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Village Technology Handbook

SECTION 1: WATER RESOURCES

Part 1: Developing Water Resources

FOREWORD

Progress is the result of man's mastery of the world he lives in. The VILLAGE TECHNOLOGY HANDBOOK is aimed at helping villagers to master the resources available to them: to improve their own lives and to bring their villages more fully into the lives of the nations of which they form a basic and important part.

Village development takes on special importance in the light of the fact that 80 percent of those who live in less-developed countries live in villages. If progress is to come to nations, progress must come to villages.

Technical information is a basic factor in progress, along with other basic factors: political, social and economic. The VILLAGE TECHNOLOGY HANDBOOK was conceived by VITA Volunteers in 1962 as a means of bridging the "technical information gap" which keeps the world's villages from learning from one another's experience. The book's aim is to gather in one publication information from many sources which has been found helpful in villages.

This handbook was first published by the U.S. Agency for International Development in two volumes in 1963 and 1964. In the 1970 edition, the two earlier volumes are integrated into one book, the editing has been made more uniform, some new information has been added and the illustrations have been improved. The entire handbook has been checked for accuracy by VITA Volunteer specialists. A new feature in this edition is the incorporation of information on other publications which cover in detail subjects which are discussed only briefly here. VITA plans to continue to improve the handbook in future editions to make it increasingly effective as a key to existing technology for village workers.

The information in the handbook has come from many sources. VITA hopes that criticism and new information will come from many of the same sources--and from other sources. The questionnaire on page ix was designed to stimulate this flow of criticism and information. VITA will test new information and then disseminate it to those who need it.

VITA is grateful to the U.S. Agency for International Development for its financial support of the revision and for its help in reviewing the contents. Thanks are also due to the Federal Extension Service, U.S. Department of Agriculture, for its help in reviewing the section on "Home Improvement".

A NOTE ON USING THE HANDBOOK

This handbook describes techniques and devices which can be made and used in villages. Hopefully the book will generate new ideas as well as pass on information which has already been tried.

Some of the practices suggested here can be adopted on an individual basis. Others, however, will require cooperation by many people and, perhaps, by government agencies. In many cases, it would be well to seek out extension services existing in your area. If local government or university extension services are available, they will be able to give you information well suited to local conditions. In some cases, there may be a need for a credit union or a consumer, marketing, housing or service cooperative. Information on credit unions is available from:

CUNA International, Inc.
World Extension Department
Box 431
Madison, Wisconsin 53701
U.S.A.

Information on cooperatives is available from:

Agricultural Cooperative Development
International
Suite 1200
1430 K St., N.W.
Washington, D.C. 20005
U.S.A.

When the materials suggested in the handbook are not available, it may be possible to substitute other materials; but be careful to make any changes in dimensions made necessary by such substitutions.

Dimensions are given in metric units in the text, with English units in parentheses. Only metric units are given in the illustrations. Conversion tables are given in the Appendix.

Reference materials, along with information on where they can be obtained, are listed at the end of a specific entry when they pertain to that entry. When they refer more generally to the field covered in a section of the book, they are given at the end of the section. If you cannot get these publications, VITA may be able to help you.

If you want to use translations of material in the handbook, we ask you to let VITA know. The material you want may already be translated; if it is not, and if you translate it, VITA would like to make your translation available to others.

If you have questions on the material presented here, if you run into problems in implementing the handbook's suggestions, or if you have other technical problems, do not hesitate to ask for the personal help of a VITA Volunteer specialist. Write to:

VITA
3706 Rhode Island Avenue
Mt. Rainier, Md. 20822
U.S.A.

VITA's Volunteer Translation Service can translate letters in languages other than English, but correspondence moves much more quickly when carried on entirely in English. To help VITA Volunteers find a useful solution to your problem as quickly as possible, you should:

1. Be quantitative--give measurements, sketches or, when possible, photos.

2. Explain what materials are available and what limitations there are on cost.

3. Describe the best solution, if any, found so far in the area.

4. Explain any pertinent social or cultural conditions.

5. Indicate a deadline for action, especially if immediate attention is needed.

6. Don't expect miracles on the first reply. Successful problem-solving often takes a number of letters back and forth.

WHAT IS VITA?

VITA (Volunteers in Technical Assistance) was established in 1959 as a private, non-profit organization responding to requests for assistance in economic and social development. VITA mobilizes and coordinates the work of over 7,000 volunteer professionals representing 96 countries, 2000 corporations, universities, and other institutions. The VITA talent bank represents know-how in commerce and industry, agriculture and education, engineering and public health, in addition to many other fields.

VITA provides the most appropriate knowledge to specific calls for assistance from individuals, organizations, small businesses and self-help development groups. In its brief history VITA has responded to over 25,000 requests. VITA meets people's needs through the mail, by telephone, and by on-site counselling. Requests have come from village councils, community development volunteers, farmers, small business owners, and from members of national and international public and private institutions. VITA's unique method matches people with need and people with knowledge to give. This partnership increases the opportunity for the success of the requester's project.

One of the most effective ways that VITA shares its information with many people in through its Publications Program. The VILLAGE TECHNOLOGY HANDBOOK has played an important role in helping to disseminate that information. Supplementing this book is VITA's Technology Manual series, how-to-do-it booklets, which cover a wide spectrum of subject matter. A publications list is available on request.

In its OVERSEAS LIAISON PROGRAM, VITA encourages the formation of similar technical assistance programs throughout the world. Cooperation with these and other organizations working in the developing countries will give VITA access to on-the-spot background information on the technological aspects of international development.

VITA is financed by contributions from private individuals, foundations and industry, and by government grants.

SYMBOLS AND ABBREVIATIONS USED IN THIS BOOK

@ . . . . at
" . . . . inch
' . . . . foot
C . . . . degrees Celsius (Centigrade)
cc . . . cubic centimeter
cm . . . centimeter
cm/sec . centimeters per second
d or dia. diameter
F . . . . degrees Fahrenheit
gm . . . gram
gpm . . . gallons per minute
HP . . . horsepower
kg . . . kilogram
km . . . kilometer
l . . . . liter
lpm . . . liters per minute
l/sec . . liters per second
m . . . . meter
ml . . . milliliters
mm . . . millimeters
m/m . . . meters per minute
m/sec . . meters per second
ppm . . . parts per million
R . . . . radius

QUESTIONNAIRE

NOTE TO THE READER: VITA's publications are compiled by VITA Volunteers because they want to help people in developing areas. With your field experience, you are in a unique position of being able to increase the usefulness of this work by sharing what you have learned with the people who will use the publications in the future. You are strongly urged to complete the following questionnaire (using additional sheets if necessary), cut it out and send it to:

VITA
3706 Rhode Island Avenue
Mt. Rainier, Md. 20822
U.S.A.

Date ____________

Name ______________________________ Agency ____________________

Address ___________________________

____

1. Which items from the VILLAGE TECHNOLOGY HANDBOOK have you put into practice?

2. Have results been good or otherwise?

3. Have you made improvements or modifications in any of the devices or techniques? If so, please describe them, including photographs or sketches if possible.

4. Have you devised any new equipment or techniques not described in the handbook which may be of use to others? If so, please describe them.

5. Did you find the handbook useful, too simple, too complex, incomplete?

6. Other comments and suggestions:

TABLE OF CONTENTS

Developing Water Sources

There are three main sources of water for small water-supply systems: ground water, surface water and rainwater. The entries which follow describe the methods of getting water from these three sources:

1. Getting Ground Water from Wells and Springs.

2. Building Small Dams to Collect Surface Water.

3. Collecting Rainwater in Cisterns.

The choice of the source of water depends on local circumstances. A study of the local area should be made to determine which source is best for providing water which is (1) safe and wholesome, (2) easily available and (3) sufficient in quantity.

Once the water is made available, it must be brought from where it is to where it is needed and steps must be taken to be sure that it is pure. These subjects are covered in sections on:

Water Lifting

Water Transport

Water Purification

An added section on Map Making gives guidelines which will be helpful in irrigation and drainage projects.

* * * * *

GETTING GROUND WATER FROM WELLS AND SPRINGS

This section explains ground water and then describes a variety of methods of collecting ground water:

1. Tubewells

   a. Well Casing and Platforms

   b. Hand-Operated Drilling Equipment

   c. Driving Wells

2. Dug Wells

3. Spring Development

FIGURE 1

<u>Ground Water</u>

Ground water is subsurface water which fills small openings (pores) of loose sediments (such as sand and gravel) or rocks. For example, if we took a clear glass bowl, filled it with sand, and then poured in some water, we would notice the water "disappear" into the sand (see Figure 1). However, if we looked through the side of the bowl, we would see water in the sand, but below the top of the sand. The sand containing the water is said to be saturated. The top of the saturated sand is called the <u>water table</u>; it is the level of the water in the sand.

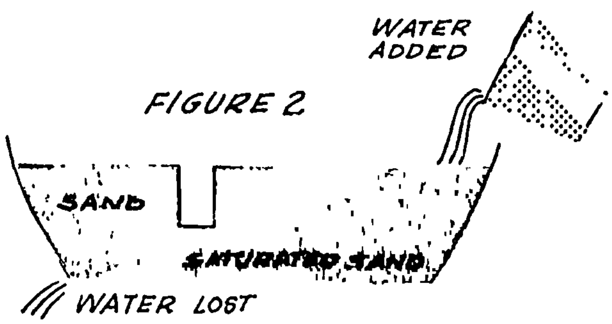
The water beneath the water table is true ground water available (by pumping) for human use. There is water in the soil above the water table, but it does not flow into a well and is not available for usage by pumping.

If we inserted a straw into the saturated sand in the bowl in Figure 1 and sucked on the straw, we would obtain some water (initially, we would get some sand too). If we sucked long enough, the water table or water level would drop toward the bottom of the bowl. This is exactly what happens when water is pumped from a well drilled below the water table.

The two basic factors in the occurrence of ground water are: (1) the presence of water, and (2) a medium to "house" the water. In nature, water is primarily provided by precipitation (rain and snow), and secondarily, by surface water features (rivers and lakes). The medium is porous rock or loose sediments.

The most abundant ground-water reservoir occurs in the loose sands and gravels in river valleys. Here the water table roughly parallels the land surface, that is, the depth to the water table is generally constant. Disregarding any drastic changes in climate, natural ground-water conditions are fairly uniform or balanced. In Figure 2, the water poured into the bowl (analogous to precipitation) is balanced by the water discharging out of the bowl at the lower elevation (analogous to discharge into a stream). This movement of ground water is slow, generally centimeters or inches per day.

FIGURE 2



When the water table intersects the land surface, springs or swamps are formed (see Figure 3). During a particularly wet season, the water table will come much closer to the land surface than it normally does and many new springs or swampy areas will appear. On the other hand, during a particularly dry season, the water table will be lower than normal and many springs will "dry up." Many shallow wells may also "go dry."

Flow of Water to Wells

A newly dug well fills with water a meter or so (a few feet) deep, but after some hard pumping it becomes dry. Has the well failed? Was it dug in the wrong place? More likely you are witnessing the phenomenon of drawdown, an effect every pumped well has on the water table, (see Figure 4).

Because water flows through sediments slowly, almost any well can be pumped dry temporarily if it is pumped hard enough. Any pumping will lower the water level to some degree, in the manner shown in Figure 4. A serious problem arises only when the drawdown due to normal use lowers the water table below the level of the well.

After the well has been dug about a meter (several feet) below the water table, it should be pumped at about the rate it will be used to see if the flow into the well is adequate. If it is not sufficient, there may be ways to improve it. Digging the well deeper or wider will not only cut across more of the water-bearing layer to allow more flow into the well, but it will also enable the well to store a greater quantity of water which may seep in overnight. If the well is still not adequate and can be dug no deeper, it can be widened further, perhaps lengthened in one direction, or more wells can be dug. If it is possible to do so safely, another method is to dig horizontal tunnels out from the bottom of the well. The goal of all these methods is to intersect more of the water-bearing layers, so that the well will produce more water without lowering the water table to the bottom of the well.

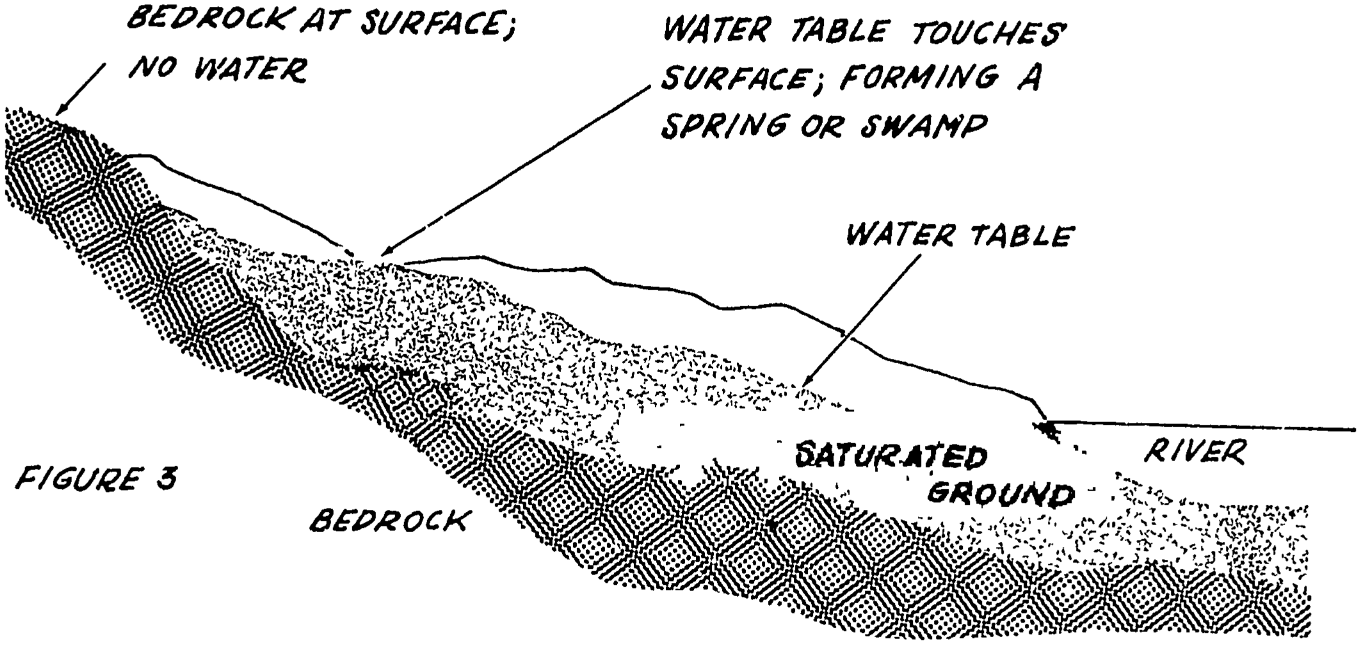


FIGURE 3

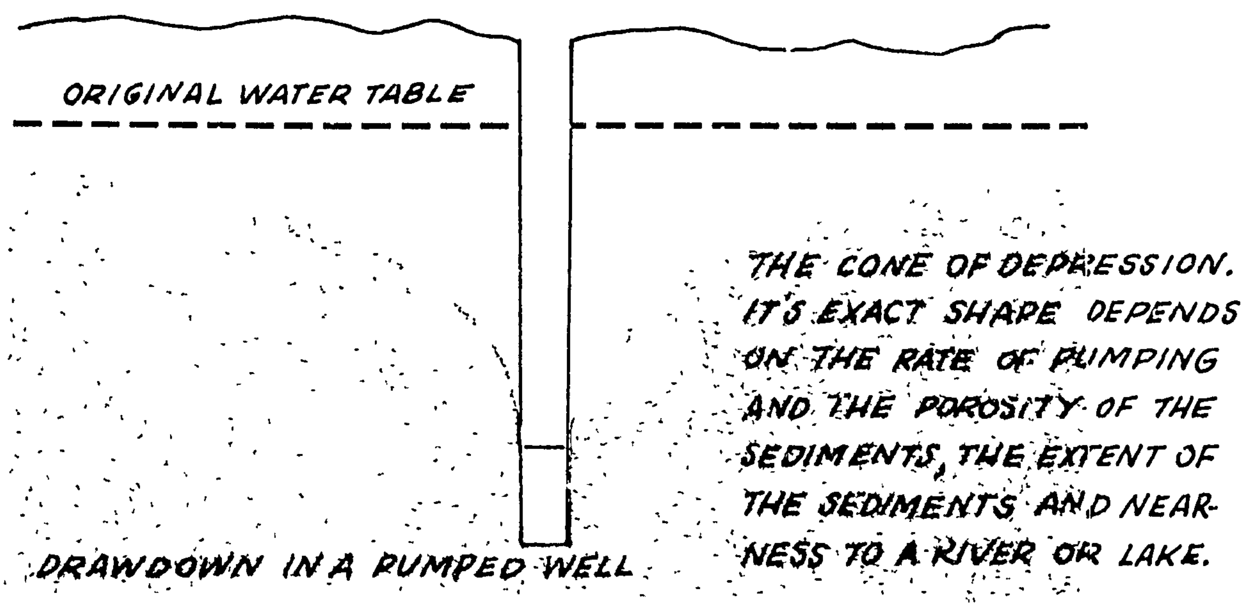


FIGURE 4

Where to Dig a Well

Four important factors to consider in choosing a well site are:

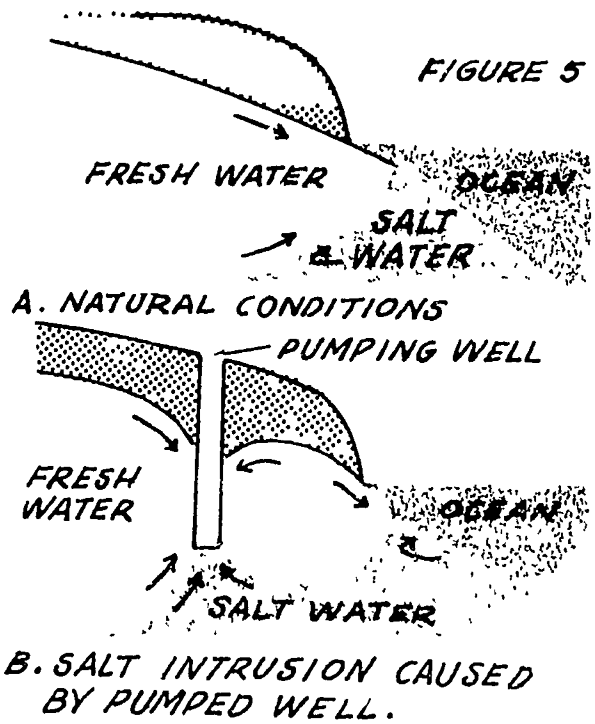
1. Nearness to Surface Water
2. Topography
3. Sediment Type
4. Nearness to Pollutants

1. Nearness to Surface Water

If there is any surface water nearby, such as a lake or a river, locate the well as near it as possible. It is likely to act as a source of water and keep the water table from being lowered as much as without it. This does not always work well, however, as lakes and slow-moving bodies of water generally have silt and slime on the bottom, which prevent water from entering the ground quickly.

There may not seem to be much point to digging a well near a river, but the filtering action of the soil will result in water that is cleaner and more free of bacteria. It may also be cooler than surface water. If the river level fluctuates during the year, a well will give cleaner water (than stream water) during the flood season, although ground water often gets dirty during and after a flood; a well will also give more reliable water during the dry season, when the water level may drop below the bed of the river. This method of water supply is used by some cities: a large well is sunk next to a lake or river and horizontal tunnels are dug to increase the flow.

Wells near the ocean, and especially those on islands, may have not only the problem of drawdown but that of salt water encroachment. The underground boundary between fresh and salt water generally slopes inland: Because salt water is heavier than fresh water, it flows in under it. If a well near the shore is used heavily, salt water may come into the well as shown in Figure 5. This should not occur in wells from which only a moderate amount of water is drawn.



2. Topography

Ground water, being liquid, gathers in low areas. Therefore, the lowest ground is generally the best place to drill or dig. If your area is flat or steadily sloping, and there is no surface water, one place is as good as another to start drilling or digging. If the land is hilly, valley bottoms are the best places to look for water.

You may know of a hilly area with a spring on the side of a hill. Such a spring could be the result of water moving through a layer of porous rock or a fracture zone in otherwise impervious rock. Good water sources can result from such features. If you can see layers of rock sticking out of the hillside, you may be able to guess where a water-bearing layer can be found by digging down from higher on the hill. This is because most layers continue over short distances.

3. Sediment Type

Ground water occurs in porous or fractured rocks of sediments. Gravel, sand and sandstone are more porous than clay, unfractured shale and granite or "hard rock."

Figure 6 shows in a general way the relationship between the availability of ground water (expressed by typical well discharges) and geologic material (sediments and various rock types). For planning the well discharge necessary for irrigating crops, a good rule of thumb for semi-arid climates -- 37.5cm (15") of precipitation a year -- is a 1500 to 1900 liters (400 to 500 U.S. gallons) per minute well which will irrigate about 65 hectares (160 acres) for about 6 months. From Figure 6, we see that wells in sediments are generally more than adequate. However, enough ground water can be obtained from rock, if necessary, by drilling a number of wells. Deeper water is generally of better quality. Water from shallow wells is generally harder than water from rock aquifers; this may be important for hospitals and some industries.

Sand and gravel are normally porous and clay is not, but sand and gravel can contain different amounts of silt and clay which will reduce their ability to carry water. The only way to find the yield of a sediment is to dig a well and pump it.

In digging a well, be guided by the results of nearby wells, the effects of seasonal fluctuations on nearby wells, and keep an eye on the sediments in your well as it is dug. In many cases you will find that the sediments are in layers, some porous and some not. You may be able to predict where you will hit water by comparing the layering in your well with that of nearby wells.

Figures 7, 8 and 9 illustrate several sediment situations and give guidelines on how deep to dig wells.

4. Nearness to Pollutants

If pollution is in the ground water, it moves with it. Therefore, a well should always be uphill and 15 to 30 meters (50 to 100 feet) away from a latrine, barnyard, or other source of pollution. If the area is flat, remember that the flow of ground water will be downward, like a river, toward any nearby body of surface water. Locate a well in the upstream direction from pollution sources.

The deeper the water table, the less chance of pollution because the pollutants must travel some distance downward before entering ground water. The water is purified as it flows through the soil.

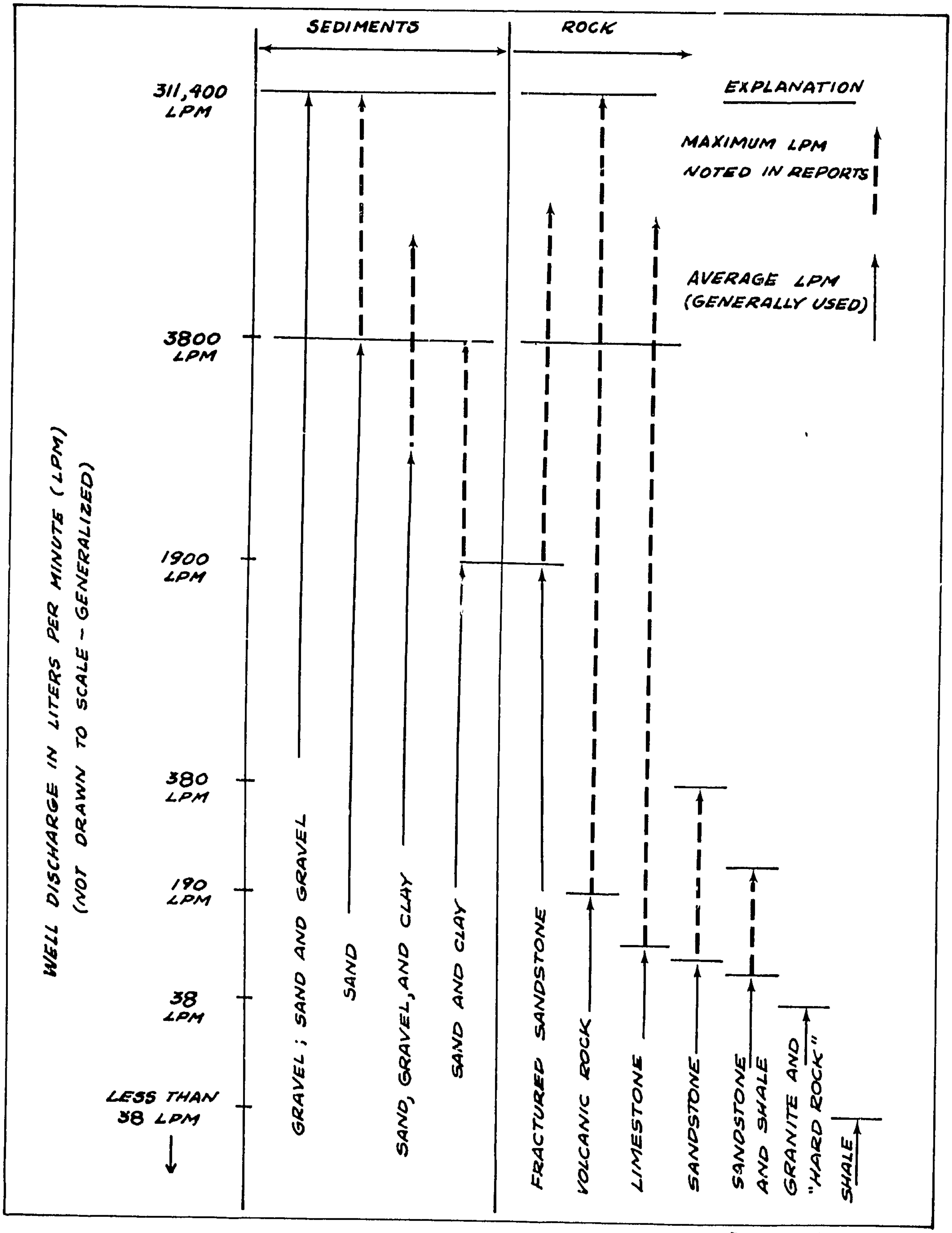
Extra water added to the pollutants will increase their flow into and through the soil, although it will also help dilute them. Pollution of ground water is more likely during the rainy than the dry season, especially if a source of pollution such as a latrine pit is allowed to fill with water. See also "Introduction to Sanitary Latrines," p. 147. Similarly, a well that is heavily used will increase the flow of ground water toward it, perhaps even reversing the normal direction of ground water movement. The amount of drawdown is a guide to how heavily the well is being used.

Polluted surface water must be kept out of the well pit. This is done by casing and sealing the well.

Well Casing and Seal

The purpose of casing and sealing wells is to prevent contaminated surface water from entering the well or nearby ground water. As water will undoubtedly be spilled from any pump, the top of the well must be sealed with a concrete slab to let the water flow away rather than re-enter the well directly. It is also helpful to build up the pump area with dirt to form a slight hill which will help drain away spilled water and rain water.

FIGURE 6 AVAILABILITY OF GROUND WATER IN WATER BEARING SEDIMENTS OR ROCK TYPES



DAVID B. RICHARDS

Figure 6. Availability of ground water from various sediments and rock types.

Aquifers (water-bearing sediments) of Sand and Gravel. Generally yield 11,400 lpm (3000 gpm) (but they may yield less depending on pump, well construction and well development).

Aquifers of Sand, Gravel, and Clay (Intermixed or Interbedded). Generally yield between 1900 lpm (500 gpm) and 3800 lpm (1000 gpm), but can yield more--between 3800 lpm (1000 gpm) and 11,400 lpm (3000 gpm)--depending on the percentage of the constituents.

Aquifers of Sand and Clay. Generally yield about 1900 lpm (500 gpm) but may yield as much as 3800 lpm (1000 gpm).

Aquifers of Fractured Sandstone. Generally yield about 1900 lpm (500 gpm) but may yield more than 3800 lpm (1000 gpm) depending on the thickness of the sandstone and the degree and extent of fracturing (may also yield less than 1900 lpm (500 gpm) if thin and poorly fractured or interbedded with clay or shale).

Aquifers of Limestone. Generally yield between 38 lpm (10 gpm) and 190 lpm (50 gpm) but have been known to yield more than 3800 lpm (1000 gpm) due to caverns or nearness to stream, etc.

Aquifers of Granite and/or "Hard Rock". Generally yield 38 lpm (10 gpm) and may yield less (enough for small household).

Aquifers of Shale. Yield less than 38 lpm (10 gpm), not much good for anything except as a last resort.

Casing is the term for the pipe, cement ring or other material that supports the well wall. It is usually impermeable in the upper part of the well to keep out polluted water (see Figure 7) and may be perforated or absent in the lower part of the well to let water enter. See also "Well Casing and Platforms," p. 12, and "Reconstructing Dug Wells," p. 59.

In loose sediment, the base of the well should consist of a perforated casing surrounded by coarse sand and small pebbles; otherwise, rapid pumping may bring into the well enough material to form a cavity and collapse the well itself. Packing the area around the well hole in the water-bearing layer with fine gravel will prevent sand from washing in and increase the effective size of the well. The ideal gradation is from sand to 6mm (1/4") gravel next to the well screen. In a drilled well it may be added around the screen after the pump pipe is installed.

Well Development

Well development refers to the steps taken after a well is drilled to insure maximum flow and well life by preparing the sediments around the well. The layer of sediments from which the water is drawn often consists of sand and silt. When the well is first pumped, the fine material will be drawn into the well and make the water muddy. You will want to pump out this fine material to keep it from muddying the water later and to make the sediments near the well more porous. However, if the water is pumped too rapidly at first, the fine particles may collect against the perforated casing or the sand grains at the bottom of the well and block the flow of water into it.

A method for removing the fine material successfully is to pump slowly until the water clears, then at successively higher rates until the maximum of the pump or well is reached. Then the water level should be permitted to return to normal and the process repeated until consistently clear water is obtained.

Another method is surging, which is moving a plunger (an attachment on a drill rod) up and down in the well. This causes the water to surge in and out of the sedimentary layer and wash loose the fine particles, as well as any drilling mud stuck on the wall of the well. Coarse sediment washed into the well can be removed by a bailing bucket, or it may be

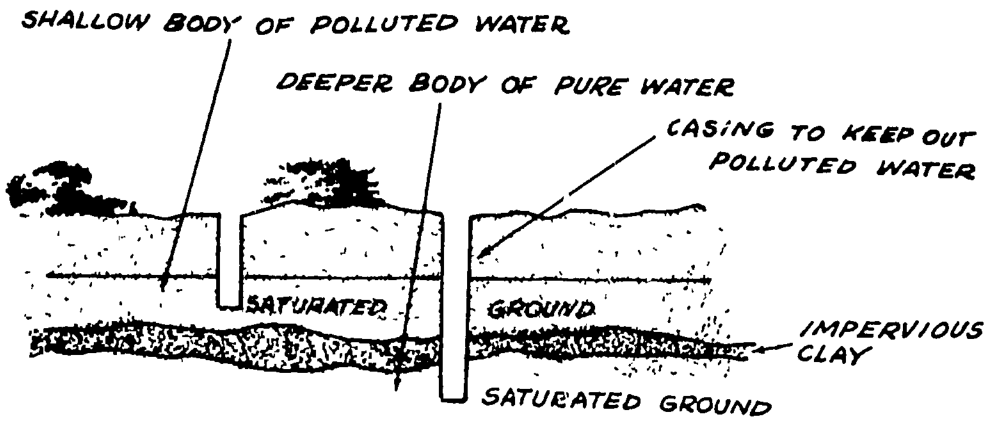
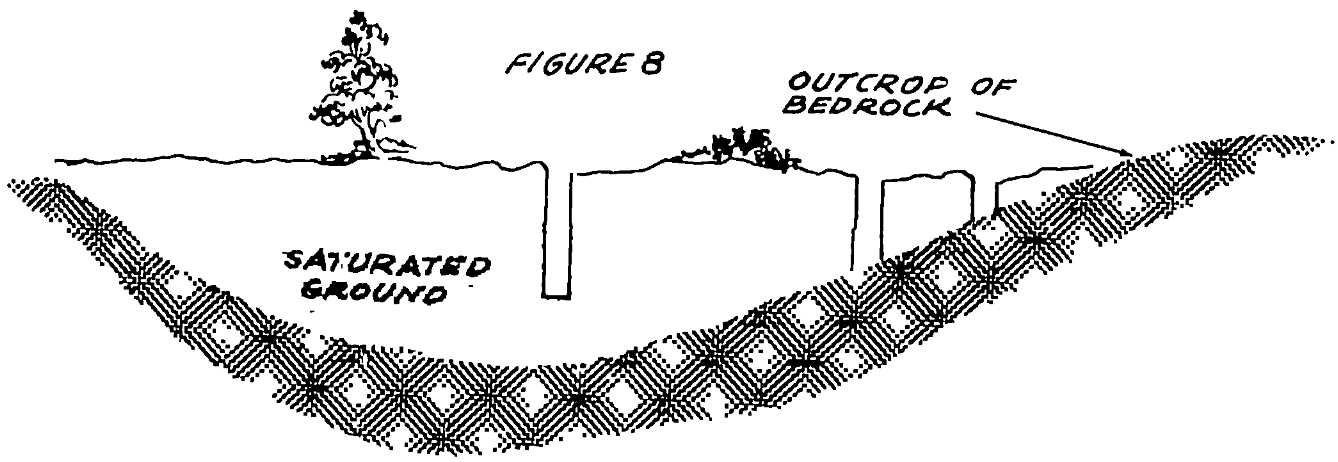


FIGURE 7

FIGURE 8



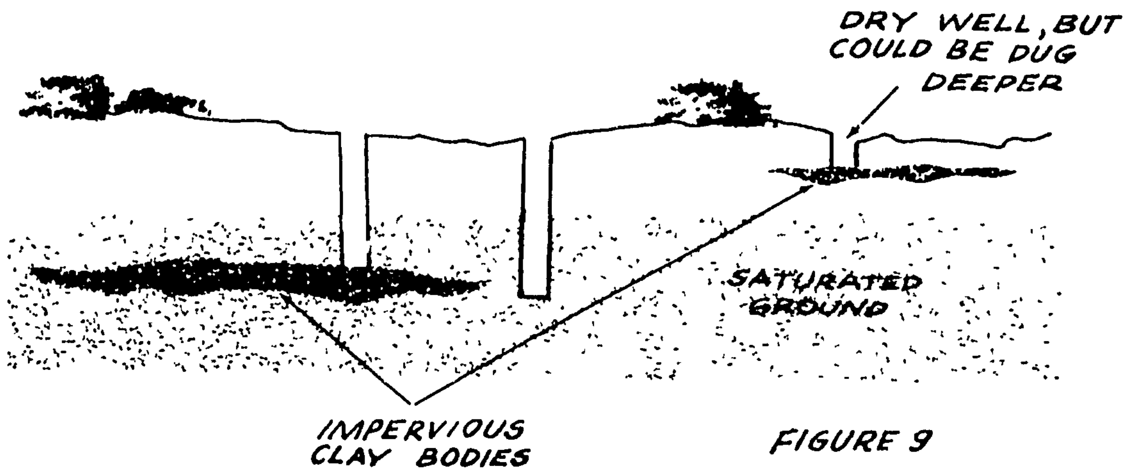


FIGURE 9

left in the bottom of the well to serve as a filter.

Sources:

Michael T. Field, VITA Volunteer, Schenectady, New York

John Chronic, VITA Volunteer, Boulder, Colorado

David B. Richards, VITA Volunteer, Fort Collins, Colorado

Yaron M. Sternberg, VITA Volunteer, Bloomington, Indiana.

A Primer on Ground Water, H. L. Baldwin and C. L. McGuinness, U. S. Government Printing Office, Washington, D. C., 1964, 26 pages, U.S. $0.25

This inexpensive booklet discusses ground water in more detail than this article and is a useful reference for anyone working with wells.

Ground Water Hydrology, D. K. Todd, Wiley & Sons, New York, 1959, 336 pages, U.S. $0.95.

One of several textbooks available, this book describes the mathematical approach to ground water study. It also contains much information on related subjects such as well development and water law.

Water Supply for Rural Areas and Small Communities, E. G. Wagner and J. N. Lanoix, World Health Organization, Geneva, 1959, 340 pages, $6.75.

This excellent book has a variety of information on ground water, wells, and water systems, all aimed at the village level.

Hydrogeology, S. N. Davis and R. J. M. DeWiest, Wiley & Sons, New York, 1966, 300 pages, U.S. $11.00

Another textbook, but concentrates on the importance of geology on the occurrence of ground water.

Water Well Handbook, K. E. Anderson, Missouri Water Well Drillers Association, P. O. Box 250, Rolla, Missouri, 1965, 281 pages, U.S. $3.00.

Comprehensive handbook used by well drillers and field engineers; includes charts, tables, and other data dealing with drilling equipment, hardware associated with well construction and installation of pumps. Many consider this the practical bible of water wells.

Ground Water and Wells, Edward E. Johnson, Inc., Saint Paul, Minnesota 55104, 440 pages, 1966, about $5.00.

An excellent semi-technical reference book used by the water-well industry covering such items as: ground water occurrence, well design as related to geology, well drilling, well maintenance, and well operation.

Wells, Department of the Army, Technical Manual (TM 5-297), 1957, Superintendant of Documents, U.S. Government Printing Office, Washington 25, D.C., 264 pages, $1.00.

An elementary, comprehensive book on well drilling and well construction. Easy to read and understand, but not as up to date as the other references above.

Small Water Supplies, Bulletin No. 10, The Ross Institute, Keppel Street (Gower Street), London, W.C. 1, England, 1967, 67 pages.

TUBEWELLS

Where soil conditions permit, the tubewells described here will, if they have the necessary casing, provide pure water. They are much easier to install and cost much less than large diameter wells.

Tubewells will probably work well where simple earth borers or earth augers work (i.e., alluvial plains with few rocks in the soil), and where there is a permeable water-bearing layer 15 to 25 meters (50 to 80 feet) below the surface. They are sealed wells, and consequently sanitary, which offer no hazard to small children. The small amounts of materials needed keep the cost down. These wells may not yield enough water for a large group, but they would be big enough for a family or a small group of families.

The storage capacity in small diameter wells is small. Their yield depends largely on the rate at which water flows from the surrounding soil into the well. From a saturated sand layer, the flow is rapid. Water flowing in quickly replaces water drawn from the well. A well which taps such a layer seldom goes dry. But even when water-bearing sand is not reached, a well with even a limited storage capacity may yield enough water for a household.

Well Casing and Platforms

In home or village wells, casing and platforms serve two purposes: (1) to keep well sides from caving in, and (2) to seal the well and keep any polluted surface water from entering the well.

Two low-cost casing techniques are described here:

1. Method A, from an American Friends Service Committee (AFSC) team in Rasulia ,Madhya Pradesh, India.

2. Method B, from an International Voluntary Services (IVS) team in Vietnam.

Method A. (See Figure 1)

Tools and Materials

Asbestos cement, tile, concrete, or even galvanized iron will do.

Casing pipe (from pump to water-bearing layer to below minimum water table).

Sand

Gravel

Cement

Device for lowering and placing casing (see Figure 2).

Drilling rig - see "Tubewell Boring"

Foot valve, cylinder, pipe, handpump.

The well hole is dug as deep as possible into the water-bearing strata. The diggings are placed near the hole to make a mound, which later will serve to drain spilled water away from the well. This is important because backwash is one of the few sources of contamination for this type of well. The entire casing pipe below water level should be perforated with many small holes no larger than 5mm (3/16") in diameter. Holes larger than this will allow coarse sand to be washed inside and plug up the well. Fine particles of sand, however, are expected to enter. These should be small enough to be pumped immediately out through the pump. This keeps the well clear. The first water from the new well may bring with it large quantities of fine sand. When this happens, the first strokes should be strong and steady and continued until the water comes clear.

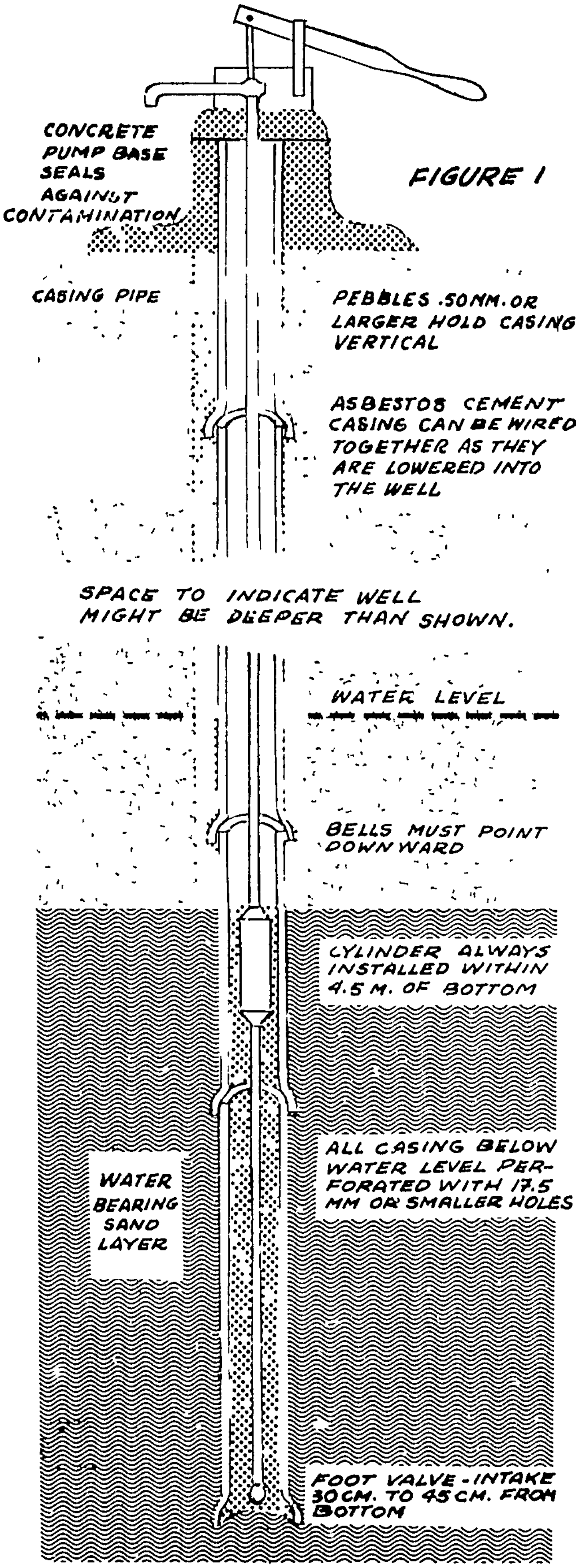
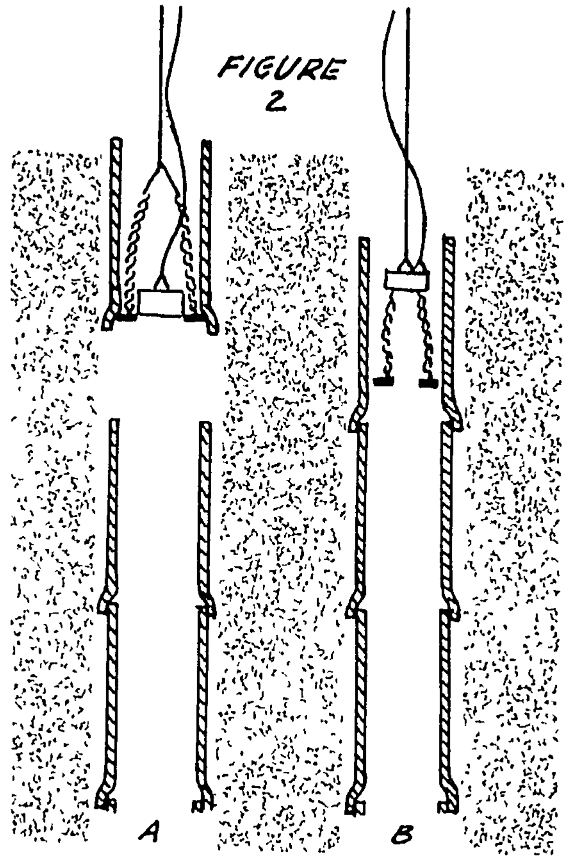


FIGURE 1

Perforated casing is lowered, bell end downward, into the hole using the device shown in Figure 2. When the casing is properly positioned, the trip cord is pulled and the next section prepared and lowered. Since holes are easily drilled in asbestos cement pipe, they can be wired together at the joint and lowered into the well. Be sure the bells point downward, since this will

FIGURE 2



prevent surface water or backwash from entering the well without the purifying filtration effect of the soil; it will also keep sand and dirt from filling the well. Install the casing vertically and fill the remaining space with pebbles. This will hold the casing plumb. The casing should rise 30 to 60cm (1' to 2') above ground level and be surrounded with a concrete pedestal to hold the pump and to drain spilled water away from the hole. Casing joints within 3 meters (10 feet) of the surface should be sealed with concrete or bituminous material.

Method B

Plastic seems to be an ideal casing material, but because it was not readily available, the galvanized iron and concrete casings described here were developed in the Ban Me Thuot area of Vietnam. The materials for one 20 meter (65') well, not including a pump, cost about U.S. $17 in 1959.

Tools and Materials

Wooden V-block, 230cm (7 1/2') long (see Figure 3)

Angle iron, 2 sections, 230cm (7 1/2') long

Pipe, 10cm (4") in diameter, 230cm (7 1/2') long

Clamps

Wooden mallet

Soldering Equipment

Galvanized sheet metal: 0.4mm x 1 meter x 2 meter (0.016" x 39 1/2" x 79") sheets

Plastic Casing

Black plastic pipe for sewers and drains was almost ideal. Its friction joints could be quickly slipped together and sealed with a chemical solvent. It seemed durable but was light enough to be lowered into the well by hand. It could be easily sawed or drilled to make a screen. Care must be taken to be sure that any plastic used is not toxic.

Galvanized Sheet Metal Casing

Galvanized sheet metal was used to make casing similar to downspouting. A thicker gauge than the 0.4mm (0.016") available would have been preferable. Because the sheet metal would not last indefinitely if used by itself, the well hole was made oversize and the ring-shaped space around the casing was filled with a thin concrete mixture which formed a cast concrete casing and seal outside the sheet metal when it hardened.

The 1 meter x 2 meter (39 1/2" x 79") sheets were cut lengthwise into three equal pieces which yielded three 2-meter (79") lengths of 10cm (4") diameter pipe.

The edges were prepared for making seams by clamping them between the two angle irons, and then pounding the edges with a wooden mallet to the shape shown in Figure 3.

FIGURE 3

The seam is made slightly wider at one end than at the other to give the pipe a slight taoer which allows successive lengths to be slipped a short distance inside one another.

The strips are rolled by bridging them over a 2-meter (79") wooden V-shaped block and applying pressure from above with a length of 5cm (2") pipe (see Figure 4). The sheet metal strips are shifted from side to side over the V-block as they are being bent to produce as uniform a surface as possible. When the strip is bent enough, the two edges are hooked together and the 5cm (2") pipe is slipped inside. The ends of the pipe are set up on wooden blocks to form an anvil, and the seam is firmly crimped as shown in Figure 4.

After the seam is finished, any irregularities in the pipe are removed by applying pressure by hand or with the wooden mallet and pipe anvil. A local tinsmith and his helper were able to make six to eight lengths (12-16 meters) of the pipe per day. Three lengths of pipe were slipped together and soldered as they were made, and the remaining joints had to be soldered as the casing was lowered into the well.

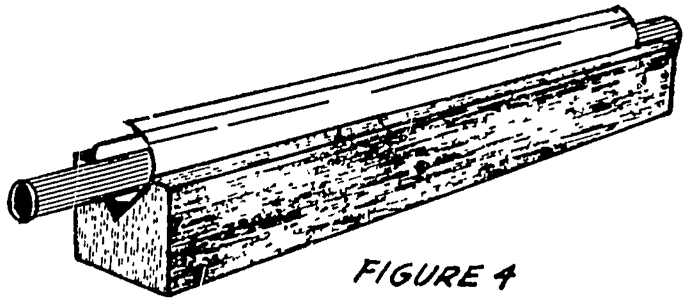


FIGURE 4

FIGURE 5

The lower end of the pipe was perforated with a hand drill to form a screen. After the casing was lowered to the bottom of the well, fine gravel was packed around the perforated portion of the casing to above the water level.

The cement grouting mortar which was used around the casings varied from pure cement to a 1:1 1/2 cement : sand ratio mixed with water to a very plastic consistency. The grout was put around the casing by gravity and a strip of bamboo about 10 meters (33 feet) long was used to "rod" the grout into place. A comparison of volume around the casing and volume of grouting used indicated that there may have been some voids left probably below the reach of the bamboo rod. These are not serious however, as long as a good seal is obtained for the first 8 to 10 meters (26 to 33 feet) down from the surface. In general, the greater proportion of cement used and the greater the space around the casing, the better seemed to be the results obtained. However, insufficient experience has been obtained to reach any final conclusions. In addition, economic considerations limit both of these factors.

Care must be taken in pouring the grout. In one case, two sections of casing were not assembled perfectly straight: the casing, as a result, was not centered in the well, the pressure of the grouting was not equal all the way around, and the casing collapsed. With reasonable care, pouring the grout in several stages and allowing it to set in-between should eliminate this. The grouting, however, cannot be poured in too many stages because a considerable amount sticks to the sides of the well each time, reducing the space for successive pourings to pass through.

A proposed modification of the above method which has not yet been tried is as follows: In areas such as Ban Me Thuot, where the structure of the material through which the well is drilled is such that there is little or no danger of cave-in, the casing serves only one purpose, as a sanitary seal. It is therefore proposed that the well be cased only about 8 meters (26 feet) down from the ground surface. To do this, the well would be drilled to the desired depth with a diameter roughly the same as that of the casing. The well would then be reamed out to a diameter 5 to 6cm (2" to 2 1/4") larger than the casing down to the depth the casing will go. A flange fitted at the bottom of the casing with an outside diameter about equal to that of the reamed hole will center the casing in the hole and support the casing on the shoulder where the reaming stopped. Grouting would then be poured as in the original method. This modification would (1) save considerable costly material, (2) allow the well to be made a smaller diameter except near the top, (3) lessen grouting difficulties, and (4) still provide adequate protection against pollution.

Concrete Tile Casing

If the well is enlarged to an adequate diameter, precast concrete tile with suitable joints could be used as casing. This would require a device for lowering the tile into the well one by one and releasing them at the bottom. Mortar would have to be used to seal the joints above the water level, the mortar being spread on each successive joint before it is lowered. Asbestos cement casing would also be a possibility where it was available with suitable joints.

No Casing

The last possibility would be to use no casing at all. It is felt that when finances or skills do not permit the well to be cased, there are certain circumstances under which an uncased well would be superior to no well at all. This is particularly true in localities where the custom is to boil or make tea out of all water before drinking it, where sanitation is greatly hampered by insufficient water supply, and where small scale hand irrigation from wells can greatly improve the diet by making gardens possible in the dry season.

The danger of pollution in an uncased well can be minimized by: (1) choosing a favorable site for the well and (2) making a platform with a drain which leads away from the well, eliminating all spilled water.

Such a well should be tested frequently for pollution. If it is found unsafe, a notice to this effect should be posted conspicuously near the well.

Well Platform

In the work in the Ban Me Thuot area, a flat 1.75 meter (5.7') square slab of concrete was used around each well. However, under village conditions, this did not work well. Large quantities of water were spilled, in part due to the enthusiasm of the villagers for having a plentiful water supply, and the areas around wells became quite muddy.

The conclusion was reached that the only really satisfactory platform would be a round, slightly convex one with a small gutter around the outer edge. The gutter should lead to a concreted drain which would take the water a considerable distance from the well.

If the well platform is too big and smooth, there is a great temptation on the part of the villagers to do their laundry and other washing around the well. This should be discouraged. In villages where animals run loose it is necessary to build a small fence around the well to keep out animals, especially poultry and pigs, which are very eager to get water, but tend to mess up the surroundings.

Sources:

Explanatory Notes on Tubewells, by Wendell Mott, American Friends Service Committee, Philadelphia, Pennsylvania, 1956 (mimeo).

Report by Richard G. Koegel, International Voluntary Services, Ban Me Thuot, Vietnam, 1959 (mimeo).

Hand-Operated Drilling Equipment

Two methods of drilling a shallow tubewell with hand-operated equipment are described here: Method A operates by turning an earth-boring auger; Method B uses a ramming action.

Method A was used by an American Friends Service Committee (AFSC) team in India; Method B was used by an International Voluntary Services (IVS) team in Vietnam.

Method A

This simple hand-drilling rig was used by an American Friends Service Committee team in India to dig wells 15 to 20cm (6" to 8") in diameter up to 15 meters (50') deep.

Tools and Materials

Earth auger, with coupling to attach to 2.5cm (1") drill line (see entry on tubewell earth augers)

Standard weight galvanized steel pipe:

For Drill Line:

4 pieces: 2.5cm (1") in diameter and 3 meters (10') long (2 pieces have threads on one end only; others need no threads.)

2 pieces: 2.5cm (1") in diameter and 107cm (3 1/2') long

For Turning Handle:

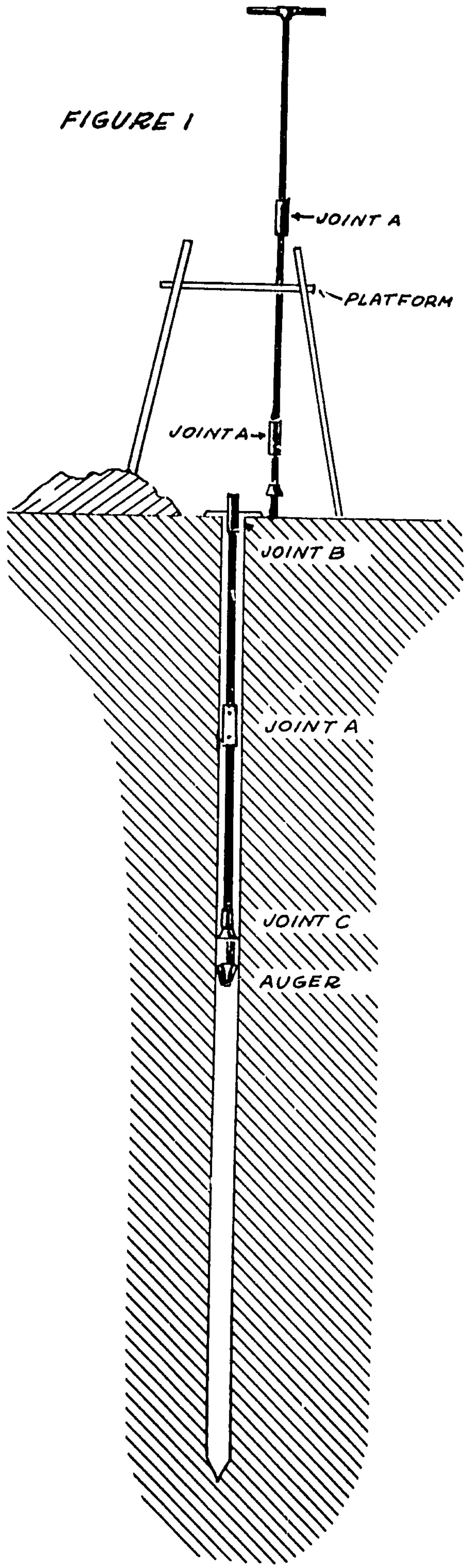
2 pieces: 2.5cm (1") in diameter and 61cm (2') long

2.5cm (1") T coupling

For Joint A:

4 pieces: 32mm (1 1/4") in diameter and 30cm (1') long

FIGURE 1



Sections and Couplings for Joint B:

23cm (9") section of 32mm (1 1/4") diameter (threaded at one end only)
35.5cm (14") section of 38mm (1 1/2") diameter (threaded at one end only)

Reducer coupling: 32mm to 25mm (1 1/4" to 1")

Reducer coupling: 38mm to 25mm (1 1/2" to 1")

8 10mm (3/8") diameter hexagonal head machine

steel/bolts 45mm (1 3/4") long, with nuts

2 10mm (3/8") diameter hex head steel machine bolts 5cm (2") long, with nuts

9 10mm (3/8") steel hex nuts

To Make Toggle Bolt:

1 3mm (1/8") diameter countersink head iron rivet 12.5mm (1/2")

1 1.5mm (1/16") sheet steel, 10mm (3/8") x 25mm (1")

Drills: 3mm (1/8"), 17.5mm (13/16"), 8.75mm (13/32")

Countersink

Thread cutting dies, unless pipe is already threaded

Small tools: wrenches, hammer, hack-saw, files

For platform: wood, nails, rope, ladder

Basically the method consists of rotating an ordinary earth auger. As the auger penetrates the earth, it fills with soil. When full it is pulled out of the hole and emptied. As the hole gets deeper, more sections of drilling line are added to extend the shaft. Joint A in Figures 1 and 2 describe a simple method for attaching new sections.

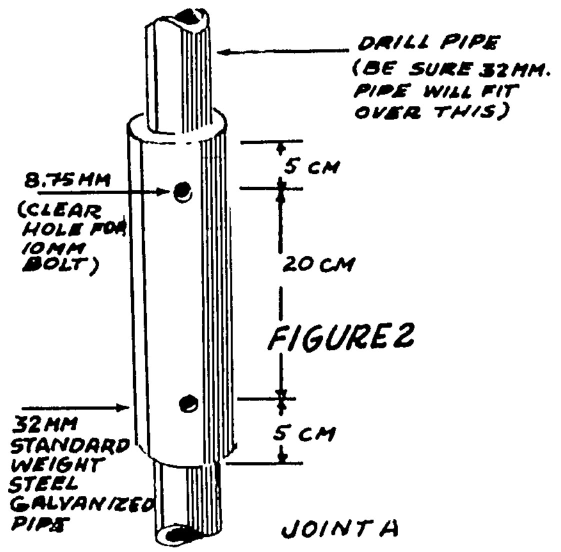


FIGURE 2

By building an elevated platform 3 to 3.7 meters (10 to 12 feet) from the ground, a 7.6 meter (25 foot) long section of drill line can be balanced upright. Longer lengths are too difficult to handle. Therefore, when the hole gets deeper than 7.6 meters (25 feet), the drill line must be taken apart each time the auger is removed for emptying. Joint B makes this operation easier. See Figures 1 and 3.

Joint C (see construction details for Tubewell Earth Auger) is proposed to allow rapid emptying of the auger. Some soils respond well to drilling with an auger that has two sides open. These are very easy to empty, and would not require Joint C. Find out what kinds of augers are successfully used in your area, and do a bit of experimenting to find the one best suited to your soil. See the entries on augers.

Joint A has been found to be faster to use and more durable than pipe threaded connectors. The pipe threads become damaged and dirty and are difficult to start. Heavy, expensive pipe wrenches get accidentally dropped into the well and are hard to get out. By using a sleeve pipe fastened with two 10mm (3/8") bolts, these troubles can be avoided. Neither a small bicycle wrench nor the inexpensive bolts will obstruct drilling if dropped in. Be sure the 32mm (1 1/4") pipe will fit over your 25mm (1") pipe drill line before purchase. See Figure 2.

Four 3 meter (10') sections and two 107cm (3 1/2') sections of pipe are the most convenient lengths for drilling a 15 meter (50') well. Drill an 8.75mm (13/32") diameter hole through each end of all sections of drill line except those attaching to Joint B and the turning handle which must be threaded joints. The holes should be 5cm (2") from the end.

When the well is deeper than 7.6 meters (25'), several features facilitate the emptying of the auger as shown in Figures 3 and 4. First the full auger is pulled up until Joint B appears at the surface. See Figure 4A. Then a 19mm (3/4") diameter rod is put through the hole. This allows the whole drill line to rest on it making it impossible for the part still in the well to fall in. Next remove the toggle bolt, lift out the top section of line and balance it beside the hole. See Figure 4B. Pull up the auger, empty it, and replace the section in the hole where it will be held by the 19mm (3/4") rod. See Figure 4C. Next replace the upper section of drill line. The 10mm (3/8") bolt acts as a stop which allows the holes to be easily lined up for reinsertion of the toggle bolt. Finally withdraw the rod and lower the auger for the next drilling. Mark the location for drilling the 8.75mm (13/32") diameter hole in the 32mm (1 1/4") pipe through the toggle bolt hole in the 38mm (1 1/2") pipe. If the hole is located with the 32mm (1 1/4") pipe resting on the stop bolt, the holes are bound to line up.

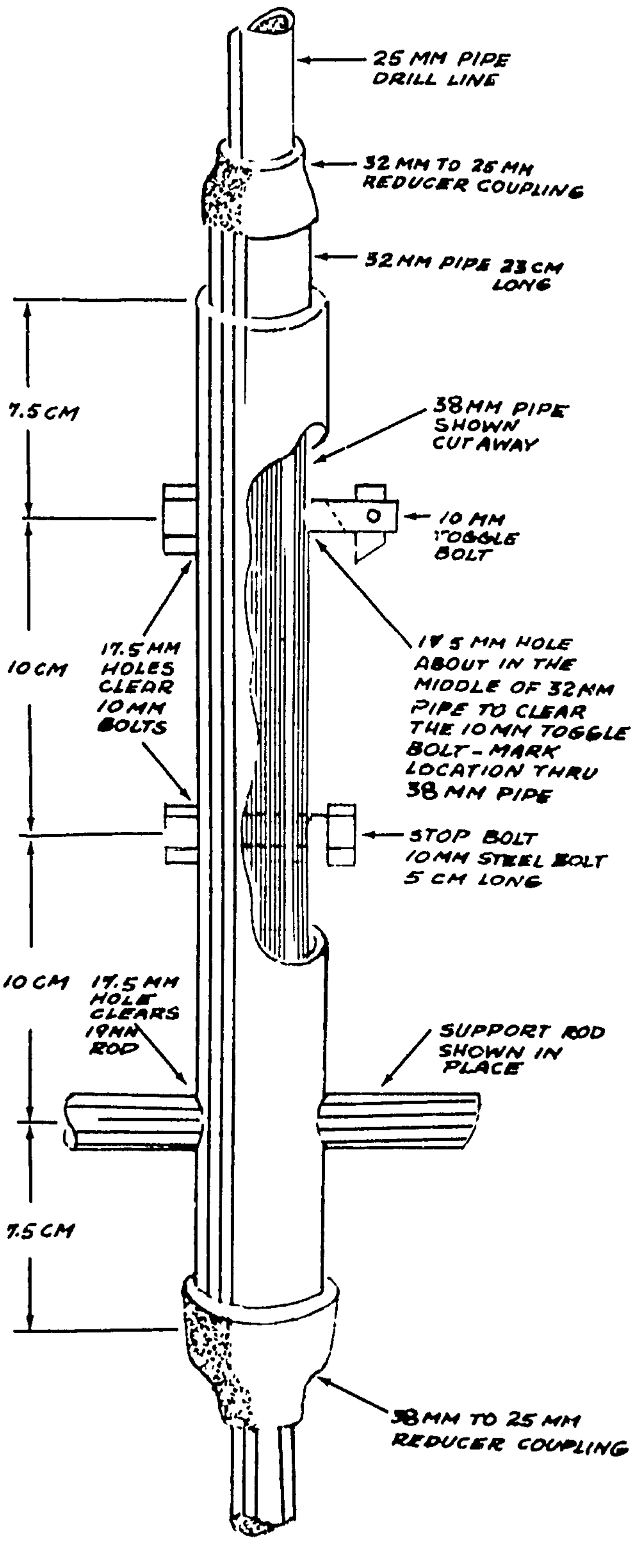


FIG. 3 JOINT B

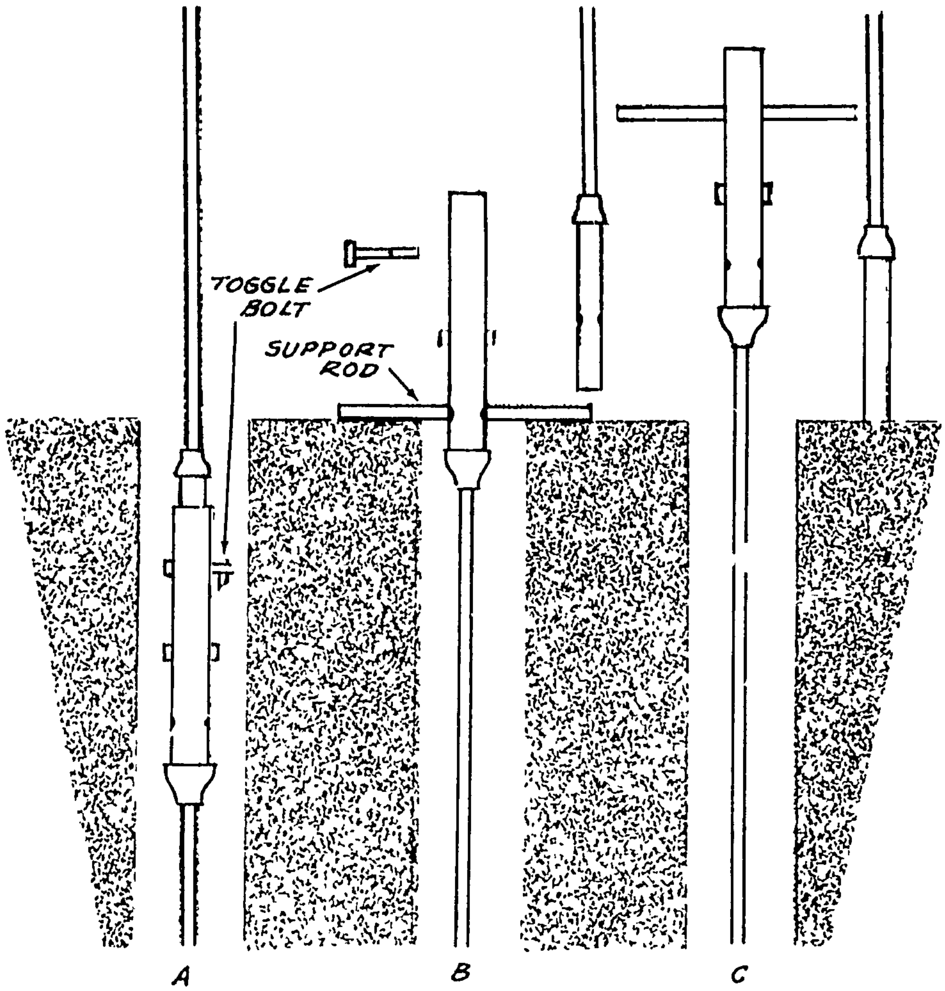


FIGURE 4 JOINT B IN OPERATION

Sometimes a special tool is needed to penetrate a water-bearing sand layer, because the wet sand caves in as soon as the auger is removed. If this happens a perforated casing is lowered into the well, and drilling is accomplished with an auger that fits inside the casing. A percussion type with a flap, or a rotary type with solid walls and a flap are good possibilities. See the entries describing these devices. The casing will settle deeper into the sand as sand is dug from beneath it. Other sections of casing must be added as drilling proceeds. Try to penetrate the water bearing sand layer as far as possible, (at least 3 feet). Ten feet of perforated casing embedded in such a sandy layer will provide a very good flow of water.

Tubewell Earth Auger

This earth auger is made from a 15cm (6") steel tube. Similar devices have long been used with power drilling equipment, but this particular design needs field trial (see Figure 5).

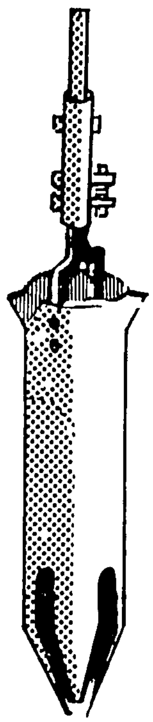


FIGURE 5
TUBEWELL EARTH AUGER

This auger can be made without welding equipment, but some of the bends in the pipe and the bar can be made much more easily when the metal is hot (see Figure 6).

An open earth auger, which is easier to empty than this one, is better suited for some soils. This auger cuts faster than the Tubewell Sand Auger.

Tools and Materials

Galvanized pipe: 32mm (1 1/4") in diameter and 21.5cm (8 1/2") long

Hexagonal head steel bolt: 10mm (3/8") in diameter and 5cm (2") long, with nut

2 hex. head steel bolts: 10mm (3/8") in diameter and 9.5cm (3 3/4") long

2 Steel bars: 1.25cm x 32mm x 236.5mm (1/2" x 1 1/4" x 9 5/16")

4 Round head machine screws: 10mm (3/8") in diameter and 32mm (1 1/4") long

2 flat head iron rivets: 3mm (1/8") in diameter and 12.5mm (1/2") long

Steel strip: 10mm x 1.5mm x 2.5cm (3/8" x 1/16" x 1")

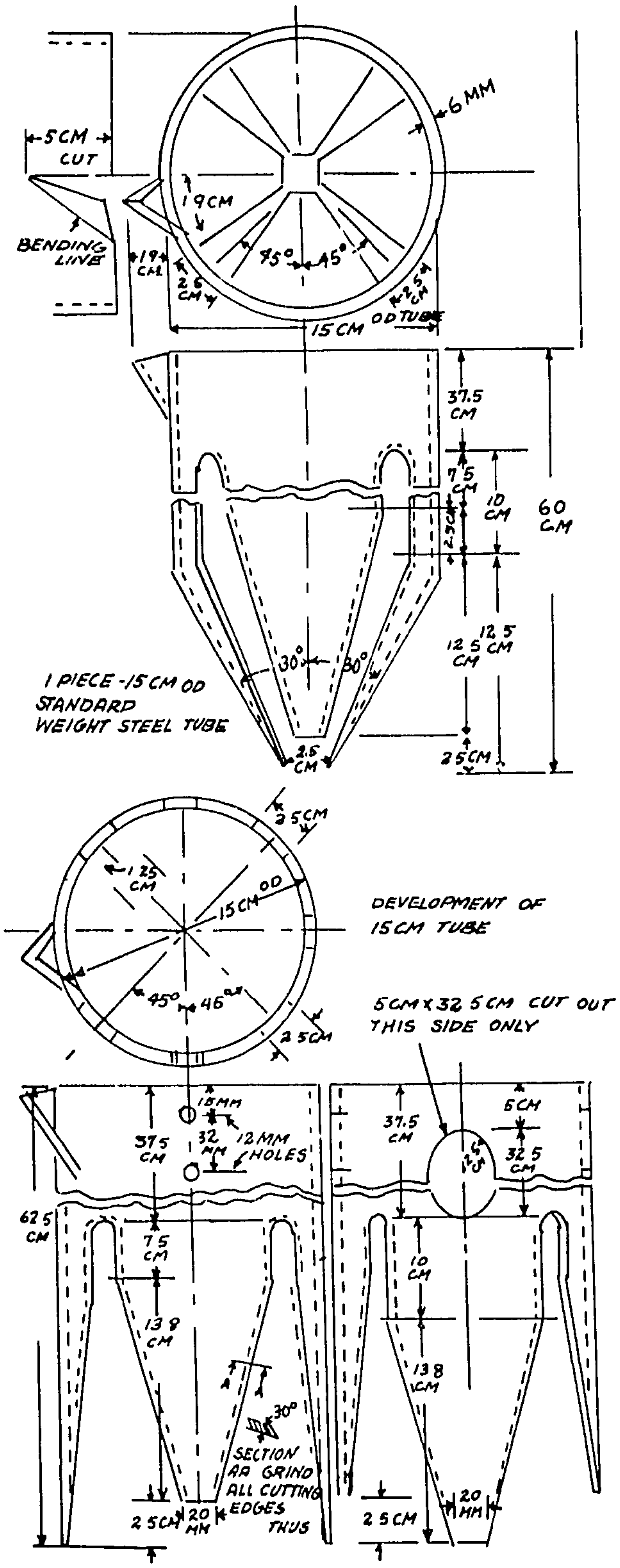
Steel tube: 15cm (6") outside diameter, 62.5cm (24 5/8") long

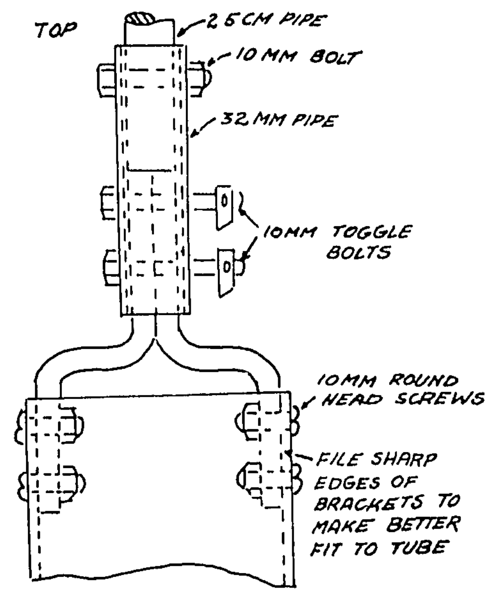
Hand tools

Source:

Wells, Technical Manual 5-297, AFM 85-23, U.S. Army and Air Force, 1957.

FIGURE 6


5CM CUT
BENDING LINE
19CM
6 MM
45°
45°
2.5 CM
15 CM OD TUBE
37.5 CM
7.5 CM
10 CM
2.5 CM
60 CM
12.5 CM
12.5 CM
30°
30°
1 PIECE - 15 CM OD STANDARD WEIGHT STEEL TUBE
2.5 CM
2.5 CM
1.25 CM
15 CM OD
DEVELOPMENT OF 15 CM TUBE
45°
46°
2.5 CM
5 CM X 32.5 CM CUT OUT THIS SIDE ONLY
15 MM
32 MM
12 MM HOLES
37.5 CM
5 CM
32.5 CM
62.5 CM
7.5 CM
10 CM
13.8 CM
13.8 CM
30°
SECTION AA GRIND ALL CUTTING EDGES THUS
2.5 CM
20 MM
2.5 CM
20 MM


TOP
2.5 CM PIPE
10 MM BOLT
32 MM PIPE
10MM TOGGLE BOLTS
10MM ROUND HEAD SCREWS
FILE SHARP EDGES OF BRACKETS TO MAKE BETTER FIT TO TUBE

Tubewell Sand Auger

This sand auger can be used to drill in loose soil or wet sand, where an earth auger is not so effective. The simple cutting head requires less force to turn than the "Tubewell Earth Auger," but it is more difficult to empty.

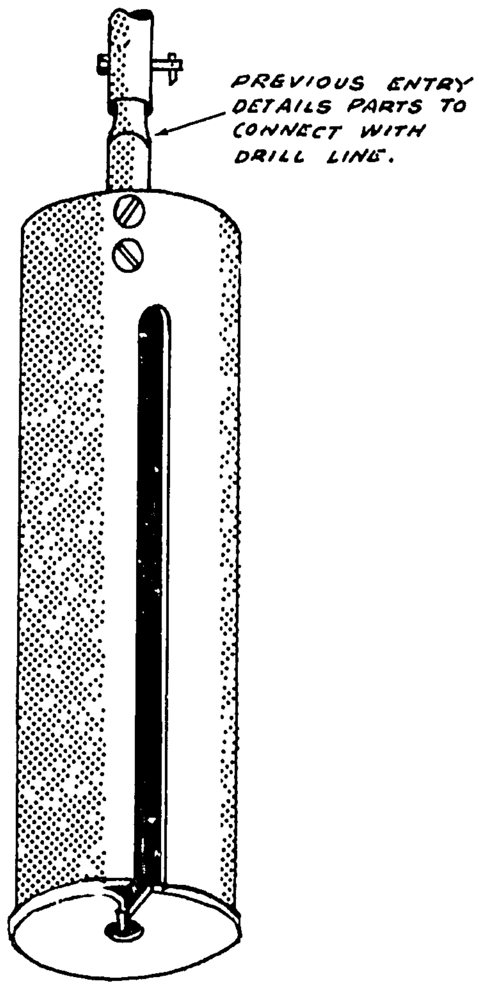


FIGURE 7
TUBEWELL SAND AUGER

A smaller version of the sand auger made to fit inside the casing pipe can be used to remove loose, wet sand.

This design needs field trial, although similar devices have long been used with power drilling equipment.

Tools and Materials

Steel tube: 15cm (6") outside diameter and 46cm (18") long

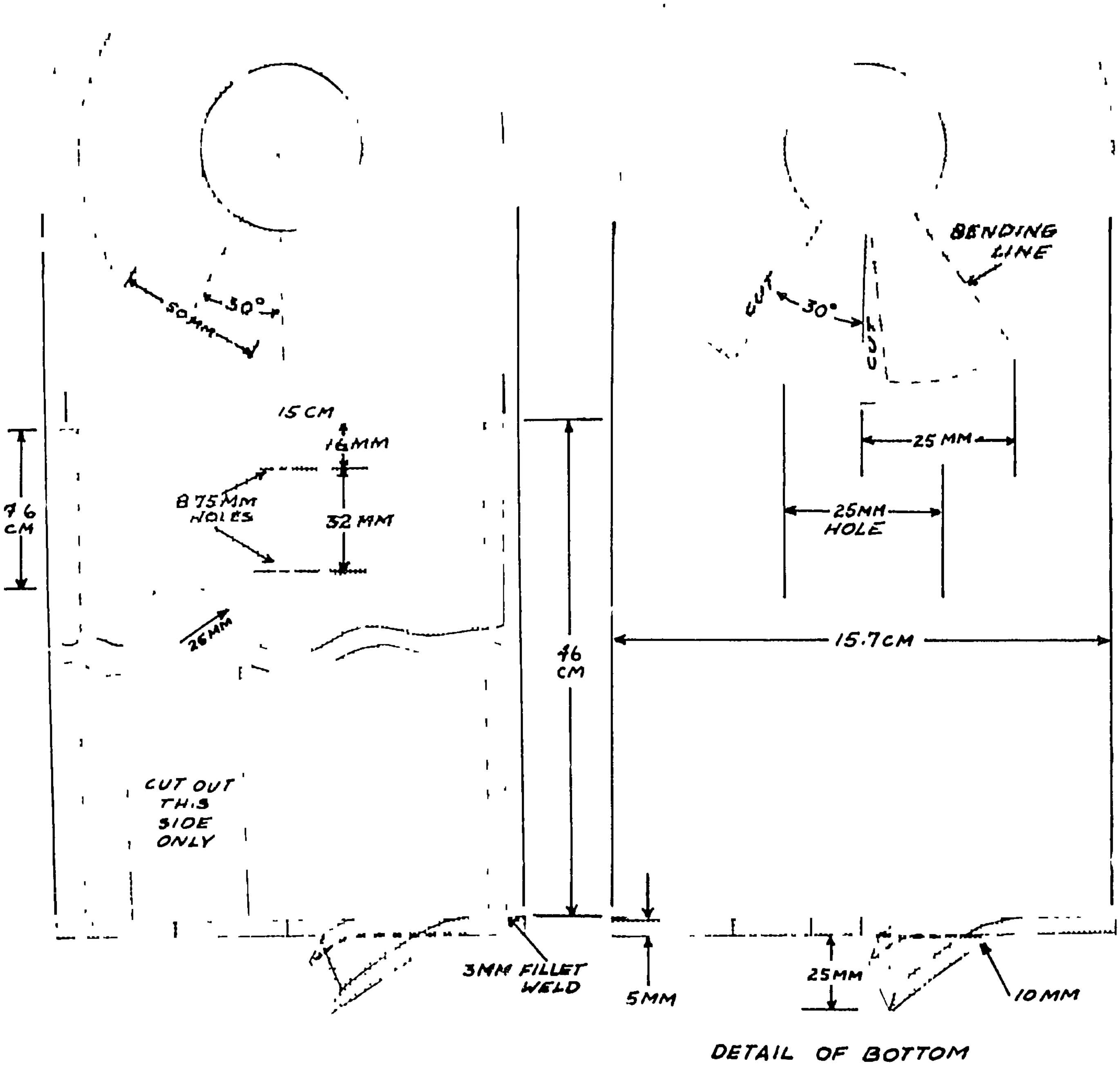
Steel plate: 5mm x 16.5cm x 16.5cm (3/16" x 6 1/2" x 6 1/2")

Acetylene welding and cutting equipment

Drill

Source:

Wells, Technical Manual 5-297, AFM 85-23, U.S. Army and Air Force, 1957.



50MM
30°
15CM
16MM
8 75MM HOLES
32 MM
76 CM
26MM
CUT OUT THIS SIDE ONLY
46 CM
3MM FILLET WELD
5MM
BENDING LINE
CUT
30°
25 MM
25MM HOLE
15.7CM
25MM
10MM
DETAIL OF BOTTOM

FIGURE 8

Tubewell Sand Bailer

The sand bailer can be used to drill from inside a perforated well casing when a bore goes into loose wet sand and the walls start to cave in. It has been used in making many tubewells in India.

Tools and Materials

Steel tube: 12.5cm (5") in diameter and 91.5cm (3') long

Truck innertube or leather: 12.5cm (5") square

Pipe coupling: 15cm to 2.5cm (5" to 1")

Small tools

By repeatedly jamming this "bucket" into the well, sand will be removed from below the perforated casing allowing it to settle deeper into the sand layer. The casing prevents the walls from caving in. The bell is removed from the first section of casing; at least one other section rests on top of it to help force it down as digging proceeds. Try to penetrate the water bearing sand layer as far as possible: 3 meters (10') of perforated casing embedded in such a sandy layer will usually provide a very good flow of water.

Be sure to try your sand "bucket" in wet sand before attempting to use it at the bottom of your well.

Source:

Explanatory Notes on Tubewells, by Wendell Mott, American Friends Service Committee, Philadelphia, Pennsylvania, 1956 (mimeo).

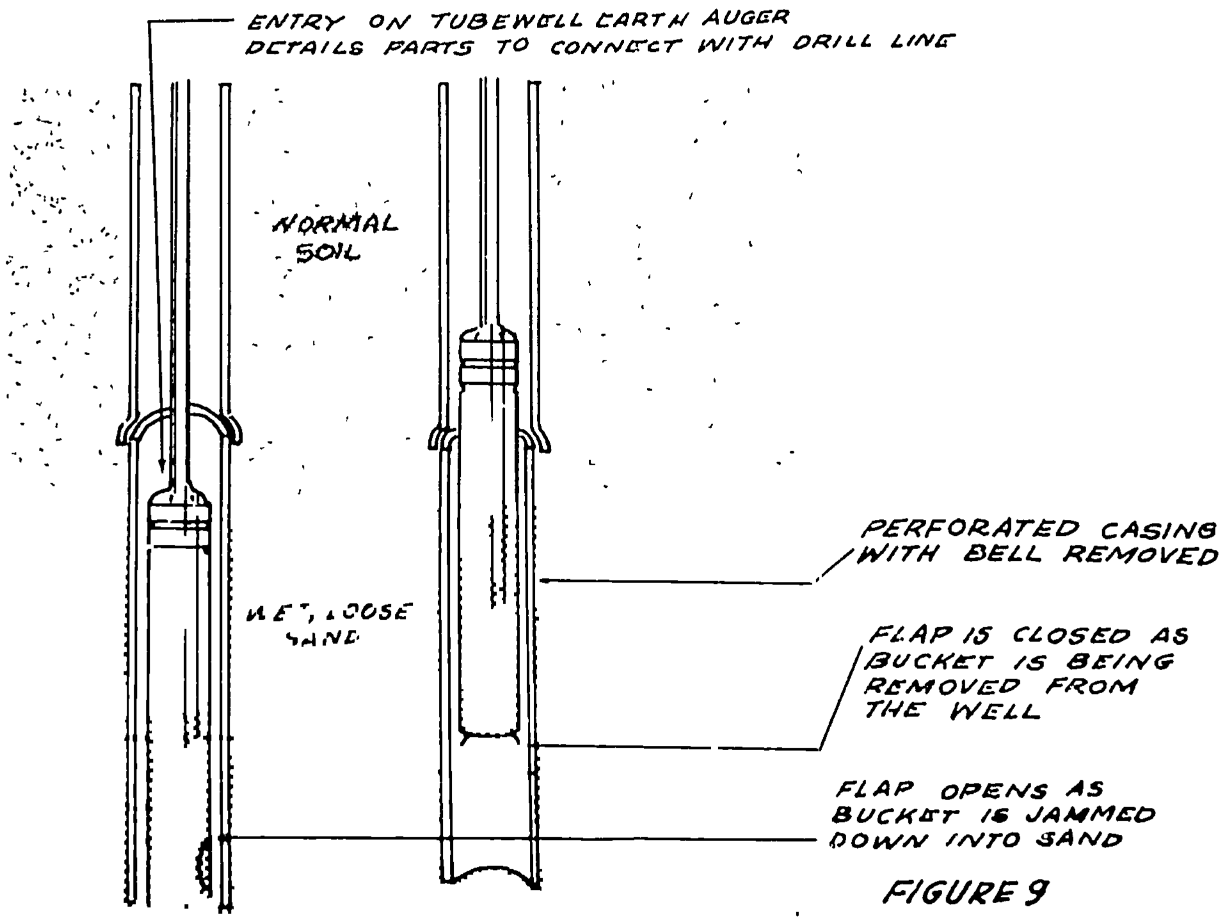


FIGURE 9

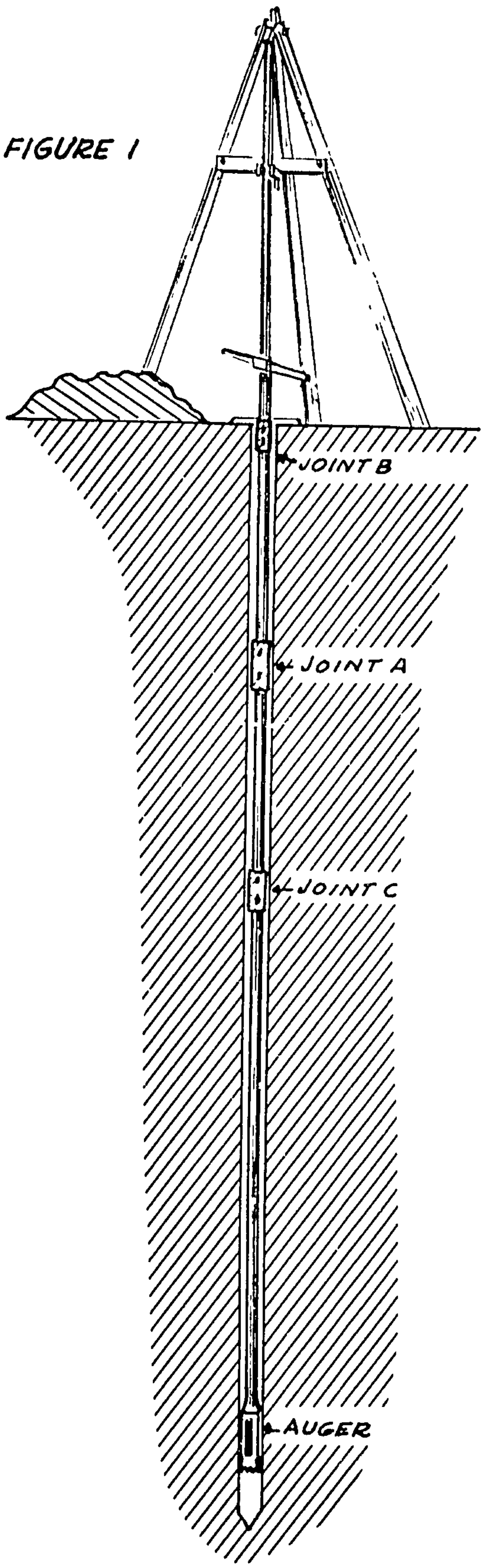
USING A SAND BAILER TO DRILL FROM INSIDE A WELL CASING

Method B

The equipment described here has been used successfully in the Ban Me Thuot area of Vietnam. One of the best performances was turned in by a crew of three inexperienced mountain tribesmen who drilled 20 meters (65') in a day and a half. The deepest well drilled was a little more than 25 meters (80'); it was completed, including the installation of the pump, in six days. One well was drilled through about 11 meters (35') of sedimentary stone.

The cost of the equipment, excluding labor, was U.S. $35.19 in 1957 in Vietnam.

FIGURE 1



Tools and Materials

For tool tray:

Wood: 3cm x 3cm x 150cm (1 1/4" x 1 1/4" x 59")

Wood: 3cm x 30cm x 45cm (1 1/4" x 12" x 17 3/4")

For safety rod:

Steel rod: 1cm (3/8") in diameter, 30cm (12") long

Drill

Hammer

Anvil

Cotter pin

For auger support:

Wood: 4cm x 45cm x 30cm (1 1/2" x 17 3/4" x 12")

Steel: 10cm x 10cm x 4mm (4" x 4" x 5/32")

Location of the Well

Two considerations are especially important for the location of village wells: (1) the average walking distance for the village population should be as short as possible; (2) it should be easy to drain spilled water away from the site to avoid creating a mudhole.

In the Ban Me Thuot area, the final choice of location was in all cases left up to the villagers. Water was found in varying quantities at all the sites chosen. (See "Getting Ground Water from Wells and Springs.)

Starting to Drill

A tripod is set up over the approximate location for the well (see Figure 1). Its legs are set into shallow holes with dirt packed around them to keep them from moving. To make sure the well is started exactly vertically, a plumb bob (a string with a stone tied to it is good enough) is then hung from the auger guide on the tripod's crossbar to locate the exact starting point. It is helpful to dip a small starting hole before setting up the auger.

Drilling

Drilling is accomplished by ramming the auger down to penetrate the earth and then rotating it by its wooden handle to free it in the hole before lifting it to repeat the process. This is a little awkward until the auger is down 30cm to 60cm (1' to 2') and should be done carefully until the auger starts to be guided by the hole itself. Usually two or three men work together with the auger. One system which worked out quite well was to use three men, two working while the third rested, and then alternate.

As the auger goes deeper it will be necessary from time to time to adjust the handle to the most convenient height. Any wrenches or other small tools used should be tied by means of a long piece of cord to the tripod so that if they are accidentally dropped in the well, they can easily be removed. Since the soil of the Ban Me Thuot area would stick to the auger, it was necessary to keep a small amount of water in the hole at all times for lubrication.

Emptying the Auger

Each time the auger is rammed down and rotated, it should be noted how much penetration has been obtained. Starting with an empty auger the penetration is greatest on the first stroke and becomes successively less on each following one as the earth packs more and more tightly inside the auger. When progress becomes too slow it is time to raise the auger to the surface and empty it. Depending on the material being penetrated, the auger may be completely full or have 30cm (1') or less of material in it when it is emptied. A little experience will give one a "feel" for the most efficient time to bring up the auger

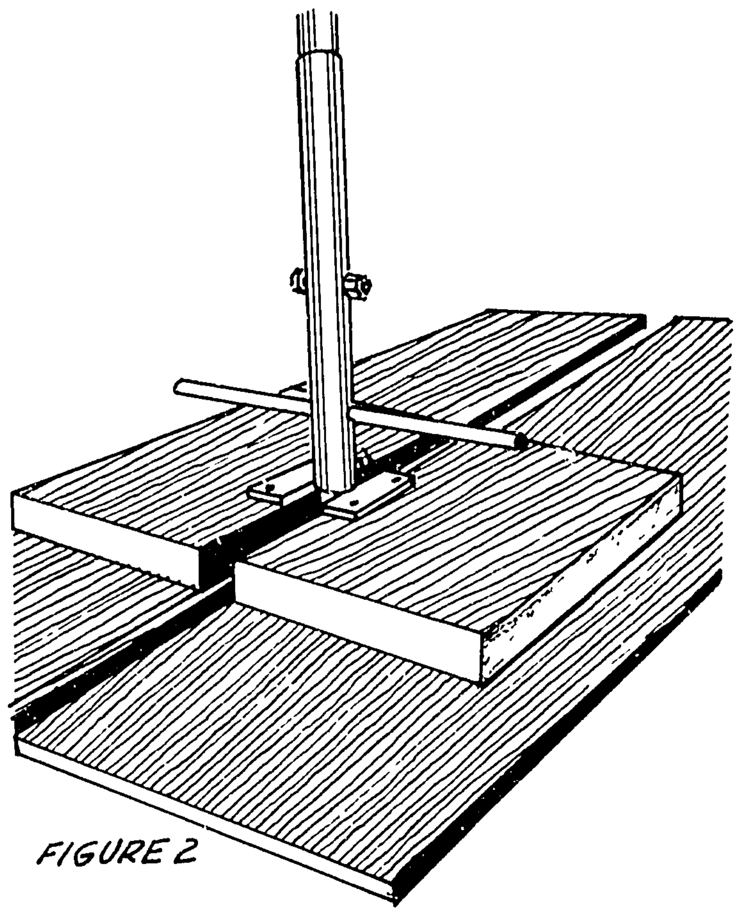


FIGURE 2

for emptying. Since the material in the auger is hardest packed at the bottom, it is usually easiest to empty the auger by inserting the auger cleaner through the slot in the side of the auger partway down and pushing the material out through the top of the auger in several passes. When the auger is brought out of the hole for emptying, it is usually leaned up against the tripod, since this is faster and easier than trying to lay it down.

Coupling and Uncoupling Extensions

The extensions are coupled by merely slipping the small end of one into the large end of the other and pinning them together with a 10mm (3/8") bolt. It has been found sufficient and time-saving to just tighten the nut finger-tight instead of using a wrench.

Each time the auger is brought up for emptying, the extensions must be taken apart. For this reason the extensions have been made as long as possible to minimize the number of joints. Thus at a depth of 18.3 meters (60'), there are only two joints to be uncoupled in bringing up the auger.

For the sake of both safety and speed, use the following procedure in coupling and uncoupling. When bringing up the auger, raise it until a joint is just above the ground and slip the auger support (see Figures 2 and 3) into place, straddling the extension so that the bottom of the coupling can rest on the small metal plate. The next step is to put the safety rod (see Figure 4) through the lower side in the coupling and secure it with either a cotter pin or a piece of wire. The purpose of the safety rod is to keep the auger from falling into the well if it should be knocked off the auger support or dropped while being raised.

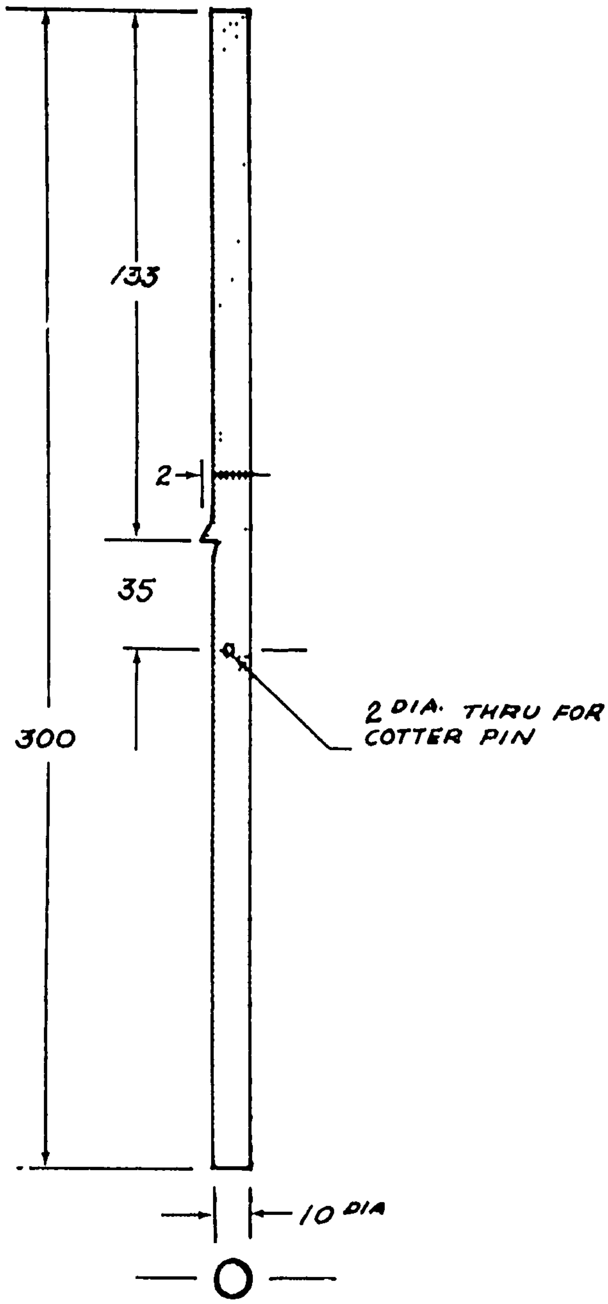


FIGURE 4 SAFETY ROD

SCALE: ½ SIZE MAT'L: MILD STEEL

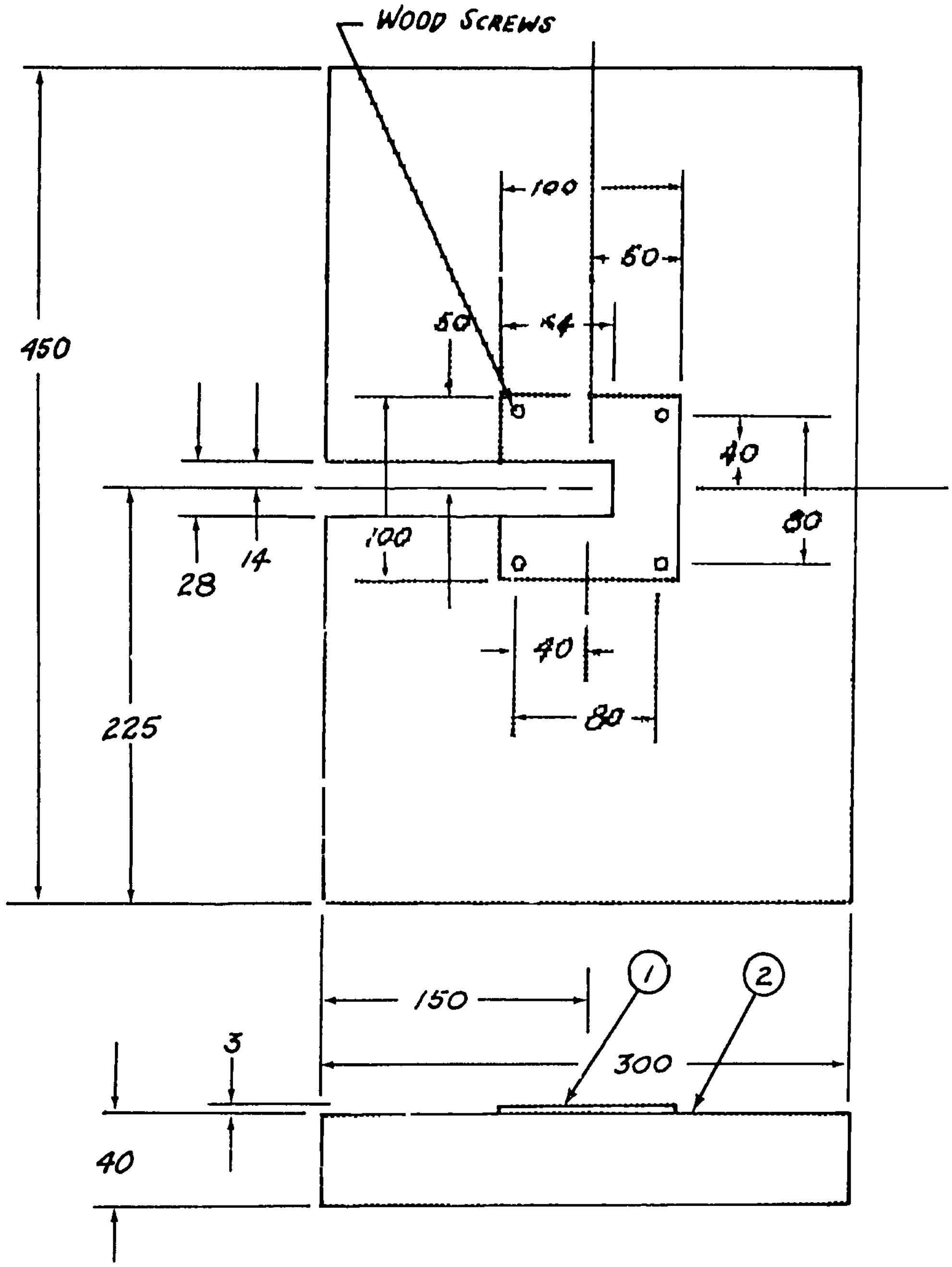


FIGURE 3 - AUGER SUPPORT

SCALE: 1/4 SIZE MAT'L: ① MILD STEEL
② HARDWOOD

Once the safety rod is in place, remove the coupling bolt and slip the upper extension out of the lower. Lean the upper end of the extension against the tripod between the two wooden pegs in the front legs, and rest the lower end in the tool tray (see Figures 5 and 6). The reason for setting the extensions in the tool tray is to keep dirt from sticking to the lower ends and making it difficult to put the extensions together and take them apart.

To couple the extensions after emptying the auger, the procedure is the exact reverse of uncoupling.

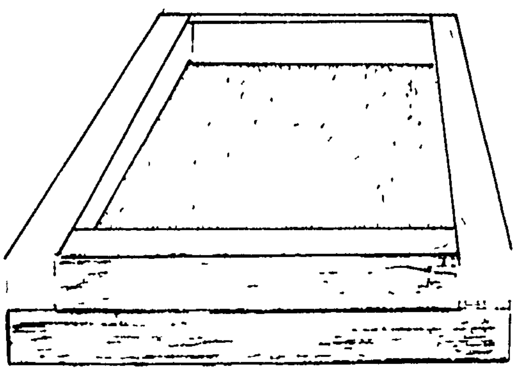


FIGURE 5 TOOL TRAY

Drilling Rock

When stone or other substances which the auger cannot penetrate are met, a heavy drilling bit must be used.

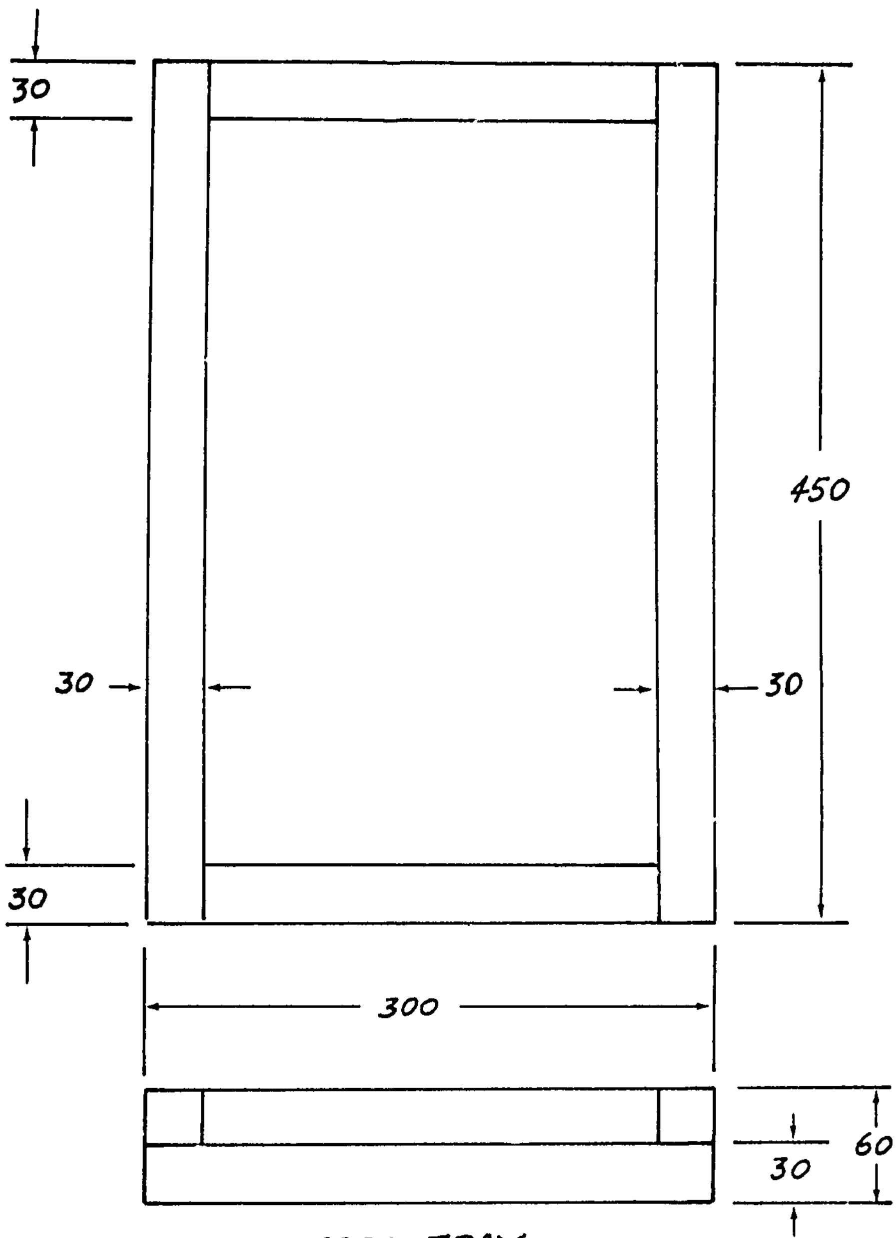
Depth of Well

The rate at which water can be taken from a well is roughly proportional to the depth of the well below the water table as long as it keeps going into water-bearing ground. However, in village wells where water can only be raised slowly by hand pump or bucket, this is not usually of major importance. The important point is that in areas where the water table varies from one time of year to the next the well must be deep enough to give sufficient water at all times.

Information on the water table variation may be obtained from already existing wells, or it may be necessary to drill a well before any information can be obtained. In the latter case the well must be deep enough to allow for a drop in the water table.

Source:

Report by Richard G. Koegel, International Voluntary Services, Ban Me Thuot, Vietnam, 1959 (mimeo).



TOOL TRAY

SCALE: 1/4 SIZE MAT'L· WOOD

FIGURE 6

Equipment

The following section gives construction details for the equipment used with Method B for well-drilling:

1. Auger, Extensions and Handle
2. Auger Cleaner
3. Demountable Reamer
4. Tripod and Pulley
5. Bailing Bucket
6. Bit for Drilling Rock

Auger, Extensions and Handle

The auger is hacksawed out of standard-weight steel pipe about 10cm (4") in diameter (see Figure 8). Lightweight tubing is not strong enough. The extensions (see Figure 9) and handle (see Figure 10) make it possible to bore deep holes.

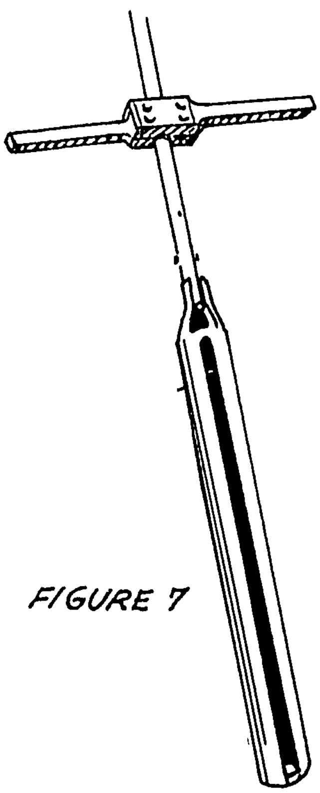


FIGURE 7

Tools and Materials

Pipe: 10cm (4") in diameter, 120cm (47 1/4") long, for auger

Pipe: 34mm outside diameter (1" inside diameter); 3 or 4 pieces 30cm (12") long, for auger and extension socket

Pipe: 26mm outside diameter (3/4" inside diameter); 3 or 4 pieces 6.1 or 6.4 meters (20' or 21') long, for drill extensions

Pipe: 18mm outside diameter (1/2" inside diameter); 3 or 4 pieces 6cm (2 3/8") long

Hardwood: 4cm x 8cm x 50cm (1 1/2" x 3 1/8" x 19 3/4"), for handle

Mild steel: 3mm x 8cm x 15cm (1/8" x 3 1/8" x 6")

4 bolts: 1cm (3/8") in diameter and 10cm (4") long

4 Nuts

Hand tools and welding equipment

In making the auger, a flared-tooth cutting edge is cut in one end of the 10cm pipe. The other end is cut, bent and welded to a section of 34mm outside-diameter (1" inside-diameter) pipe, which forms a socket for the drill line extensions. A slot which runs nearly the length of the auger is used for removing soil from the auger. Bends are made stronger and more easily and accurately when the steel is hot. At first, an auger with two cutting lips similar to a post-hole auger was used; but it became plugged up and did not cut cleanly. In some soils, this type of auger may be more effective.

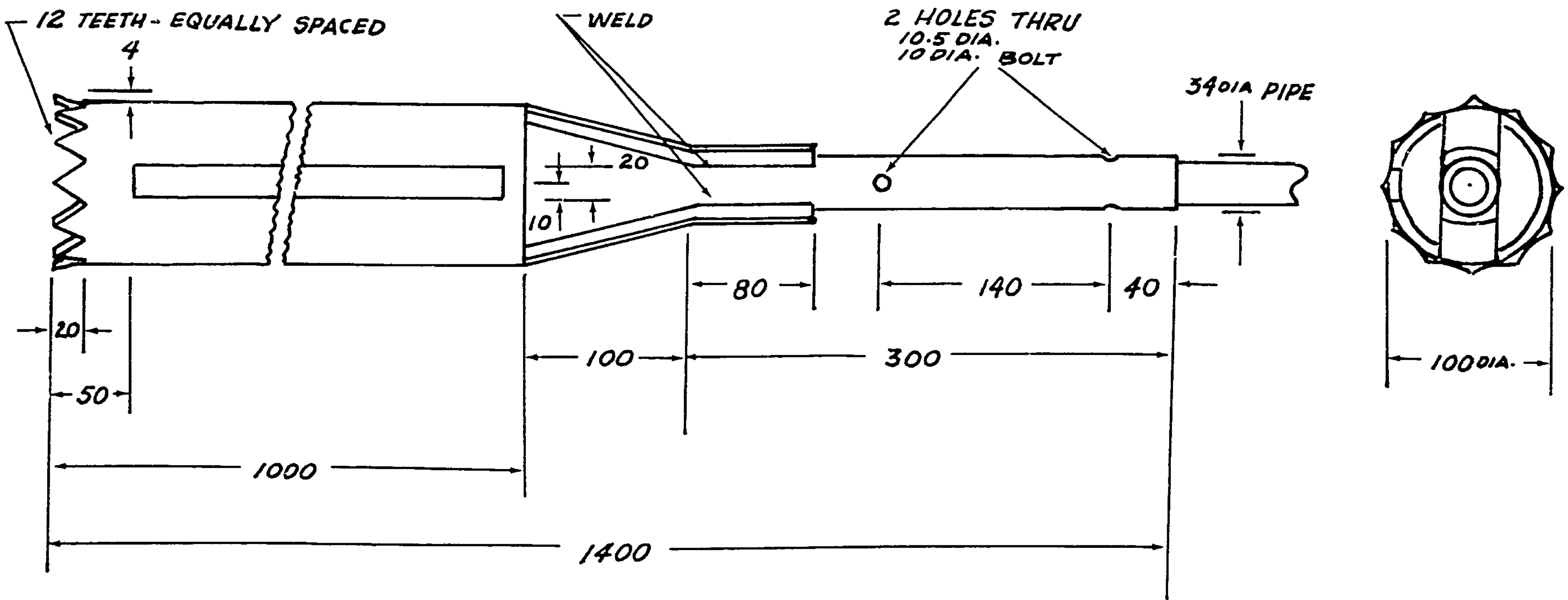


FIGURE 8, CUTTING HEAD, WELL DRILLING AUGER

SCALE: 1/4 SIZE MAT'L. MILD STEEL

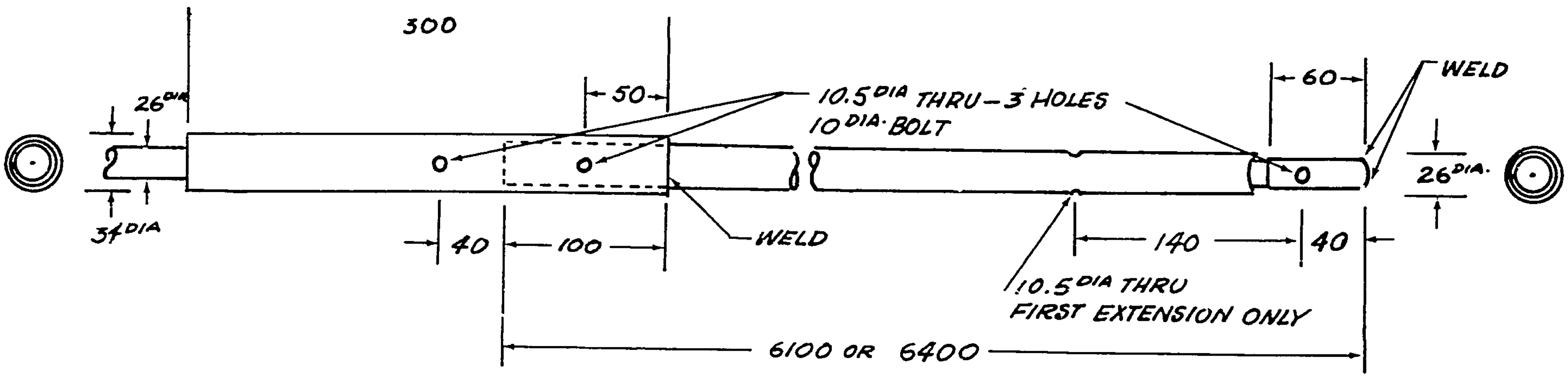


FIGURE 9 EXTENSION, WELL DRILLING AUGER

SCALE: 1/4 SIZE MAT'L: MILD STEEL

NOTE: 34 DIA. COUPLING MAY BE OMITTED ON LAST EXTENSION

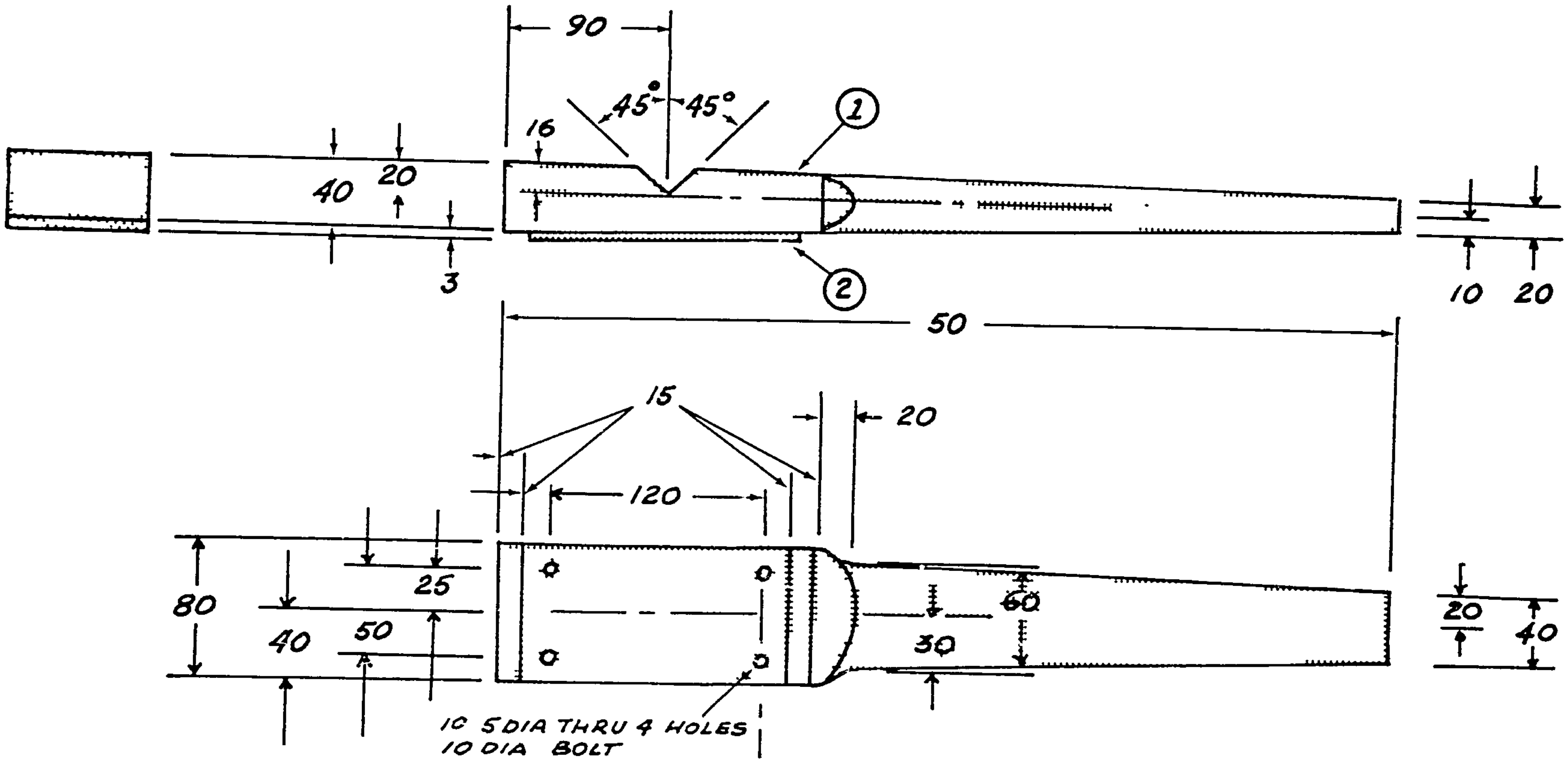


FIGURE 10, HANDLE, WELL DRILLING AUGER
NOTE: 2 REQUIRED PER SET
SCALE: 1/4 SIZE MAT'L: (1) HARDWOOD
(2) MILD STEEL

Auger Cleaner

Soil can be removed rapidly from the auger with this auger cleaner (see Figure 11). Figure 12 gives construction details.

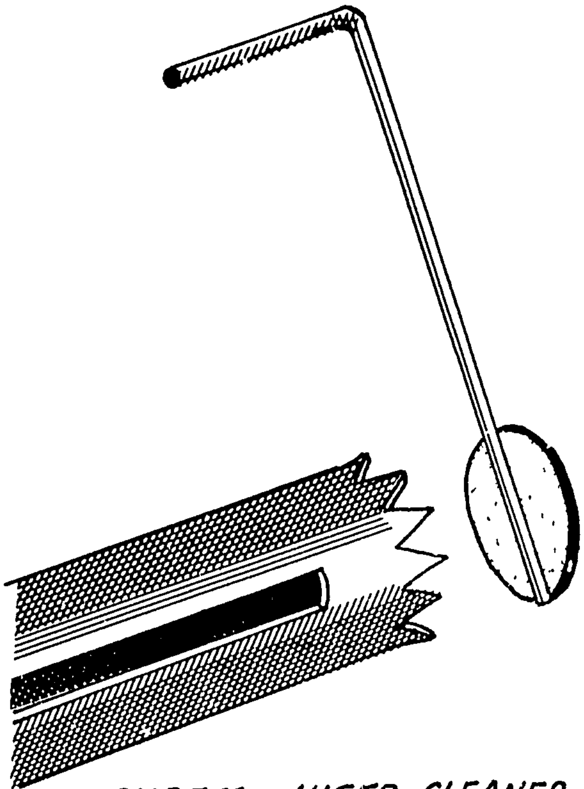


FIGURE 11 AUGER CLEANER

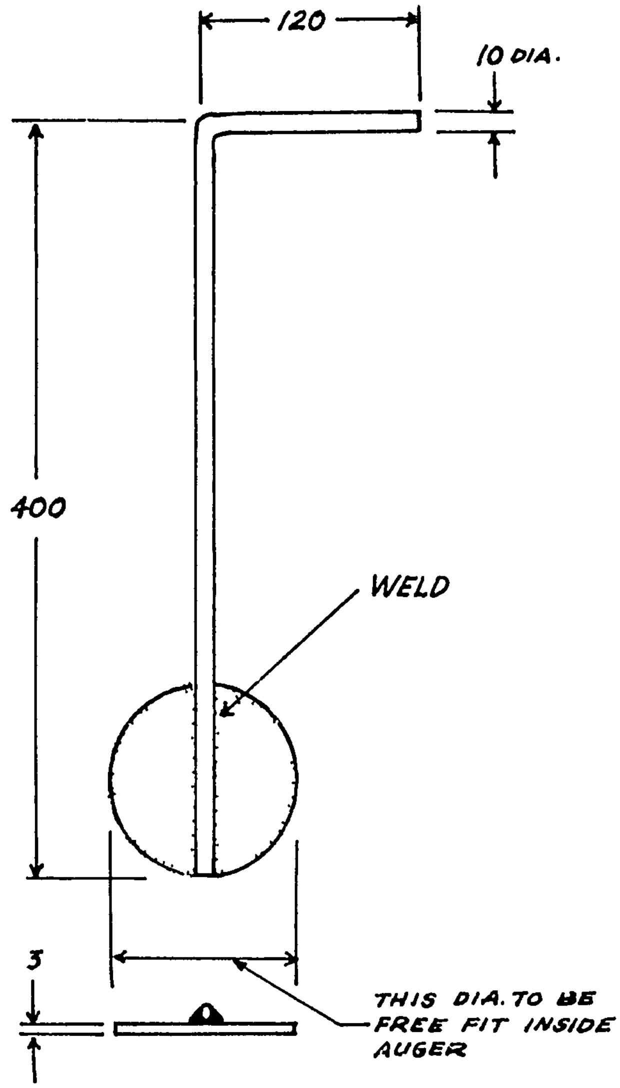


FIGURE 12
SCALE: 1/4 SIZE MAT'L: MILD STEEL

Tools and Materials

Mild steel: 10cm (4") square and 3mm (1/8") thick

Steel rod: 1cm (3/8") in diameter and 52cm (20 1/2") long

Welding equipment

Hacksaw

File

Demountable Reamer

If the diameter of a drilled hole has to be made bigger, the demountable reamer described here can be attached to the auger.

Tools and Materials

Mild steel: 20cm x 5cm x 6mm (8" x 2" x 1/4"), to ream a well diameter of 19cm (7 1/2")

2 Bolts: 8mm (5/16") in diameter and 10cm (4") long

Hacksaw

Drill

File

Hammer

Vise

The reamer is mounted to the top of the auger with two hook bolts (see Figure 13). It is made from a piece of steel 1cm (1/2") larger than the desired well diameter (see Figure 14).

After the reamer is attached to the top of the auger, the bottom of the auger is plugged with some mud or a piece of wood to hold the cuttings inside the auger.

In reaming, the auger is rotated with only slight downward pressure. It should be emptied before it is too full so that not too many cuttings will fall to the bottom of the well when the auger is pulled up.

Because the depth of a well is more important than the diameter in determining the flow and because doubling the diameter means removing four times the amount of earth, larger diameters should be considered only under special circumstances. (See "Well Casing and Platforms," page 12.)

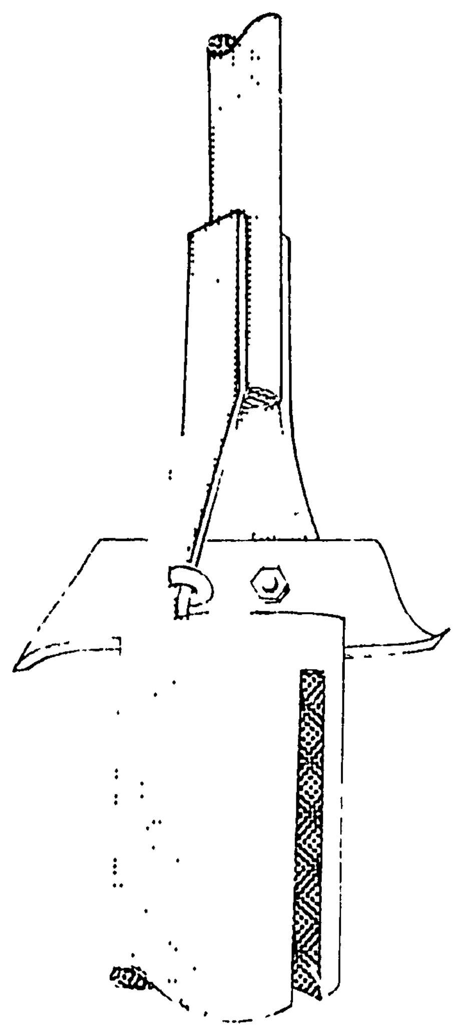


FIGURE 13

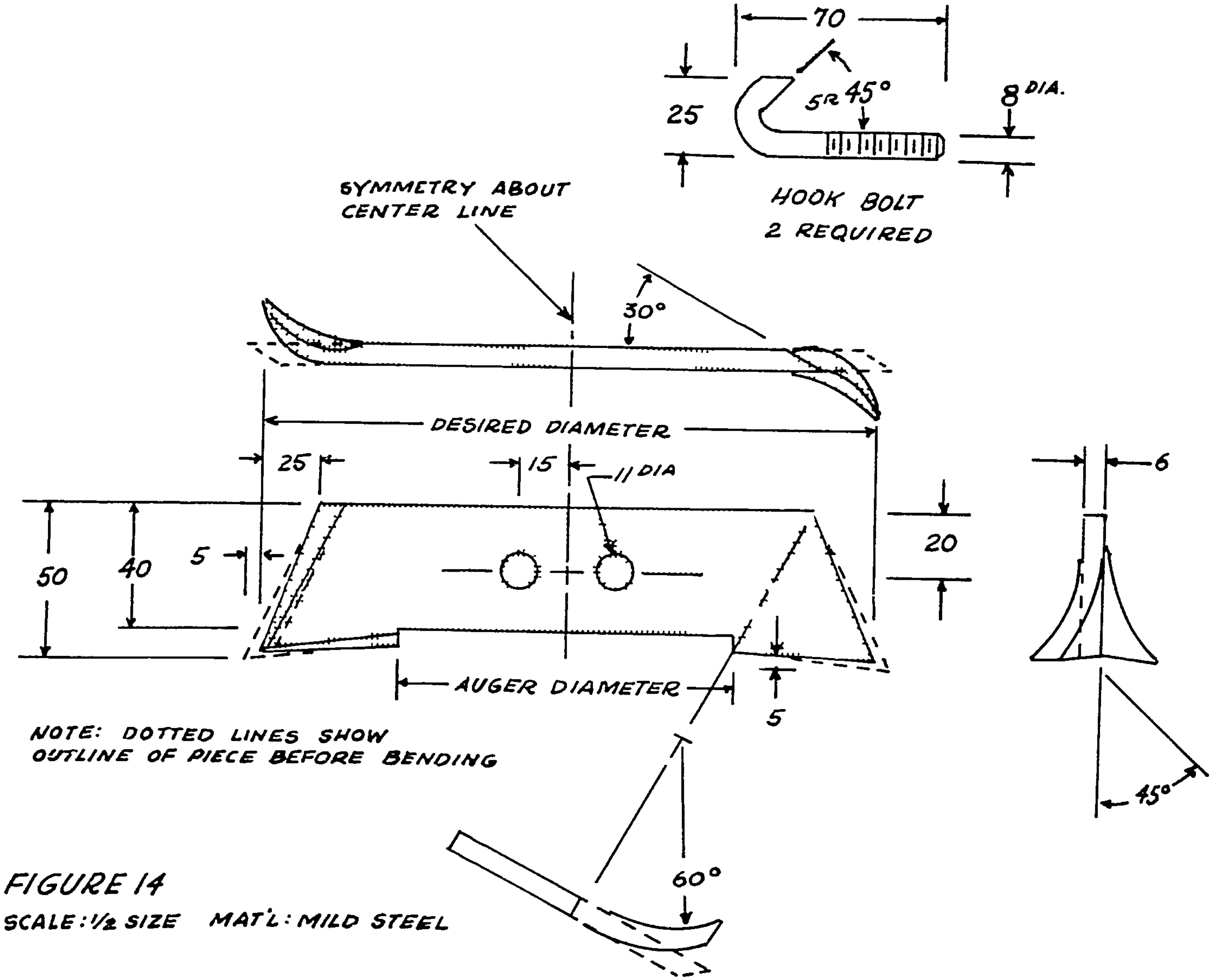


FIGURE 14

SCALE: 1/2 SIZE MAT'L: MILD STEEL

Tripod and Pulley

The tripod (see Figures 15 and 16), which is made of poles and assembled with 16mm (5/8") bolts, serves three purposes: (1) to steady the extension of the auger when it extends far above ground; (2) to provide a mounting for the pulley (see Figures 17 and 19) used with the drill bit and bailing bucket; and (3) to provide a place for leaning long pieces of casing, pipe for pumps or auger extensions while they are being put into or taken out of the well.

When a pin or bolt is put through the holes in the two ends of the "L"-shaped pulley bracket (see Figures 15 and 18) which extend horizontally beyond the front of the tripod crossbar, a loose guide for the upper part of the auger extension is formed.

To keep the extensions from falling when they are leaned against the tripod, two 30cm (12") long wooden pegs are driven into drilled holes near the top of the tripod's two front legs (see Figure 19).

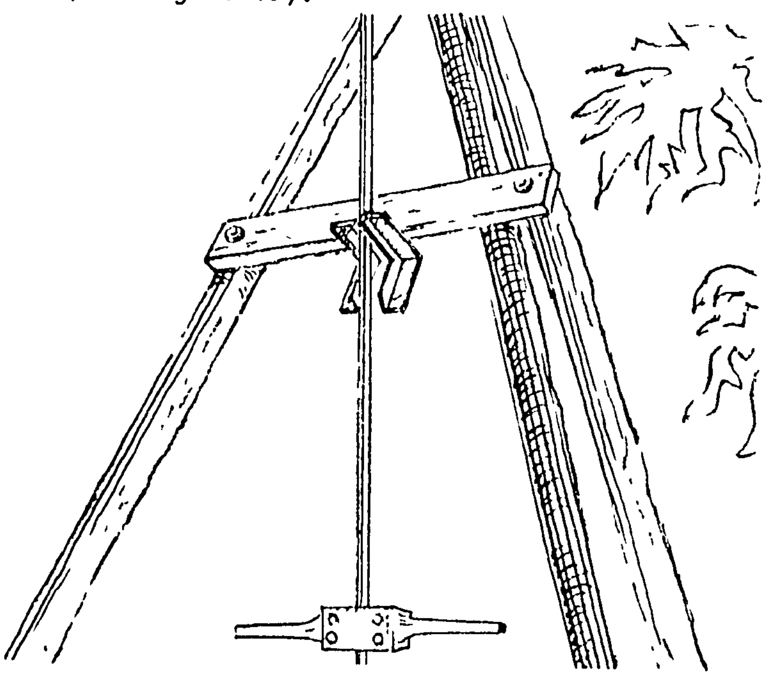


FIGURE 15

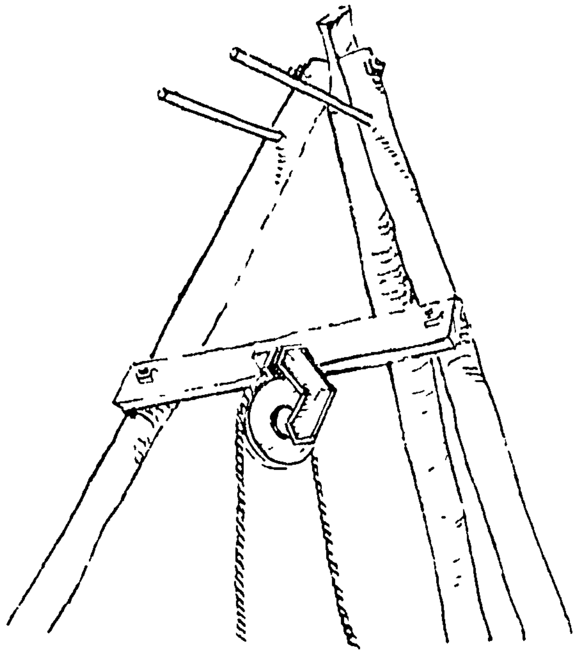


FIGURE 16

Tools and Materials

3 Poles: 15cm (3") in diameter and 4.25 meters (14') long

Wood for cross bar: 1.1 meter (43 1/2") x 12cm (4 3/4") square

For pulley wheel:

Wood: 25cm (10") in diameter and 5cm (2") thick

Pipe: 1.25cm (1/2") inside diameter, 5cm (2") long

Axle bolt: to fit close inside 1.25cm (1/2") pipe

Angle iron: 80cm (31 1/2") long, 50cm (19 3/4") webs, 5mm (3/16") thick

4 Bolts: 12mm (1/2") in diameter, 14cm (5 1/2") long; nuts and washers

Bolt: 16mm (5/8") in diameter and 40cm (15 3/4") long; nuts and washers

2 Bolts: 16mm (5/8") in diameter and 25cm (9 7/8") long; nuts and washers

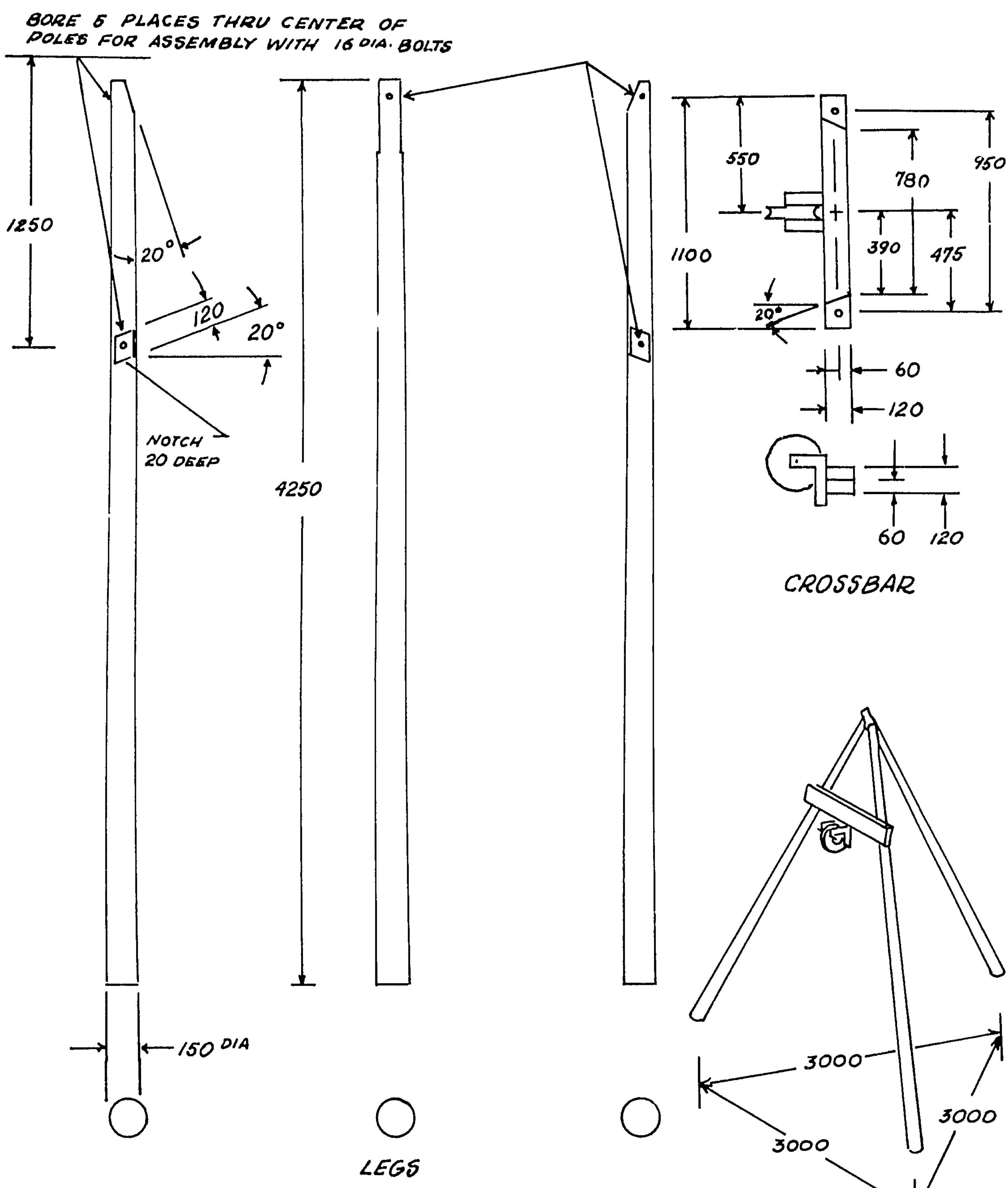

BORE 5 PLACES THRU CENTER OF POLES FOR ASSEMBLY WITH 16 DIA. BOLTS
1250
20°
120
20°
NOTCH 20 DEEP
4250
150 DIA
550
780
950
1100
390
475
20°
60
120
60
120
CROSSBAR
3000
3000
3000
LEGS

FIGURE 17

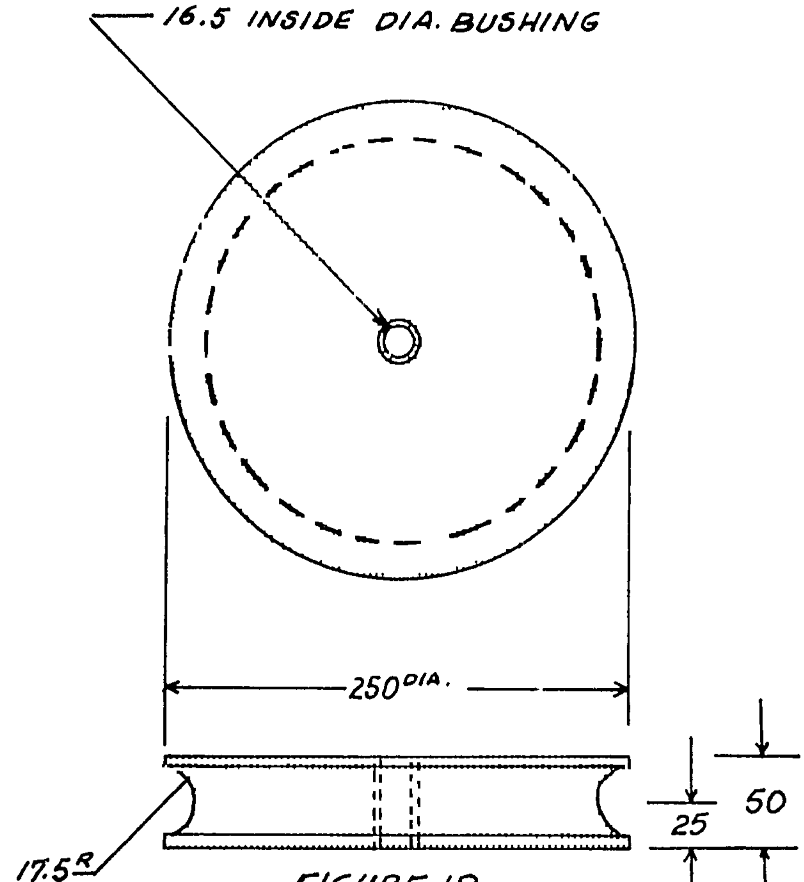
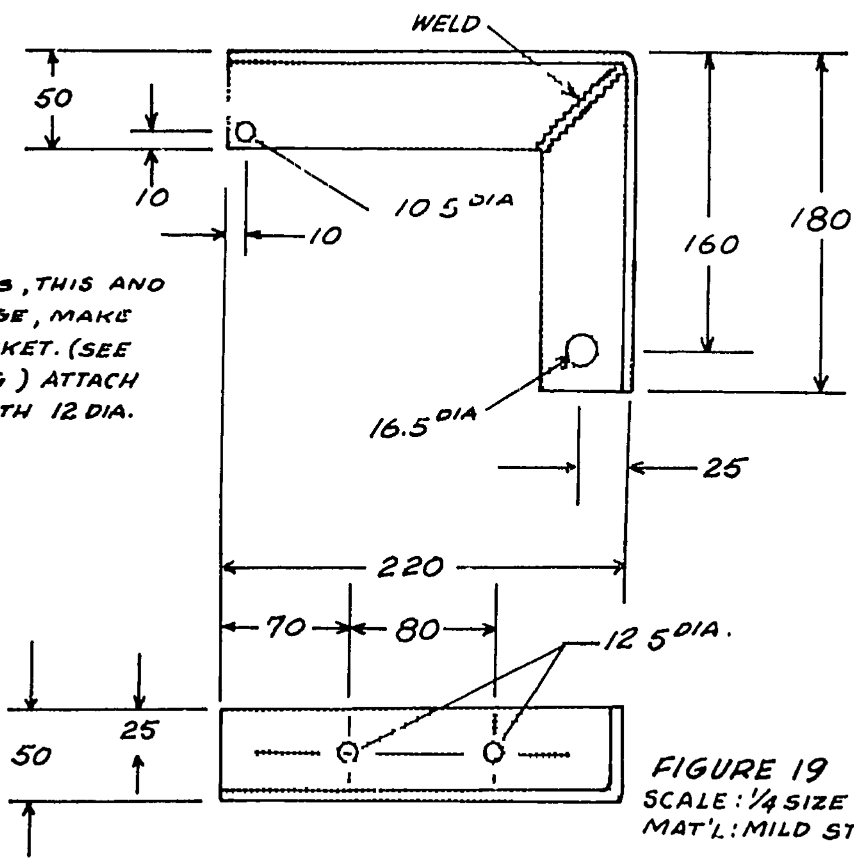


FIGURE 18

SCALE: 1/4 SIZE MAT'L HARDWOOD



NOTE: TWO PIECES, THIS AND IT'S MIRROR IMAGE, MAKE ONE PULLEY BRACKET. (SEE TRIPOD DRAWING) ATTACH TO CROSSBAR WITH 12 DIA. BOLTS.

FIGURE 19

SCALE: 1/4 SIZE

MAT'L: MILD STEEL

Bailing Bucket

The bailing bucket can be used to remove soil from the well hole when cuttings are too loose to be removed with the auger.

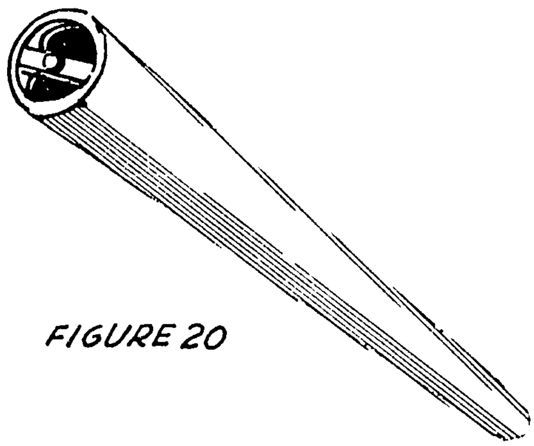


FIGURE 20

Tools and Materials

Pipe: about 8.5cm (3 3/8") in diameter 1 to 2 cm (1/2" to 3/4") smaller in diameter than the auger, 180cm (71") long

Steel rod: 10mm (3/8") in diameter and 25cm (10") long; for bail (handle)

Steel plate: 10cm (4") square, 4mm (5/32") thick

Steel bar: 10cm x 1cm x 5mm (4" x 3/8" x 3/16")

Machine screw: 3mm (1/8") in diameter; 16mm (5/8") long; nut and washer

Truck innertube: 4mm (5/32") thick, 10mm (3/8") square

Welding equipment

Drill, hacksaw, hammer, vise, file

Rope

Both standard weight pipe and thin-walled tubing were tried for the bailing bucket. The former, being heavier, was harder to use, but did a better job and stood up better under use. Both the steel bottom of the bucket and the rubber valve should be heavy because they receive hard usage. The metal bottom is reinforced with a crosspiece welded in place (see Figures 20 and 21).

Using the Bailing Bucket

When water is reached and the cuttings are no longer firm enough to be brought up in the auger, the bailing bucket must be used to clean out the well as work progresses.

For using the bailing bucket the pulley is mounted in the pulley bracket with a 16mm (5/8") bolt as axle. A rope attached to the bailing bucket is then run over the pulley and the bucket is lowered into the well. The pulley bracket is so designed that the rope coming off the pulley lines up vertically with the well, so that there is no need to shift the tripod.

The bucket is lowered into the well, preferably by two men, and allowed to drop the last meter or meter and one-half (3 to 5 feet) so that it will hit the bottom with some speed. The impact will force some of the loose soil at the bottom of the well up into the bucket. The bucket is then repeatedly raised and dropped 1 to 2 meters (3 to 6 feet) to pick up more soil. Experience will show how long this should be continued to pick up as much soil as possible before raising and emptying the bucket. Two or more men can raise the bucket, which should be dumped far enough from the well to avoid messing up the working area.

If the cuttings are too thin to be brought up with the auger but too thick to enter the bucket, pour a little water down the well to dilute them.

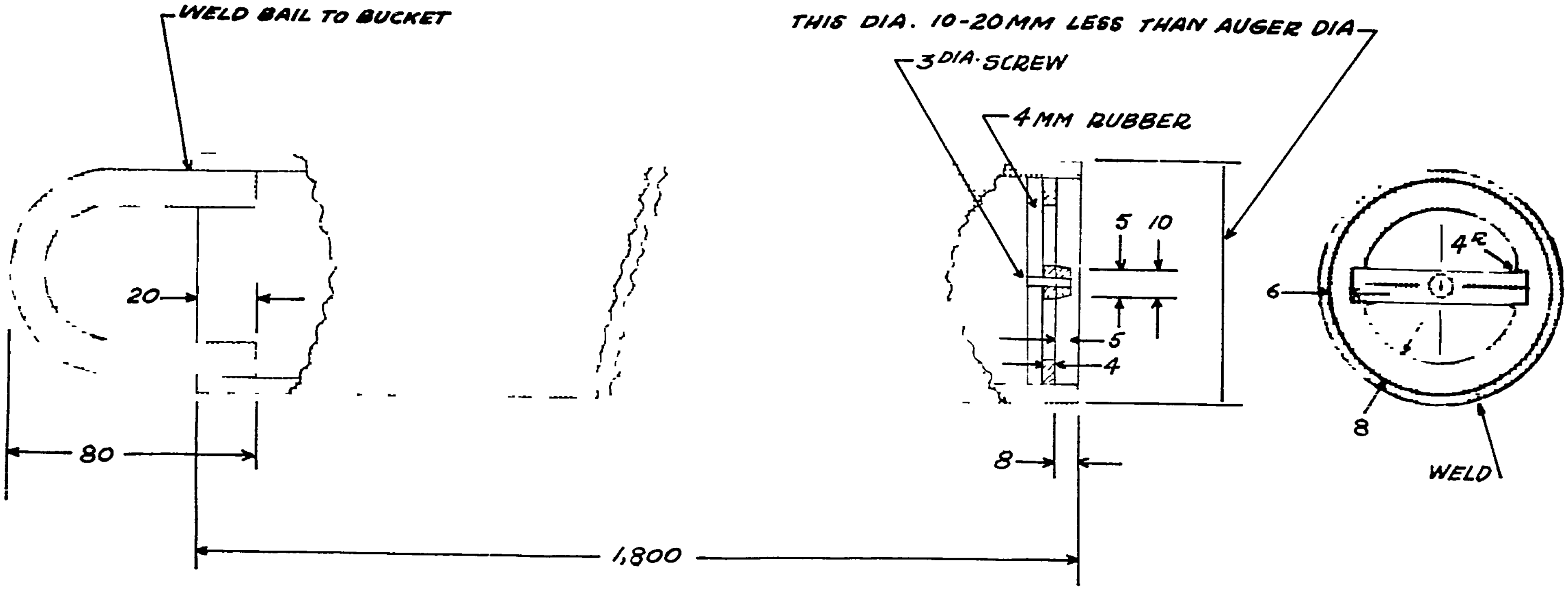


FIGURE 21

SCALE: ½ SIZE MAT'L: MILD STEEL

Bit for Drilling Rock

The bit described here has been used to drill through layers of sedimentary stone up to 11 meters (36') thick.

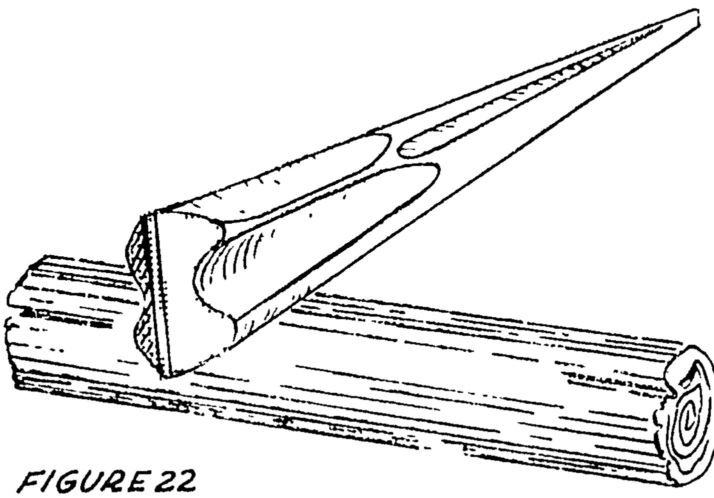


FIGURE 22
HEAVY BIT FOR DRILLING ROCK

Tools and Materials

Mild steel bar: about 7cm (2 3/4") in diameter and about 1.5 meters (5') long, weighing about 80kg (175 pounds)

Stellite (a very hard type of tool steel) insert for cutting edge

Anvil and hammers, for shaping

Steel rod: 2.5cm x 2cm x 50cm (1" x 3/4" x 19 3/4") for bail

Welding equipment

The drill bit for cutting through stone and hard formations is made from the 80kg (175-pound) steel bar (see Figures 22 and 23). The 90-degree cutting edge is hard-surfaced with stellite and a bail (or handle) for attaching a rope is welded to the top. The bail should be large enough to make "fishing" easy if the rope breaks. A 2.5cm (1") rope was used at first, but this was subject to much wear when working in mud and water. A 1cm (3/8") steel cable was substituted for the rope, but it was not used enough to be able to show whether the cable or the rope is better. One advantage of rope is that it gives a snap at the end of the fall which rotates the bit and keeps it from sticking. A swivel can be mounted between the bit and the rope or cable to let the bit rotate.

If a bar this size is difficult to find or too expensive, it might be possible to make one by welding a short steel cutting end onto a piece of pipe which is made heavy enough by being filled with concrete. This has not been tried.

In using the drilling bit, the pulley is put in place as with the bailing bucket, and the bit is attached to its rope or cable and lowered into the well. Since the bit is heavy, wrap the rope once or twice around the back leg of the tripod so that the bit cannot "get away" from the workers with the chance of someone being hurt or the equipment getting damaged. The easiest way found to raise and drop the bit was to run the rope through the pulley and then straight back to a tree or post where it was attached at shoulder height or slightly lower. Workers line up along the rope and raise the bit by pressing down on the rope; they drop it by allowing the rope to return quickly to its original position (see Figure 24). This requires five to seven men; occasionally more helped. Frequent rests are necessary; usually after every 50 to 100 strokes. Because the work is harder near the ends of the rope than in the middle, the positions of the workers should be rotated to distribute the work evenly.

A small amount of water should be kept in the hole for lubrication and to mix with the pulverized stone to form a paste which can be removed with a bailing bucket. Too much water will

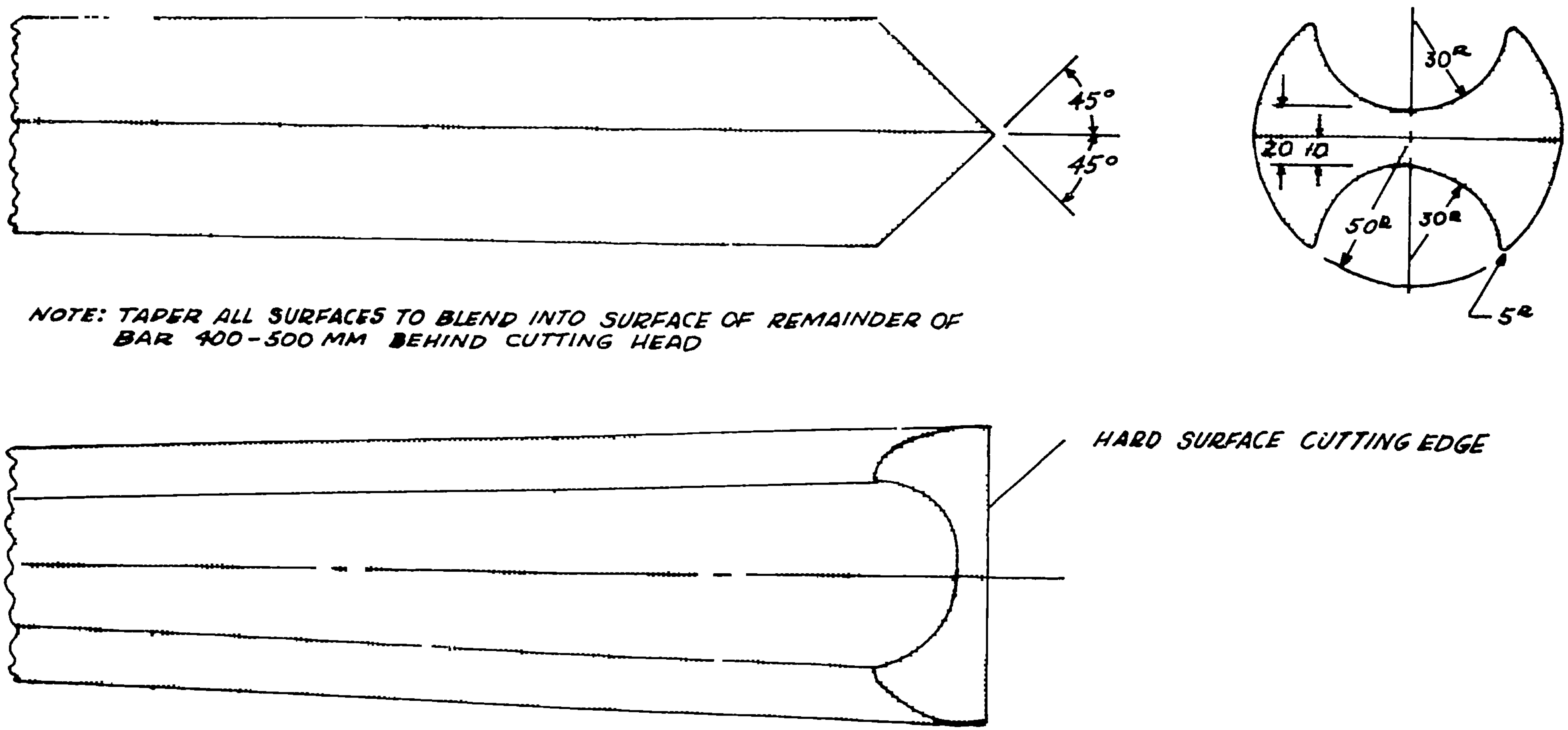


FIGURE 23

SCALE: 1/2 SIZE   MAT'L: MILD STEEL

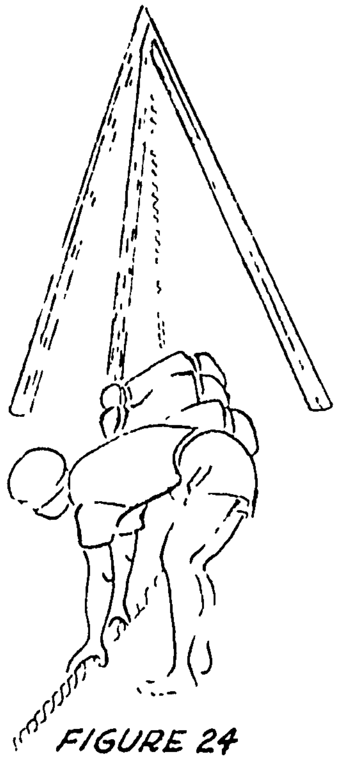


FIGURE 24

slow down the drilling.

The speed of drilling is, of course, dependent on the type of stone encountered. In the soft water-bearing stone of the Ban Me Thuot area it was possible to drill several meters (about 10 feet) per day. However, when hard stone such as basalt is encountered, progress is measured in centimeters (inches). The decision must then be made whether to continue trying to penetrate the rock or to start over in a new location. Experience in the past has indicated that one should not be too hasty in abandoning a location, since on several occasions what were apparently thin layers of hard rock were penetrated and drilling then continued at a good rate.

On occasion the bit has become stuck in the well and it has been necessary to use a lever arrangement consisting of a long pole attached to the rope to free it (see Figure 25). On other occasions a crude windlass was used consisting of a horizontal pole which was used to wrap the rope around a vertical pole pivoted on the ground and held in place by several men (see Figure 26). When the above two failed, it was necessary to borrow a chain hoist. Twice when the rope was allowed to become too worn, it was broken when trying to retrieve a stuck bit. It was then necessary to fit a hook to one of the auger extensions, attach enough extensions together to reach the desired depth, and after hooking the bit, to pull with the chain hoist. A rope or cable may also be used for this purpose, but it is considerably more difficult to hook onto the bit.

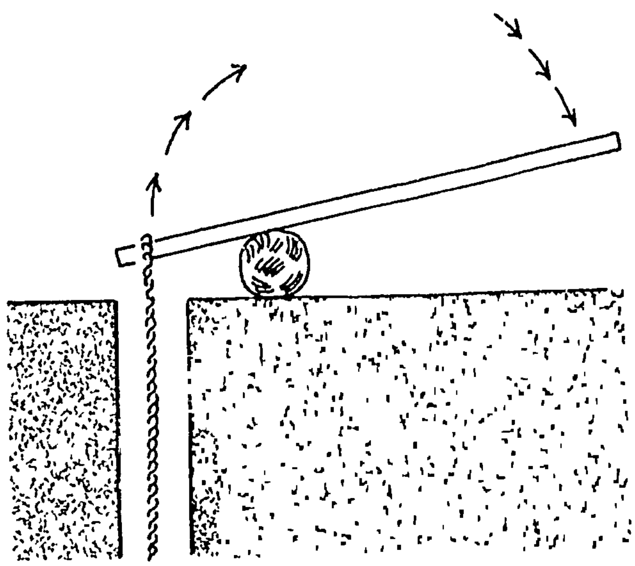
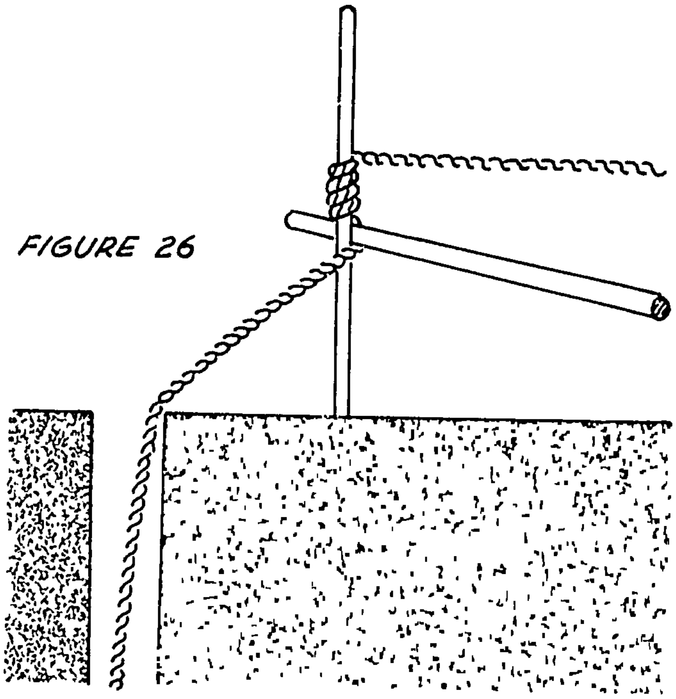


FIGURE 25

FIGURE 26



Drilling Mechanically

A method for raising and dropping the bit mechanically, not used on the project but used successfully elsewhere, is:

1. Jack up the rear wheel of a car and replace the wheel with a small drum.

2. Take the rope which is attached to the bit and come from the tripod on the pulley and wrap it loosely around the drum.

3. Pull the unattached end of the rope taut and set the drum in motion. The rope will move with the drum and raise the bit.

4. Let the end of the rope go slack quickly to drop the bit.

It will probably be necessary to polish and/or grease the drum.

DRY BUCKET WELL DRILLING

The dry-bucket method is a simple and quick method of drilling wells in dry soil which is free of rocks. It can be used for 5cm to 7.5cm (2" to 3") diameter wells in which steel pipe is to be installed. For wells which are wider in diameter, it is a quick method of removing dry soil before completing the bore with a wet bucket, tubewell sand bailer or tubewell sand auger.

A 19.5-meter (64') hole was dug in less than 3 hours with this method in north Florida. The method works best in sandy soil, according to the author of this entry, who has drilled 30 wells with it.

<u>Tools and Materials</u>

Dry bucket

Rope: 16mm (5/8") or 19mm (3/4") in diameter and 6 to 9 meters (20' to 30') longer than the deepest well to be drilled

3 Poles: 10cm (4") in diameter at large end and 3.6 to 4.5 meters (12' to 15') long

Chain, short piece

Pulley

Bolt: 12.5mm (1/2") in diameter and 30 to 35cm (12" to 14") long (long enough to reach through the upper ends of the three poles)

The dry bucket is held about 10cm (several inches) above the ground, centered above the hole location and then dropped (see Figure 1). This drives a small amount of soil up into the bucket. After this is repeated two or three times, the bucket is removed, held to one side and tapped with a hammer or a piece of iron to dislodge the soil. The process is repeated until damp soil is reached and the bucket will no longer remove soil.

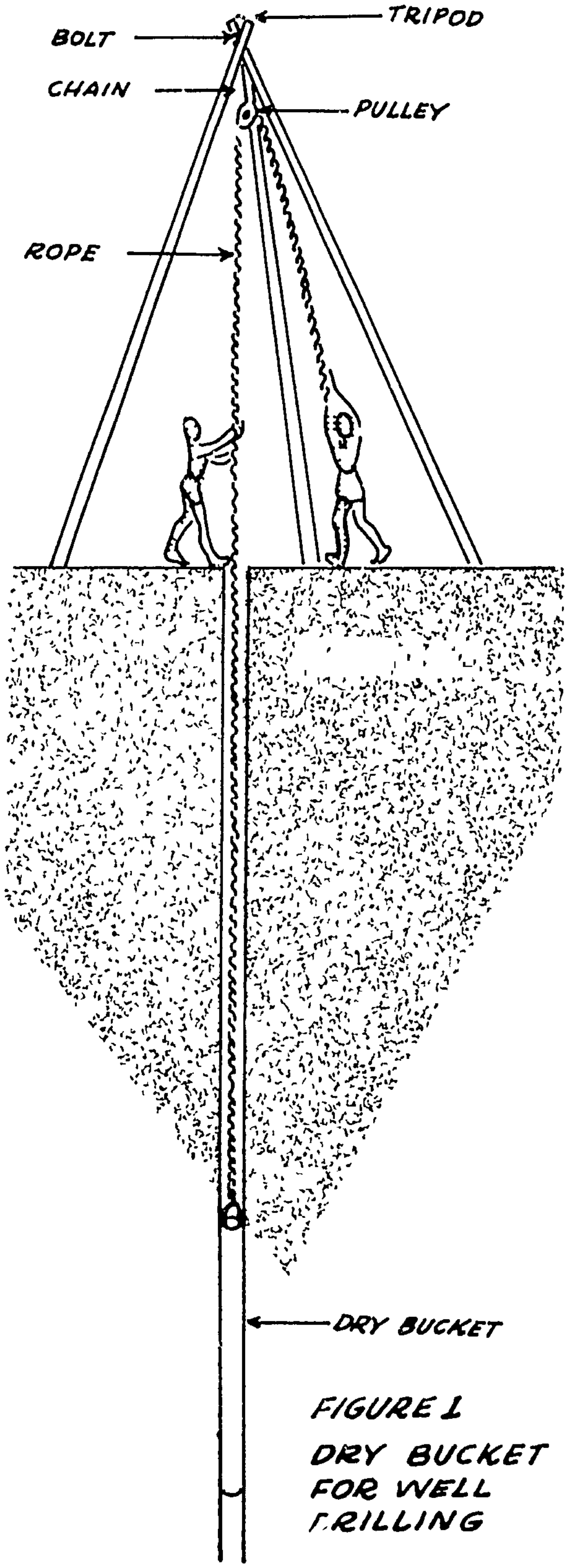


FIGURE 1
DRY BUCKET FOR WELL DRILLING

Dry Bucket for Well Drilling

A dry bucket is simply a length of pipe with a bail or handle welded to one end and a slit cut in the other.

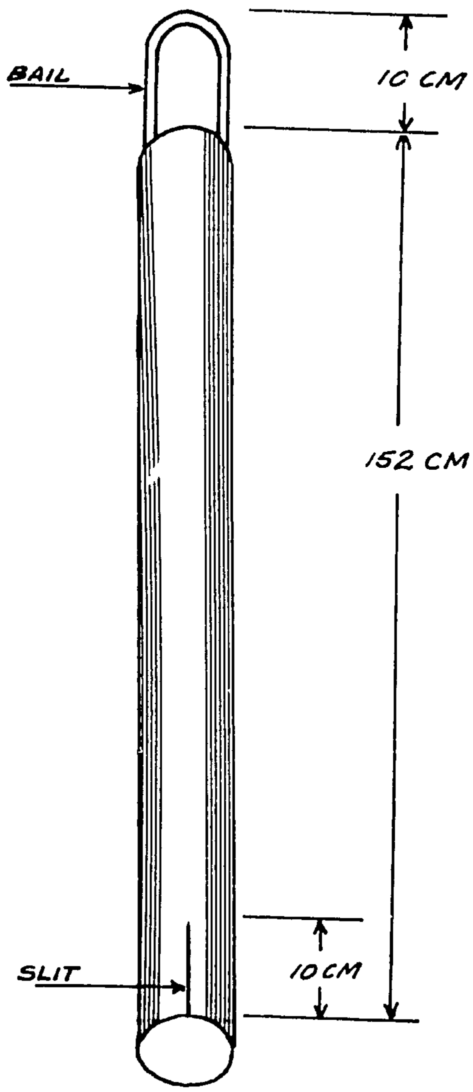


FIGURE 2

Bend the iron rod into a U-shape small enough to slide inside the pipe. Weld it in place as in Figure 2.

File a gentle taper on the inside of the opposite end to make a cutting edge (see Figure 3).

Cut a slit in one side of the sharpened end of the pipe (see Figure 2).

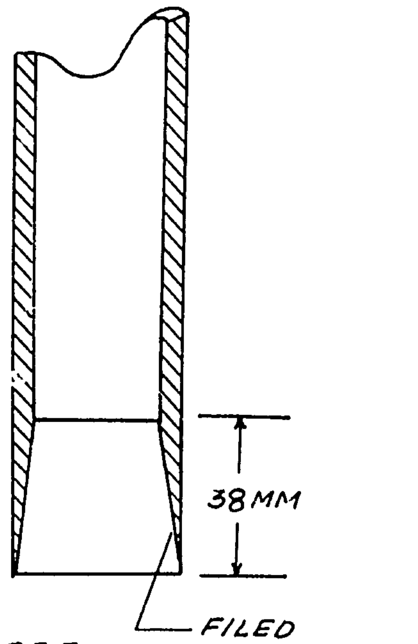


FIGURE 3

Tools and Materials

Hacksaw

File

Iron rod: 10mm (3/8") or 12.5mm (1/2") in diameter and 30cm (1') long

Iron pipe: slightly larger in diameter than the largest part of casing to be put in the well (usually the coupling) and 152cm (5') long

Source:

John Brelsford, VITA Volunteer, New Holland, Pennsylvania

DRIVING WELLS

A pointed strainer called a well point, properly used, can quickly and cheaply drive a sanitary well, usually less than 7.6 meters (25') deep. In soils where the driven well is suitable, it is often the cheapest and fastest way to drill a sanitary well. In heavy soils, particularly clay, drilling with an earth auger is faster than driving with a well point.

Tools and Materials

Well point and driving cap: usually obtainable from the United States for about $10, through mail order houses (see Figure 1)

Pipe: 3cm (1") in diameter

Heavy hammer and wrenches

Pipe compound

Special pipe couplings and driving arrangements are desirable but not necessary

Driven wells are highly successful in coarse sand where there are not too many rocks and the water table is within 7 meters (23') of the surface. They are usually used as shallow wells where the pump cylinder is at ground level. If conditions for driving are very good, 10cm (4") diameter points and casings that can accept the cylinder of a deep well, can be driven to depths of 10 to 15 meters (33' to 49').

The most common types of well points are:

1. a pipe with holes covered by a screen and a brass jacket with holes. For general use, a #10 slot or 60 mesh is recommended. Fine sand requires a finer screen, perhaps a #6 slot or 90 mesh;
2. a slotted steel pipe with no covering screen, which allows more water to enter but is less rugged.

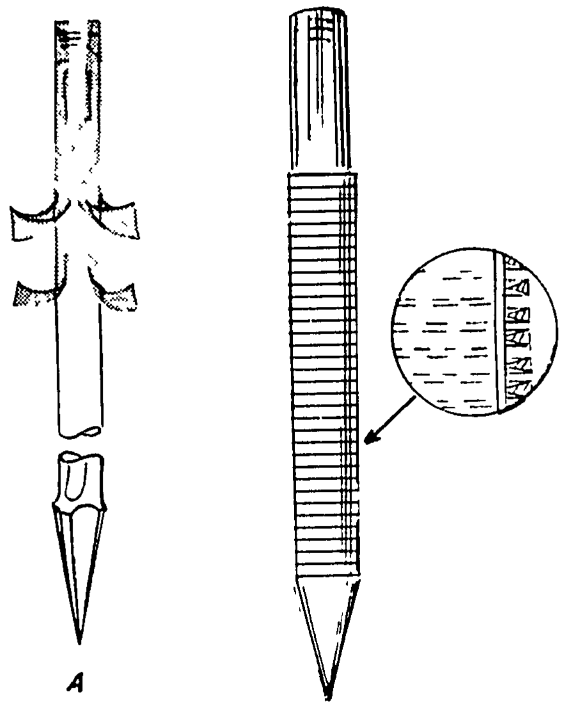


FIGURE 1

Before starting to drive the point, make a hole at the site with handtools. The hole should be plumb and should be slightly larger in diameter than the well point.

The joints must be carefully made to prevent tnread breakage and assure air-tight operation. Clean and oil the threads carefully and use joint compound and special drive couplings when available. To insure that joints stay tight, give the pipe a fraction of a turn after each blow, until the top joint is permanently set. Do not twist the whole string and do not twist and pound at the same time. The latter may help get past stones, but soon will break the threads and make leaky joints.

Be sure the drive cap is tight and butted against the end of the pipe (see Figure 2). Check with a plumb bob to see that the pipe is vertical. Test it occasionally and keep it straight by pushing on the pipe while driving. Hit the drive cap squarely each time or you may damage the equipment.

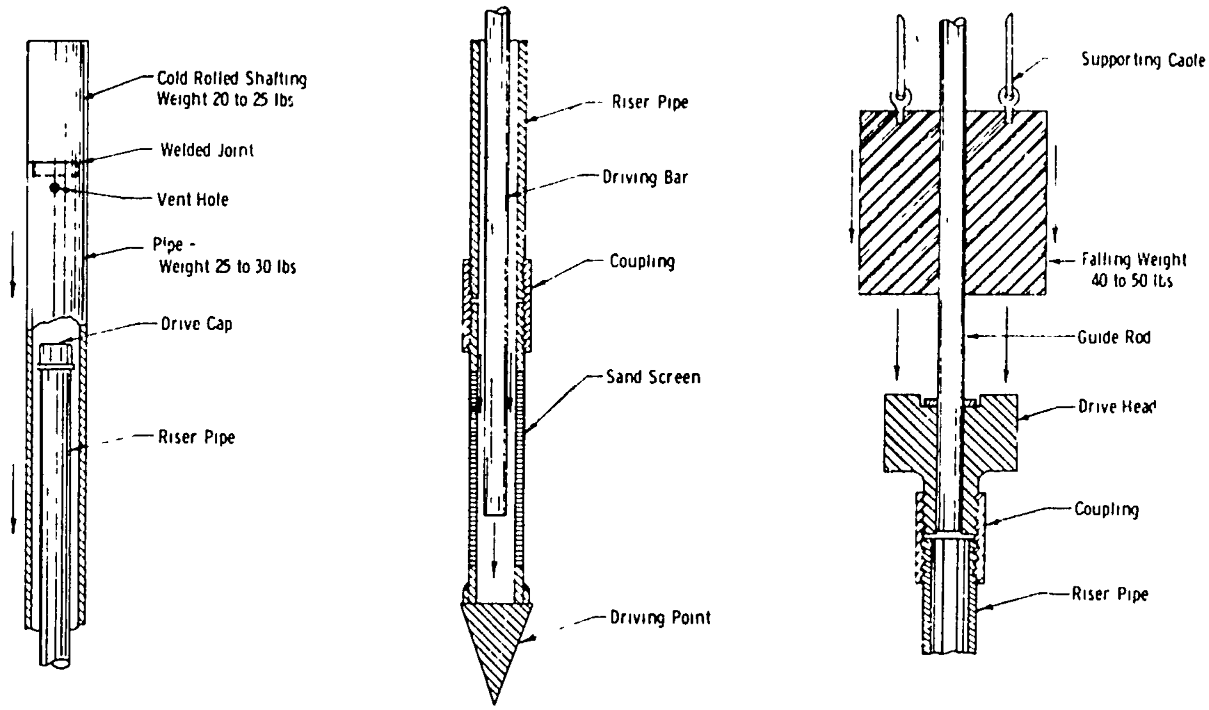


FIGURE 2

DRIVING METHODS

Several techniques can help avoid damage to the pipe. The best way is to drive with a steel bar that is dropped inside the pipe and strikes against the inside of the steel well point. It is retrieved with a cable of rope. Once water enters the well, this method does not work.

Another way is to use a driver pipe which makes sure that the drive cap is hit squarely. A guide rod can be mounted on top of the pipe and a weight dropped over it, or the pipe itself can be used to guide a falling weight which strikes a special drive-clamp (see Figure 2).

Type of formation	Driving conditions	Rate of descent	Sound of blow	Rebound	Resistance to rotation
Soft moist clay	Easy driving	Rapid	Dull	None	Slight but continuous
Tough hardened clay	Difficult driving	Slow but steady	None	Frequent rebounding	Considerable
Fine sand	Difficult driving	Varied	None	Frequent rebounding	Slight
Coarse sand	Easy driving (especially when saturated with water)	Unsteady irregular penetration for successive blows	Dull	None	Rotation is easy and accompanied by a gritty sound
Gravel	Easy driving	Unsteady irregular penetration for successive blows	Dull	None	Rotation is irregular and accompanied by a gritty sound
Boulder and rock	Almost impossible	Little or none	Loud	Sometimes of both hammer and pipe	Dependent on type of formation previously passed through by pipe

FIGURE 3

from: Wells, TM5-297/AFM 85-23, 1957
Army Technical Manual, P. 21

Figure 3 is a table which will help identify the formations being penetrated. Experience is needed...but this may help you to understand what is happening.

When you think that the water-bearing layer has been reached, stop driving and attach a handpump to try the well. Usually, easier driving shows that the water-bearing level has been reached, especially in coarse sand. If the amount of water pumped is not enough, try driving a meter or so (a few feet) more. If the flow decreases, pull the point back until the point of greatest flow is found. The point can be raised by using a lever arrangement like a fence-post jack, or, if a drive-monkey is used, by pounding the pipe back up.

Sometimes sand and silt plug up the point and the well must be 'developed' to clear this out and improve the flow. First try hard, continuous pumping at a rate faster than normal. Mud and fine sand will come up with the water, but this should clear in about an hour. It may help to allow the water in the pipe to drop back down, reversing the flow periodically. With most pitcher pumps this is easily accomplished by lifting the handle very high; this opens the check valve, allowing air to enter and the water rushes back down the well.

If this does not clear up the flow, there may be silt inside the point. This can be removed by putting a 19mm (3/4") pipe into the well and pumping on it. Either use the pitcher pump or quickly and repeatedly raise and lower the 19mm (3/4") pipe. By holding your thumb over the top of the pipe on the upstroke, a jet of muddy water will result on each downstroke. After getting most of the material out, return to direct pumping. Clean the sand from the valve and cylinder of the pump after developing the well. If you have chosen too fine a screen, it may not be possible to develop the well successfully. A properly chosen screen allows the fine material to be pumped out, leaving a bed of coarse gravel and sand that provides a highly porous and permeable water-gathering area.

The final step is to fill in the starting borehole with puddled clay or, if clay is not available, with well-tamped earth. Make a solid, waterproof pump platform (concrete is best) and provide a place for spilled water to drain away.

Source:

Water Supply for Rural Areas and Small Communities, by E. G. Wagner and J. N. Lanoix, World Health Organization, 1959.

DUG WELLS

A village well must often act as a reservoir, because at certain hours of the day the demand for water is heavy, whereas during the night and the heat of the day there is no call on the supply. What is suggested here is to make the well large enough to allow the water slowly percolating in to accumulate when the well is not in use in order to have an adequate supply when the demand on it is heavy. For this reason wells are usually made 183 to 213cm (6' to 7') in diameter.

Wells cannot store rainy season water for the dry season, and there is seldom any reason for making a well larger in diameter than 213cm (7').

The depth of a well is much more important than the diameter in determining the amount of water that can be drawn when the water level is low. A deep, narrow well will often provide more water than a wide shallow one.

Remember that tubewells are much easier to construct than a dug well, and should be used if your region allows their construction and an adequate amount of water can be drawn from a tubewell during the busy hours (see section on Tubewells).

Deep dug wells have several disadvantages. The masonry lining needed is very expensive. An open well is very easily-contaminated by organic matter which falls in from the surface and by the buckets used to lift the water. There is an added problem of disposing of the great quantity of soil removed from a deep well.

Sealed Dug Well

This well has an underground concrete tank which is connected to the surface with a casing pipe, rather than a large-diameter lining as described in the preceding entry. The advantages are that it is relatively easy to build, easy to seal, takes up only a small surface area and is low in cost.

More than 45 of these wells were installed in India by an American Friends Service Committee Team there; all performed perfectly for several years, except for one which was not dug deep enough. The total cost of an installation, excluding labor, was Rs. 230 or about U.S. $50.

Tools and Materials

4 reinforced concrete rings with iron hooks for lowering, 91.5cm (3') in diameter

1 reinforced concrete cover with a seating hole for casing pipe

Washed gravel to surround tank: 1.98 cubic meters (70 cubic feet)

Sand for top of well: 0.68 cubic meters (24 cubic feet)

Concrete pipe: 15cm (6") in diameter, to run from the top of the tank cover to at least 30.5cm (1') above ground

Concrete collars: for joints in the concrete pipe

Cement: 4.5kg (10 pounds) for mortar for pipe joints

Deep-well pump and pipe

Concrete base for pump

Tripod, pulleys, rope for lowering rings

Special tool for positioning casing when refilling, see "Positioning Casing Pipe," below

Digging tools, ladders, rope

A villager in Barpali, India, working with an American Friends Service Committee unit there suggested this radical new idea: make a masonry tank at the bottom of the well, roof it over, and draw the water from it with a pump. The resulting sealed well has many advantages:

1. It provides pure water, safe for drinking.

2. It presents no hazard of children falling in.

3. Drawing water is easy, even for small children.

4. The well occupies little space, a small courtyard can accommodate it.

5. The cost of installation is greatly reduced.

6. The labor involved is much reduced.

7. There is no problem of getting rid of excavated soil, since most of it is replaced.

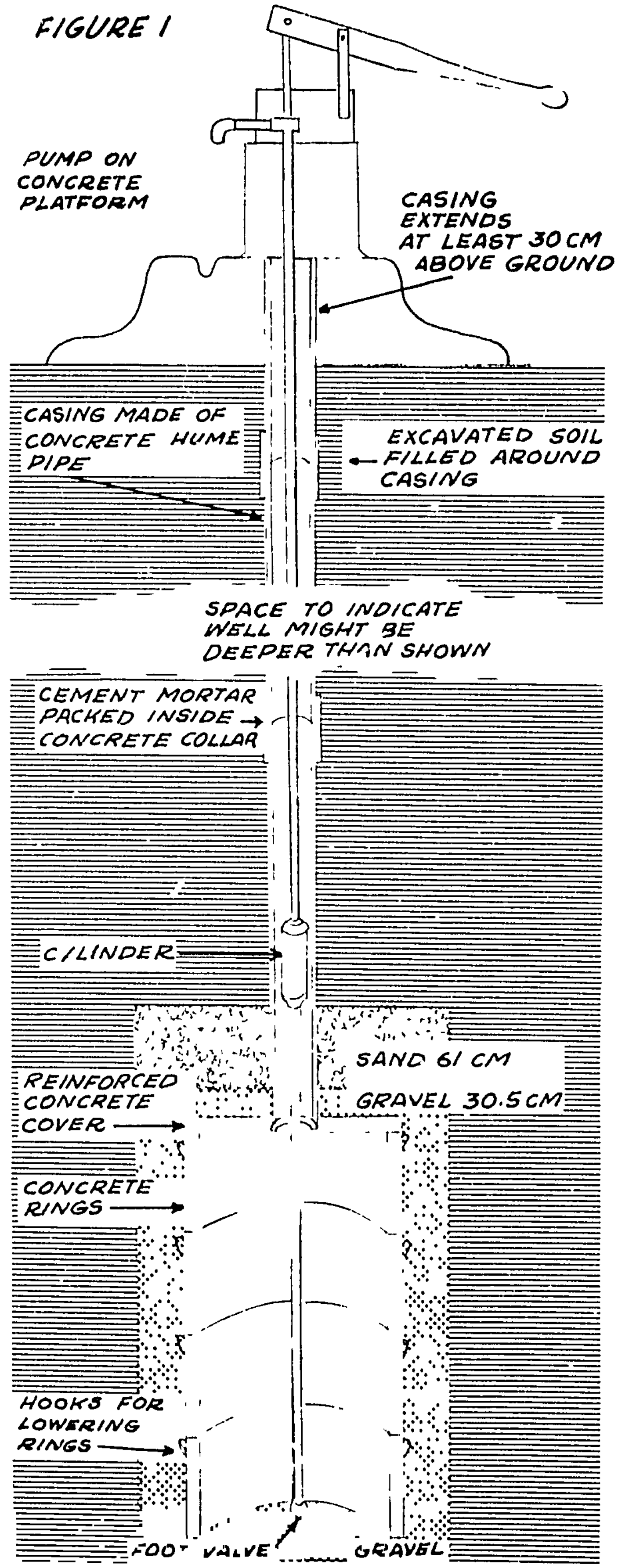
8. The casing enables the pump and pipe to be easily removed for servicing.

9. The gravel and sand surrounding the tank provide an efficient filter to prevent silting, allows a large surface area for percolating water to fill the tank, and increases the effective stored volume in the tank.

On the other hand, there are three minor disadvantages: only one person can pump at one time, the pump might go out of order, and a certain amount of technical skill is required to make the parts used in the well and to install them properly.

A well is dug 122cm (4') in diameter and about 9 meters (30') deep. The digging should be done in the dry season, after the water table has

FIGURE I



dropped to its lowest level. There should be a full 3 meter (10') re-accumulation of water within 24 hours after the well has been bailed or pumped dry. Greater depth is, of course, desirable.

Over the bottom of the well, spread 15cm (6") of clean, washed gravel or small rock. Lower the four concrete rings and cover into the well and position them there to form the tank. A tripod of strong poles with block and tackle is needed to lower the rings, because they weigh about 180kg (400 pounds) each. The tank formed by the rings and cover is 183cm (6') high and 91.5cm (3') in diameter. The cover has a round opening which forms a seat for the casing pipe and allows the suction pipe to penetrate to about 15cm (6") from the gravel bottom.

Positioning the Casing Pipe

The first section of concrete pipe is positioned in the seat and grouted (mortared) in place. It is braced vertically by a wooden plug with four hinged arms to brace against the sides of the wall. Gravel is packed around the concrete rings and over the top of the cover till the gravel layer above the tank is at least 15cm (6") deep. This is then covered with 61cm (2') of sand. Soil removed from the well is then shoveled back until filled within 15cm (6") of the top of the first section of casing. The next section of casing is then grouted in place, using a concrete collar made for this purpose. The well is filled and more sections of casing added until the casing extends at least 30cm (1') above the surrounding soil level.

The amount of soil which will not pack back into the well can be used to make a shallow hill around the casing to encourage spilled water to drain away from the pump. A concrete cover is placed on the casing and a pump installed.

If concrete or other casing pipe cannot be obtained, a chimney made of burned bricks and sand-cement mortar will suffice. The pipe is somewhat more expensive, but much easier to install.

Source:

"A Safe Economical Well," American Friends Service Committee, Philadelphia, Pennsylvania, 1956 (mimeo).

Deep Dug Well

Untrained workers can safely dig a deep, sanitary well with simple, light equipment, if they are well supervised. The basic method is outlined here.

Tools and Materials

Shovels, mattocks

Buckets

Rope--deep wells require wire rope

Forms--steel, welded and bolted together

Tower with winch and pulley

Cement

Reinforcing rod

Sand

Aggregate

Oil

The hand dug well is the most widespread of any kind of well. Unfortunately, most of these wells were dug by uninformed people and now are infected by parasitic and bacterial disease. By using modern methods and materials, dug wells can safely be made 60 meters (196.8') deep and will give a permanent source of pure water.

Experience has shown that for one man, the average width of a round well for best digging speed is 1 meter (3 1/4'). However 1.3 meters (4 1/4') is best for two men digging together and they dig more than twice as fast as one man. Thus, two men in the larger hole is usually best.

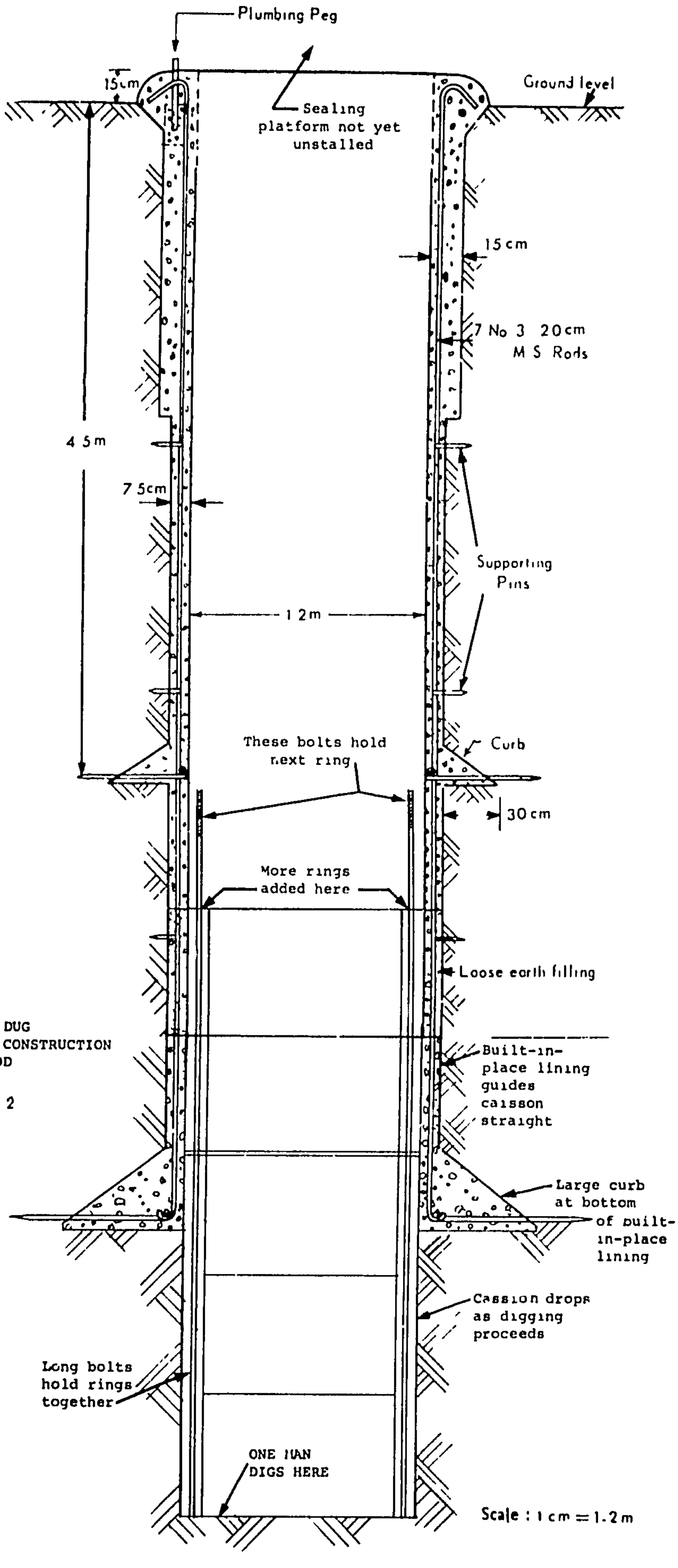
Dug wells always need a permanent lining (except in solid rock, where the best method is usually to drill a tubewell).

The lining prevents collapse of the hole, supports the pump platform, stops entrance of contaminated surface water, and supports the well intake which is the part of the well through which water enters. It is usually best to build the lining while digging, since this avoids temporary supports and reduces danger of cave-ins.

Dug wells are lined in two ways: (1) where the hole is dug and the lining is built in its permanent place and (2) where sections of lining are added to the top and the whole lining moves down as earth is removed from beneath it. The second method is called caissoning. Often a combination of both is best, as shown in Figure 2.

If possible, use concrete for the lining because it is strong, permanent, made mostly of local materials, and can be handled by unskilled workers with good speed and results. (See section on Concrete Construction).

Masonry and brickwork are widely used in many countries and can be very satisfactory if conditions are right. In bad ground, however, unequal pressures can make them bulge or collapse. Building with these materials is slow and a thicker wall is required than with concrete. There is also always the danger of movement during construction in loose sands or swelling shale before the cement has set firmly between the bricks or stones. This danger is prevented with concrete by leaving the form in place to support the lining, until the concrete is hard. Also, there may not be any skilled masons in the area; suitable stone or well-fired brick may not be readily available.



DEEP DUG
WELL CONSTRUCTION
METHOD

FIG. 2

Wood and steel are not good for lining wells. Wood requires bracing, tends to rot and hold insects; sometimes it will make the water taste badly. Worst of all, it will not make the well watertight against contamination. Steel is seldom used because it is expensive, rusts quickly and usually is subject to bulging and bending.

The general steps in finishing the first 4.6 meters (15') are:

- set up a tripod winch over cleared, level ground and reference points for plumbing and measuring the depth of the well.
- two men dig the well while another raises and unloads the dirt until the well is exactly 4.6 meters (15') deep.
- the hole is accurately trimmed to size using a special jig mounted on the reference points.
- the forms are carefully placed and filled one by one with tamped concrete.

After this is done, dig to 9.1 meters (30'), trim and line this part also with concrete. A 12.5cm (5") gap between the first and second of these sections is filled with pre-cut concrete which is grouted (mortared) in place. Each lining is self-supporting as it has a curb. The top of the first section of lining is thicker than the second section and extends above the ground to make a good foundation for the pump housing and to make a safe seal against ground water.

This method is used until the water-bearing layer is reached where an extra-deep curb is constructed. From this point on, caissoning is used.

Caissons are concrete cylinders fitted with bolts for attaching them together. They are cast and cured on the surface in special molds, prior to use. Several caissons are lowered into the well and assembled together. Then a workman digs and the caissons drop lower as earth is removed from beneath them. The concrete lining guides the caissons.

If the water table is high when the well is dug, extra caissons are bolted in place so that the well can be finished by a small amount of digging and without concrete work, during the dry season.

Evaluation

Details on plans and equipment for this process are found in Water Supply for Rural Areas and Small Communities, by E. G. Wagner and J. N. Lanoix, World Health Organization, 1959.

Source :

Water Supply for Rural Areas and Small Communities, Wagner and Lanoix.

Reconstructing Dug Wells

Open dug wells are not very sanitary, but they can often be rebuilt by relining the top 3 meters (10') with a watertight lining, digging and cleaning the well and covering it; this method is to install a buried concrete slab; see Figure 3 for construction details.

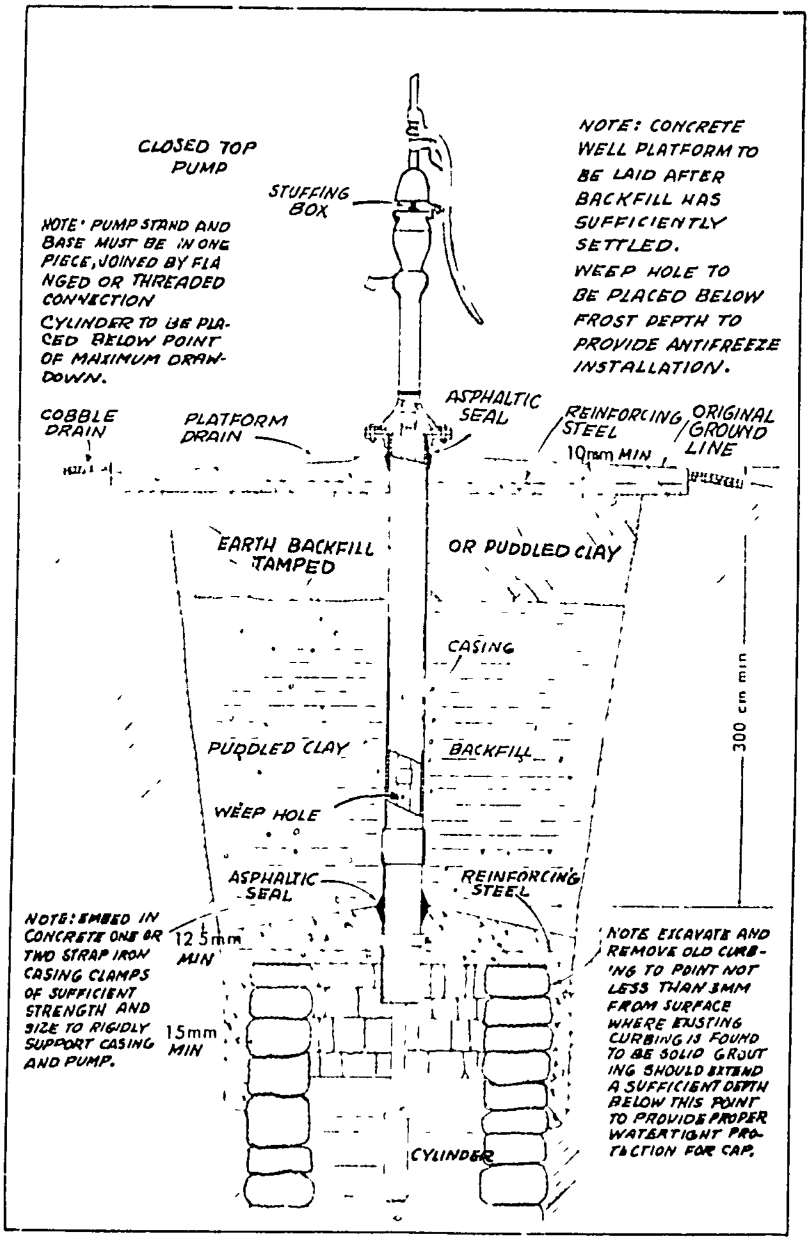
Tools and Materials

Tools and materials for reinforced concrete

A method for entering tne well

Pump and drop pipe

Fig 3



Before starting, check the following:

- Is the well dangerously close to a privy or other source of contamination? Is it close to a water source? Is it desirable to dig a new well elsewhere instead of cleaning this one? Could a privy be moved, instead?
- Has the well ever gone dry? Should you deepen it as well as clean it?
- Surface drainage should generally slope away from the well and there should be effective disposal of spilled water.
- What method will you use to remove the water and what will it cost?
- Before entering the well to inspect the old lining, check for a lack of oxygen by lowering a lantern or candle. If the flame remains lit, it is reasonably safe to enter the well. If the flame goes out, the well is dangerous to enter. When the well is entered, have a rope tied to the person and two strong men to pull him out in case of accident.

Relining the Wall

The first job is to prepare the upper 3 meters (10') of the lining for concrete by removing loose rock and chipping away old mortar with a chisel, as deep as possible (see Figure 4). The next task is to clean out and deepen the well, if that is necessary. All organic matter and silt should be bailed out. The well may be dug deeper, particularly during the dry season, with the methods outlined in the article on "Deep Dug Wells." One way to increase the water yield is to drive a well point deeper into the water-bearing soil. This normally will not raise the level of water in the well, but may make the water flow into the well faster. The well point can be piped directly to the pump, but this will not make use of the reservoir capacity of the dug well.

The material removed from the well can be used to help form a mound around the well so water will drain away from the well site. Usually, additional soil will be needed for this mound. A drain lined with rock should be provided to take spilled water away from the concrete apron that covers the well.

Reline the well with concrete troweled in place over wire mesh reinforcement. The largest aggregate should be pea-sized gravel and the mix should be fairly rich with concrete, using no more than 5 1/2 to 6 gallons of water to a 94-pound sack of cement. Extend the lining 70cm (27 1/2 inches) above the original ground surface.

Installing the Cover and Pump

Cast the well cover so that it makes a watertight seal with the lining to keep surface impurities out. The cover will also support the pump. Extend the slab out over the mound about a meter (a few feet) to help drainage away from the site. Make a manhole and space for the drop pipe of the pump. Mount the pump off center so there is room for the manhole. The pump is mounted on bolts cast into the cover. The manhole must be 10cm (4") higher than the surface of the slab. The manhole cover must overlap by 5cm (2") and should be fitted with a lock to prevent accidents and contamination. Be sure that the pump is sealed to the slab.

Disinfecting the Well

Disinfect the well by using a stiff brush to wash the walls with a very strong solution of chlorine. Then add enough chlorine in the well to make it about half the strength of the solution used on the walls. Sprinkle this last solution all over the surface of the well to distribute it

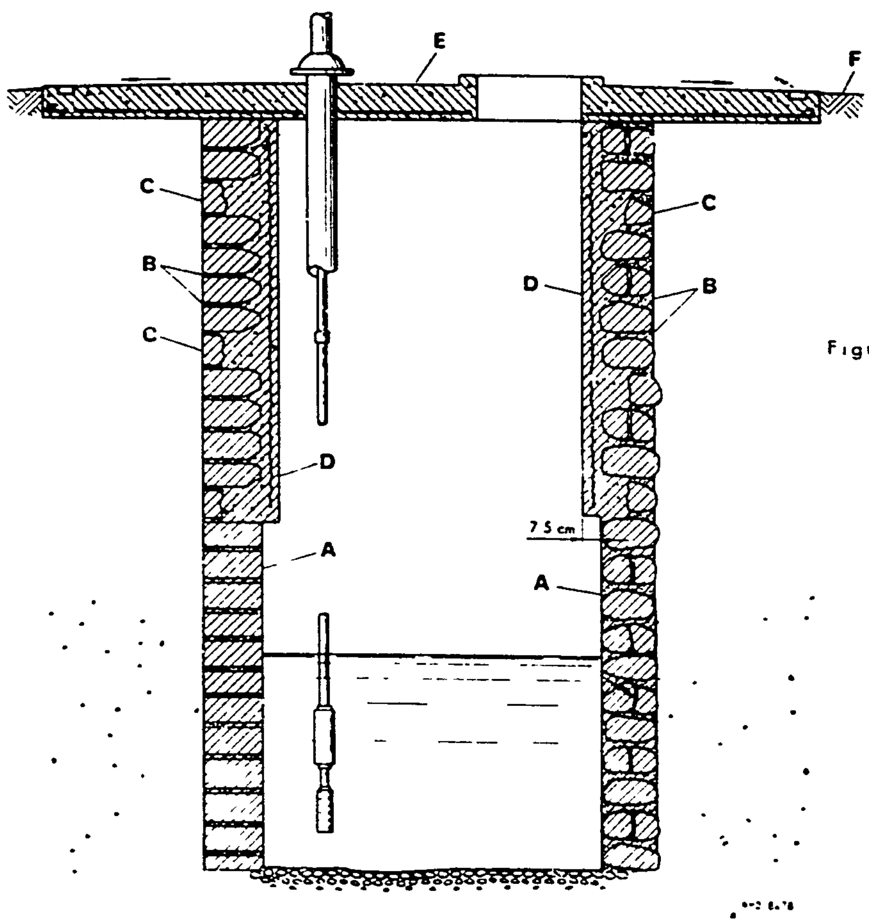
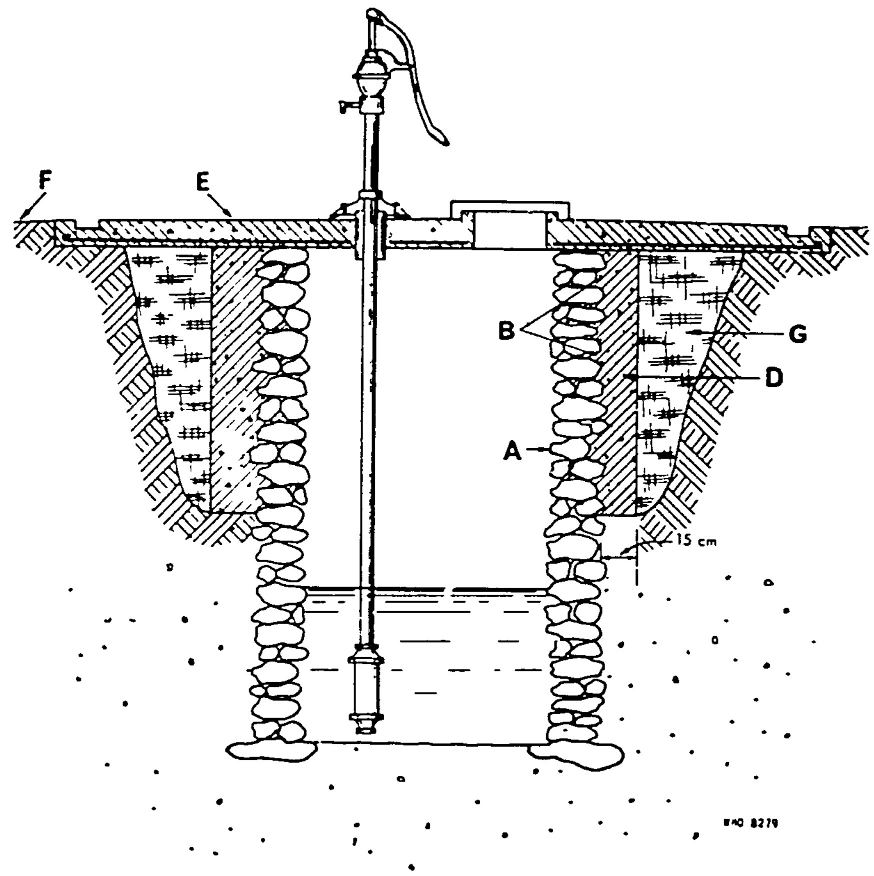


Figure 4



A = Existing masonry or brick walls with cracked mortar joints
B = Old mortar removed with chisel as far back as possible
C = Stone or bricks dug out to provide key for new concrete lining
D = New concrete lining, built to a depth of at least 3 m (10 ft) below outside ground level, or to low water level in well For concrete use pea-sized gravel and wire-mesh for temperature reinforcement
E = New concrete well top incorporating sanitary features (manhole with raised edges slope for proper drainage proper pump installation etc)
F = Outside ground level (adequate drainage being provided for excess water or surface run-off)
G = Backfill with clay, well tamped in layers 15 cm (6 in) thick

evenly. Cover the well and pump up the water until the water smells strongly of chlorine. Let the chlorine remain in the pump and well for one day and then pump it until the chlorine is gone.

Testing the Water

Have the well water tested several days after disinfection to be sure that it is pure. If it is not, repeat the disinfection and testing. If it is still not pure, get expert advice.

Sources:

Water Supply for Rural Areas and Small Communities, by E. G. Wagner and J. N. Lanoix, World Health Organization, 1959.

Manual of Individual Water Supply Systems, U.S. Department of Health, Education and Welfare, Public Health Service Publication No. 24.

APPENDIX

Simple methods are given here for converting English and metric units of measurement. Following these is a series of useful conversion tables for units of area, volume, weight, pressure and power.

LENGTH CONVERSION

The chart in Figure 3 is useful for quick conversion from meters and centimeters to feet and inches, or vice versa. For more accurate results and for distances greater than 3 meters, use either the tables in Figure 2 or the equations.

The chart in Figure 3 has metric divisions of one centimeter to three meters, and English units in inches and feet to ten feet. It is accurate to about plus or minus one centimeter.

Example:

An example will explain how to use the tables. Suppose you wish to find how many inches are equal to 66cm. On the "Centimeters into Inches" table look down the leftmost column to 60cm and then right to the column headed 6cm. This gives the result, 25.984 inches.

FIGURE 1

Equations:

1 inch = 2.54cm
1 foot = 30.48cm
= 0.3048m
1 yard = 91.44cm
= 0.9144m
1 mile = 1.607km
= 5280 feet
1cm = 0.3937 inches
1m = 39.37 inches
= 3.28 feet
1km = 0.62137 miles
= 1000 meters

FIGURE 2

INCHES INTO CENTIMETERS
(1 in. = 2.539977 cm)

inches	0	1	2	3	4	5	6	7	8	9
0	cm	2 54	5	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 86
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

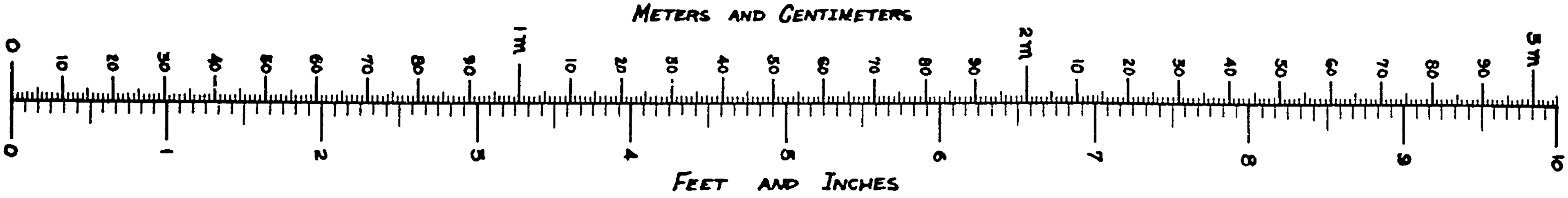


FIGURE 3

WEIGHT CONVERSION

The chart in Figure 5 converts pounds and ounces to kilograms and grams or vice versa. For weights greater than ten pounds, or more accurate results, use the tables (Figure 4) or conversion equations. See "Length Conversion," Figure 2, for an example of the use of the tables.

On the chart, notice that there are sixteen divisions for each pound to represent ounces. There are 100 divisions only in the first kilogram, and each division represents ten grams. The chart is accurate to about plus or minus twenty grams.

<u>Equations</u>:

1 ounce = 28.35 grams
1 pound = 0.4536 kilograms
1 gram = 0.03527 ounce
1 gram = 2.205 pounds

FIGURE 4

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	[illegible] 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

FIGURE 5

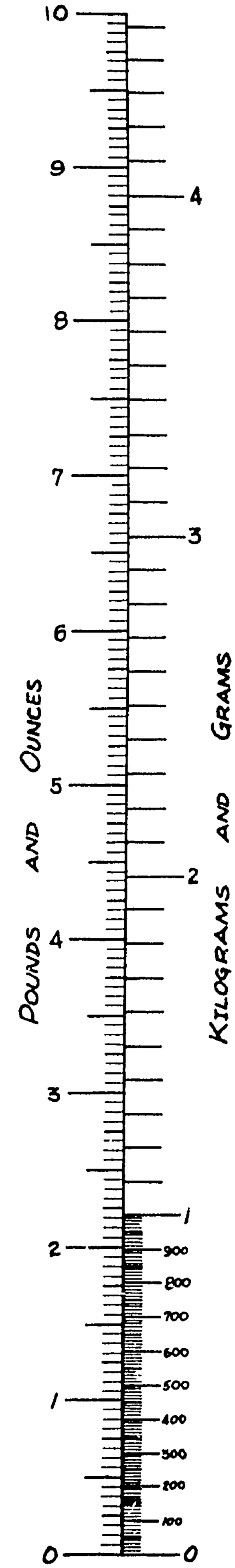
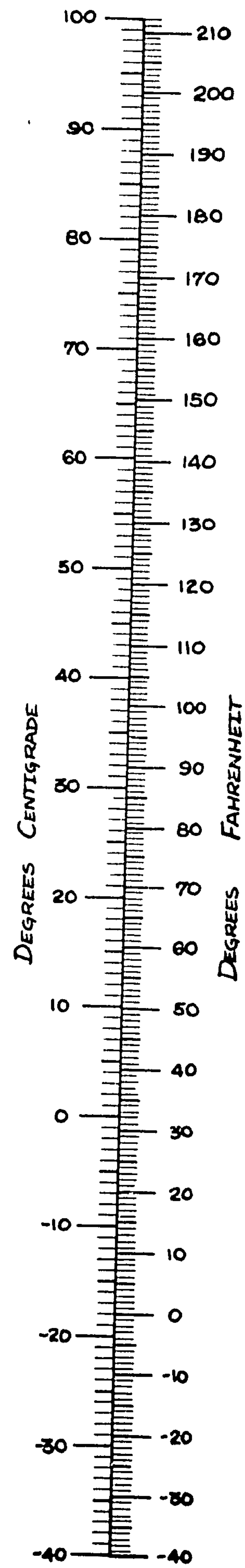


FIGURE 1



TEMPERATURE CONVERSION

The chart in Figure 1 is useful for quick conversion from degrees Celsius (Centigrade) to degrees Fahrenheit and vice versa. Although the chart is fast and handy, you must use the equations below if your answer must be accurate to within one degree.

Equations:

Degrees Celsius = 5/9 x (Degrees Fahrenheit -32)

Degrees Fahrenheit = 1.8 x (Degrees Celsius) +32

Example:

This example may help to clarify the use of the equations; 72F equals how many degrees Celsius?

72F = 5/9 (Degrees F -32)

72F = 5/9 (72 -32)

72F = 5/9 (40)

72F = 22.2C

Notice that the chart reads 22C, an error of about 0.2C.

Conversion Tables

Units of Area

1 Square Mile	= 640 Acres	= 2.5899 Square Kilometers
1 Square Kilometer	= 1,000,000 Square Meters	= 0.3861 Square Mile
1 Acre	= 43,560 Square Feet	
1 Square Foot	= 144 Square Inches	= 0.0929 Square Meter
1 Square Inch	= 6.452 Square Centimeters	
1 Square Meter	= 10.764 Square Feet	
1 Square Centimeter	= 0.155 Square Inch	

Units of Volume

1.0 Cubic Foot	= 1728 Cubic Inches	= 7.48 U.S. Gallons
1.0 British Imperial Gallon = 1.2 U.S. Gallons		
1.0 Cubic Meter	= 35.314 Cubic Feet	= 264.2 U.S. Gallons
1.0 Liter	= 1000 Cubic Centimeters	= 0.2642 U.S. Gallons

Units of Weight

1.0 Metric Ton	= 1000 Kilograms	= 2204.6 Pounds
1.0 Kilogram	= 1000 Grams	= 2.2046 Pounds
1.0 Short Ton	= 2000 Pounds	

Conversion Tables

Units of Pressure

1.0 Pound per square inch	= 144 Pounds per square foot
1.0 Pound per square inch	= 27.7 Inches of Water*
1.0 Pound per square inch	= 2.31 Feet of Water*
1.0 Pound per square inch	= 2.042 Inches of Mercury*
1.0 Atmosphere	= 14.7 Pounds per square inch (PSI)
1.0 Atmosphere	= 33.95 Feet of Water
1.0 Foot of Water = 0.433 PSI	= 62.355 Pounds per square foot
1.0 Kilogram per square centimeter	= 14.223 Pounds per square inch
1.0 Pound per square inch	= 0.0703 Kilogram per square centimeter

* at 62 degrees Fahrenheit (16.6 degrees Celsius)

Units of Power

1.0 Horsepower (English)	= 746 Watts = 0.746 Kilowatt (KW)
1.0 Horsepower (English)	= 550 Foot Pounds per second
1.0 Horsepower (English)	= 33,000 Foot Pounds per minute
1.0 Kilowatt (KW) = 1000 Watts	= 1.34 Horsepower (HP) English
1.0 Horsepower (English)	= 1.0139 Metric Horsepower (cheval-vapeur)
1.0 Metric Horsepower	= 75 Meters X Kilogram/Second
1.0 Metric Horsepower	= 0.736 Kilowatt = 736 Watts