 | 3.150 | 3.543 |
| 10 | 3.937 | 4.331 | 4.724 | 5.118 | 5.512 | 5.906 | 6.299 | 6.693 | 7.087 | 7.480 |
| 20 | 7.874 | 8.268 | 8.661 | 9.055 | 9.449 | 9.843 | 10.236 | 10.630 | 11.024 | 11.417 |
| 30 | 11.811 | 12.205 | 12.598 | 12.992 | 13.386 | 13.780 | 14.173 | 14.567 | 14.961 | 15.354 |
| 40 | 15.748 | 16.142 | 16.535 | 16.929 | 17.323 | 17.717 | 18.110 | 18.504 | 18.898 | 19.291 |
| 50 | 19.685 | 20.079 | 20.472 | 20.866 | 21.260 | 21.654 | 22.047 | 22.441 | 22.835 | 23.228 |
| 60 | 23.622 | 24.016 | 24.409 | 24.803 | 25.197 | 25.591 | 25.984 | 26.378 | 26.772 | 27.165 |
| 70 | 27.559 | 27.953 | 28.346 | 28.740 | 29.134 | 29.528 | 29.921 | 30.315 | 30.709 | 31.102 |
| 80 | 31.496 | 31.890 | 32.283 | 32.677 | 33.071 | 33.465 | 33.858 | 34.252 | 34.646 | 35.039 |
| 90 | 35.433 | 35.827 | 36.220 | 36.614 | 37.008 | 37.402 | 37.795 | 38.189 | 38.583 | 38.976 |

EQUATIONS

1 inche= 2.54 cm.
1 foot = 30.48 cm.
       = 0.3048 m.
1 yard = 91.44 cm.
       = 0.9144 m.
1 mile = 1.6 km.

1 cm. = 0.3937 in.
1 m.  = 39.37 in.
      = 3.28 ft.
1 km. = 0.62137 mile



# BIBLIOGRAPHY

Agricultural Mathematics for Peace Corps Volunteers, New York (Development and Research Corporation), 1968

Design and Operation of Septic Tanks, World Health Organization, Geneva

Domestic Water Supply and Sewage Disposal Guide, Anderson, Edwin P., New York (Theo. Audel & Co.), 1960

Elements of Water Supply and Waste-Water Disposal, Fair, G.M. and Geyer, J.C., John Wiley and Sons, Inc., 1961

Excreta Disposal for Rural Areas and Small Communities, Wagner and Lanoix, Geneva (World Health Organization), 1958

Farmstead Sewage and Refuse Disposal, Agriculture Information Bulletin No. 274 Agricultural Research Service, U.S. Department of Agriculture, Washington, D.C., 1963

Manual of Individual Water Supply Systems, Public Health Service Publication No. 24 (U.S. Department of Health, Education and Welfare) Washington, D.C., 1962

Manual of Septic - Tank Practice, Public Health Service Publication No. 526 (U.S. Department of Health, Education, and Welfare) Washington, D.C., 1967

"Minimum Requirements for the Disposal of Sanitary Sewage in Unsewered Areas", The Sanitary Code, Article XI, Commonwealth of Mass., Department of Public Health, 1962

Municipal and Rural Sanitation, Ehlers, V.M. and Steel, E.W., McGraw-Hill Book Company, Inc., 1958

Plumbing: Repairs and Utilities, Technical Manual TM5-619, War Department, 1945

Recommended Practice for Distribution Systems Records, American Water Works Association, New York, 1940

Rural Sanitation in the Tropics, Bulletin No. 8, The Ross Institute, London (The London School of Hygiene and Tropical Medicine, Keppel Street - Gower St. - London, W.C. 1.), 1965

Rural Water Supply and Sanitation, Wright, F.B. (John Wiley and Sons, Inc.), 1956

Safe Water -- Bulletin ES No. 4, Olympia, Washington (Washington State Department of Health)

Sewage Disposal, (Cornell Rural Housing Leaflet No. 10), Hoff, Paul R., (New York State College of Agriculture, Cornell University), 1947

Soils Suitable for Septic Tank Filter Fields, Bender, William H., U.S. Department of Agriculture, Soil Conservation Service, Agriculture Information Bulletin No. 243; 1961

Stock-Water Developments -- Wells, Springs, and Ponds; Farmer's Bulletin No. 1859, U.S. Department of Agriculture, 1940

Studies on Household Sewage Disposal Systems, Weibel, S.R., Straub, C.P., Thoman, J.R.; Cincinnati, Ohio (Federal Security Agency; Public Health Service Environmental Health Center), 1949

Suggested Design Criteria for Waterworks in Recreational Areas, Pacific Southwest and Columbia Basin Inter-Agency Committees, 1965

Water and Man's Health, Miller, Arthur P., (Office of Human Resources and Social Development, Agency for International Development) Washington, D.C., 1962

Water Supply and Plumbing Cross-Connections; Hazards in Household and Community Systems, U.S. Department of Health, Education and Welfare (Public Health Service), 1963

Water Supply and Sewage Disposal, Paris (Organization for European Economic Co-operation) 1953

Water Supply for Rural Areas and Small Communities, Wagner and Lanoix, Geneva (World Health Organization), 1959

Water Systems, Washington (National Radio Institute), 1964

Water Treatment - A Guide to the Treatment of Water and Effluents Purification, James, G.V.; Cleveland, Ohio (CRC Press, A Division of the Chemical Rubber Co.) Third Edition, 1966

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