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Village
Technology
Handbook


Volunteers in Technical Assistance
1815 North Lynn Street
Arlington, Virginia 22209 USA


Village Technology Handbook
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(This is the third edition of a manual first published in 1963, with the support
of
the U. S. Agency for International Development, and revised in 1970, which has
gone through eight major printings.)
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Manufactured in the United States of America.

Set in Times Roman type on an IBM personal computer, a gift to VITA from International Business Machines Corporation, using WordPerfect software donated by WordPerfect Corporation.

Village Technology Handbook

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Foreword

The Village Technology Handbook has been an important tool for development
workers and do-it-yourselfers for 25 years. First published in 1963 under the
auspices of the U.S. Agency for International Development, the Handbook has
gone through eight major printings. Versions in French and Spanish, as well as
English, are on shelves in bookstores, on desks in government offices and local
organizations, in school libraries and technical centers, and in the field kits
of
village workers around the world. The technologies it contains, like the chain
and
washer pump, the evaporative food cooler, and the hay box cooker, have been
built for technology fairs and demonstration centers throughout the developing
world-and more importantly, have been adopted and adapted by people everywhere.

Because the Handbook has been a faithful friend for so long, this revision was approached with care. As even the best of friendships needs an occasional reassessment, our question was how to update the book without damaging its fundamental utility-to avoid throwing the baby out with the bath water.

We began by circulating sections of the book to VITA Volunteers with expertise in the various technical areas. We asked them to take a good hard look at what was presented and let us know what should be revised, updated, discarded, replaced. The volunteers' replies affirmed what tens of thousands of users around
the world have recognized over the years, that the basic material was sound. Where they suggested changes, additions, and deletions, we have done our best to oblige.

Concurrently, we reviewed the comments that many of those users have sent to us over the years. Comments on what worked, what caused trouble, and what would be nice to have included. With so much going on in the development of small-scale, village technologies, the latter category was extensive. But because so
much of the original book is still very applicable today, we opted to make the additions and changes selectively. We made the decision to add to this volume where it seemed most feasible, and to begin to compile a companion volume that will cover a selection of those other technologies.

Since the Handbook is primarily intended for "do-it-yourselfers" in villages and rural regions, most space still is allocated to the development of water resources
and to agriculture. And rather than simply replacing everything and starting

over,
this new edition reorganizes some sections, updates several of the original
articles, and includes a number of new ones on frequently requested topics. The
new articles cover energy efficient stoves, the use of wind power to pump water,
stabilized earth construction, a novel ceramics kiln, small-scale candle and
paper
production, high yield gardening, oral rehydration therapy, and malaria control.
An
all-new reference section is also provided.

VITA is committed to assisting sustainable growth: that is, to progress, based
on
expressed needs, that increases self reliance. Access to clearly presented
technical
information is a key to such growth. VITA searches out, develops, and
disseminates
techniques and devices that contribute to self suffiency. The Village
Technology Handbook is one such VITA effort to support sustainable growth with
easy to read technical information for the communities of the world.

VITA Volunteers are similarly committed to helping VITA help others, and many
of them were involved in this project, reviewing material in their technical
fields.
VITA wishes to thank Robert M. Ross and David C. Neubert for reviewing the
sections on agriculture; Phil D. Weinert, Charles G. Burney, Walter Lawrence,
and
Steven Schaefer, water resources and purification; Malcolm C. Bourne and Norman
M. Spain, food processing and preservation; Dwight R. Brown and William
Perenchio,

construction; Charles D. Spangler, sanitation; Jeff Wartluft, Mark Hadley, Marietta Ellis, Gerald Kinsman, and Peter Zweig, home improvement; Dwight Brown and Victor Palmeri, crafts and village industries; and Grant Rykken, communications.

Most especially, we would like to thank VITA Volunteer engineer and literacy specialist Len Doak, who was coaxed out of retirement and away from the fishing docks to coordinate the revision, sort out the comments, and pull the new pieces together.

VITA staff who were involved included Suzanne Brooks, administrative support and graphics; Julie Berman, administrative support; Margaret Crouch, editorial; and Maria Garth, typesetting.

And finally, this effort has given all of us a new respect for Dan Johnson, one of
VITA's "founding fathers" and currently a member of the Board of Directors, who devoted a year of his life to putting the original Handbook together a quarter of
a century ago. That so much of that work has stood the test of time is due in no small measure to the care with which he and the other VITA Volunteers who worked with him approached their task.

--VITA Publications
January 1988

Notes on Using the Handbook

INTRODUCTION

The Village Technology Handbook contains eight major subject sections, each containing
several articles. The articles cover both the broad topic areas such as
agriculture, as well as specific agricultural projects such as building a
scraper.

If you are planning an entirely new project you would benefit by reading the entire
section through. If you are planning a specific project (such as building a
wind-driven water pump) only that article need be read.

The skills needed for each of the projects described vary considerably, but none
of the projects requires more than the usual construction and trade skills such as
carpentry, welding, or farming that are generally found in most modest sized
villages.

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

If you need translations of articles from the Handbook, we ask that you let us
know. The book itself has been translated into English, French, and Spanish, and
some individual articles may be available in other languages.

The articles in the Handbook came from many sources. Your comments and suggestions

for changes, difficulties with any of the projects described, or ideas for
new articles are welcome. Those kinds of comments were a very important element
in preparing this revised edition, and we expect to rely on them in the
future as well. Please send your comments so that we may continue to share.

SUMMARY OF THE HANDBOOK BY SECTION

Section 1. Water

Water resources are so vital that extensive coverage is provided. Much of this
material is from the original, but it has been reorganized and updated. The
sequence of articles begins with principles of hydrology that explain where
underground water is likely to be found. This is followed by articles on types
of
wells and how to make well drilling tools and how to drill or dig the wells.

Next come articles on practical methods to lift water from wells and to
transport
it. Articles on several pumps and water piping occur here. A new article on
wind-driven
pumps is in this section. A number of charts and tables help in the
calculation of pipe size and water flow.

Water storage and purification are the topics of the next series of articles.
This
section is unchanged from the earlier edition, but several new references are
fisted.

Section 2. Health and Sanitation

Next to pure water, sanitation is one of the most critical health needs of any
society. This section begins with two brief articles on the principles for
disposal
of human waste. These are followed by details of how to build various types of
latrines. Also included is an article on bilharziasis (schistosomiasis) and a
new
articles on malaria control and oral rehydration therapy.

Section 3. Agriculture

Seven topics are covered, beginning with earth moving devices to level fields
and
build irrigation ditches. This is followed by directions for an irrigation
system
based on concrete tile, including how to make the tile in the field. A variety
of
material on raising poultry is included, and a new article on small, high yield
gardens has been added.

Section 4. Food Processing and Preservation

The articles in this section describe storage and handling of different types of
food, evaporative coolers and other cold storage technologies, and a variety of
other storage and processing systems and devices. The section has been revised
and updated and new references have been added.

Section 5. Construction

Much of this section deals with construction of buildings and walls using concrete
or bamboo. A new article on stabilized earth construction has been added, and instructions for making glues to use in construction are also included.

Section 6. Home Improvements

Washing clothes, cooking, making soap, and making bedding are covered here. An important new addition is an article on the construction of an energy efficient cookstove developed in West Africa. The stove has shown more than double the fuel efficiency of the traditional open fire.

Section 7. Crafts and Village Industry

Traditional crafts that lend themselves to development as small businesses are discussed in this section--pottery, hand papermaking, and candle making. Ceramic kilns described include an alternative kiln design fueled by waste motor oil.

Section 8. Communications

This section remains unchanged from the original on the premise that while changes, in communications could actually fill volumes on their own, there are many places in developing areas where the simple technologies presented here are still quite useful. Simple writing instruments and silk screen printing are discussed.
The skills and materials described should be available in most rural villages.

SOURCES OF ADDITIONAL INFORMATION

Each article in the Handbook concludes with one or more source references. These
and other sources of information have been compiled into the new expanded
Reference section at the back of the book. VITA publications that are listed may
be ordered directly from VITA Publications, Post Office Box 12028, Arlington,
Virginia 22204 USA.

You may also request technical assistance from VITA Volunteer experts by writing
to VITA, 1815 North Lynn Street, Suite 200, Arlington, Virginia 22209 USA.

About VITA

Volunteers in Technical Assistance (VITA) is a private, nonprofit, international
development organization. It makes available to individuals and groups in
developing
countries a variety of information and technical resources aimed at fostering
self sufficiency--needs assessment and program development support; by-mail and
on-site consulting services; information systems training; and management of
long-term
field projects.

Throughout its history, VITA has concentrated on practical and workable
technologies
for development. It has collected, organized, tested, synthesized, and
disseminated information on these technologies to more than 70,000 requesters
and
hundreds of organizations in the developing countries. As the information
revolution
dawned, VITA found itself in a leadership position in the effort to bring the

benefits of that revolution to those in the Third World who are traditionally passed over in the development process.

Perhaps of greatest significance is VITA's emphasis on technologies that are commercially viable. These have the potential of creating new wealth through adding value to local materials, thereby creating jobs and increasing income as well as strengthening the private sector. We have increasingly translated our experiences in information management to the implementation of projects in the field. This evolution from information to implementation to create jobs, businesses,
and new wealth is what VITA is really about. It provides missing links without creating dependency.

VITA places special emphasis on the areas of agriculture and food processing, renewable energy applications, water supply and sanitation, housing and construction,
and small business development. VITA's activities are facilitated by the active involvement of thousands of VITA Volunteer technical experts from around the world, and by its documentation center containing specialized technical material of interest to people in developing countries.

VITA currently publishes over 150 technical manuals, papers, and bulletins, many available in French and Spanish as well as English. Manuals deal with construction
or implementation details for such specific topics as windmills, reforestation, water wheels, and rabbit raising. In addition, VITA Technical Bulletins present plans and case studies of specific technologies to encourage further experimentation
and testing. The technical papers-"Understanding Technology"-offer general

introductions to the applications and necessary resources for technologies or
technical systems. Included in the series are topics that range from composting
to
Stirling engines, from sanitation at the community level to tropical root crops.
Publications catalogues are available upon request.

VITA News is a quarterly magazine that provides an important communications
link among far-flung organizations involved in technology transfer and
adaptation.
The News contains articles about projects, issues, and organizations around the
world, reviews of new books, technical abstracts, and a resources bulletin
board.

VITA derives its income from government, foundation, and corporate grants; fees
for services; contracts; and individual contributions.

For further information write to VITA, 1815 North Lynn Street, Suite 200,
Arlington, Virginia 22209 USA.

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
l/pm . . . 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
```

Water Resources
<see image>

Developing Water Sources

There are three main sources of water for small water-supply systems: ground water, surface water, and rainwater. The choice of the source of water depends on local circumstances and the availability of resources to develop the water source.

A study of the local area should be made to determine which source is best for

providing water that is (1) safe and wholesome, (2) easily available, and (3) sufficient in quantity. The entries that follow describe the methods for tapping ground water:

o Tubewells
- Well Casings and Platforms
- Hand-Operated Drilling Equipment
- Driven Wells

o Dug Wells
o Spring Development

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 the major sections that follow:

o Water Lifting and Transport
o Water Storage and Treatment

GETTING GROUND WATER FROM WELLS & SPRINGS

This section defines ground water, discusses its occurrence, and explains its movement. It describes how to decide on the best site for a well, taking into consideration the nearness to surface water, topography, sediment type, and nearness to pollutants. It also discusses briefly the process of capping and sealing
the well and developing the well to assure maximum flow of water.

Ground Water

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
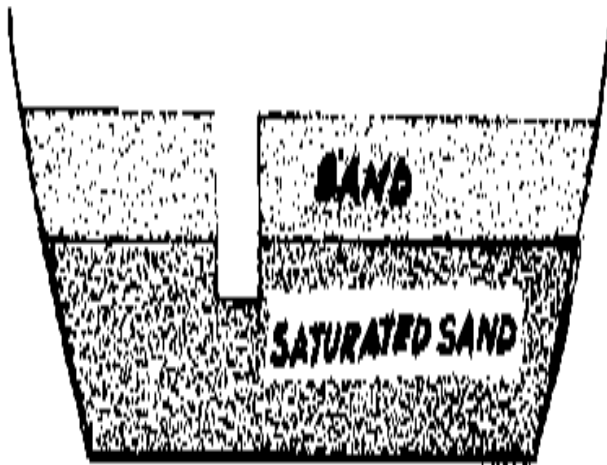through

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FIGURE 1

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 water table; 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 use 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 provided by
precipitation (rain and snow) and 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

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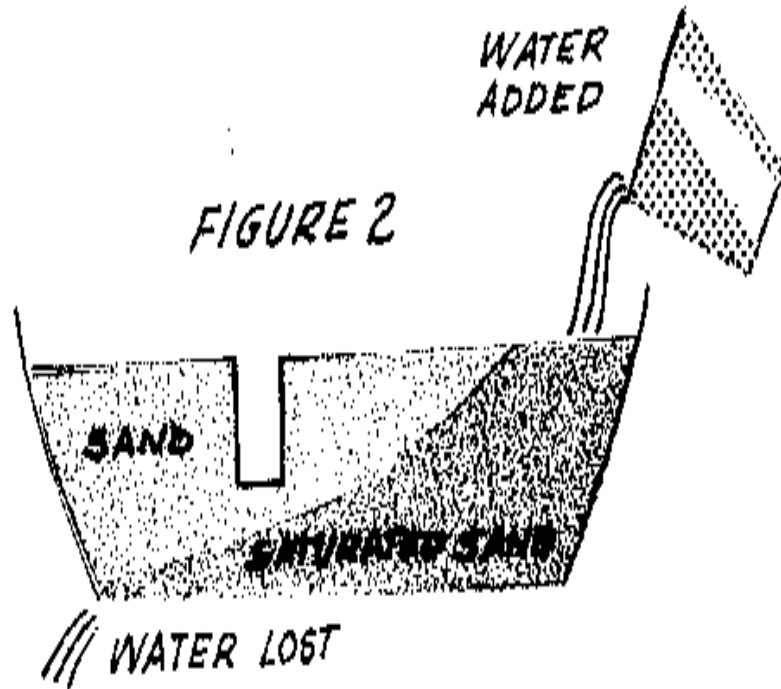
balanced by the water discharging out of the bowl at the lower elevation (analogous
to discharge into a stream).
This movement of ground water is
slow, generally just centimeters or
inches per day.

When the water table intersects the land surface, springs or swamps are formed (see Figure 3). During a
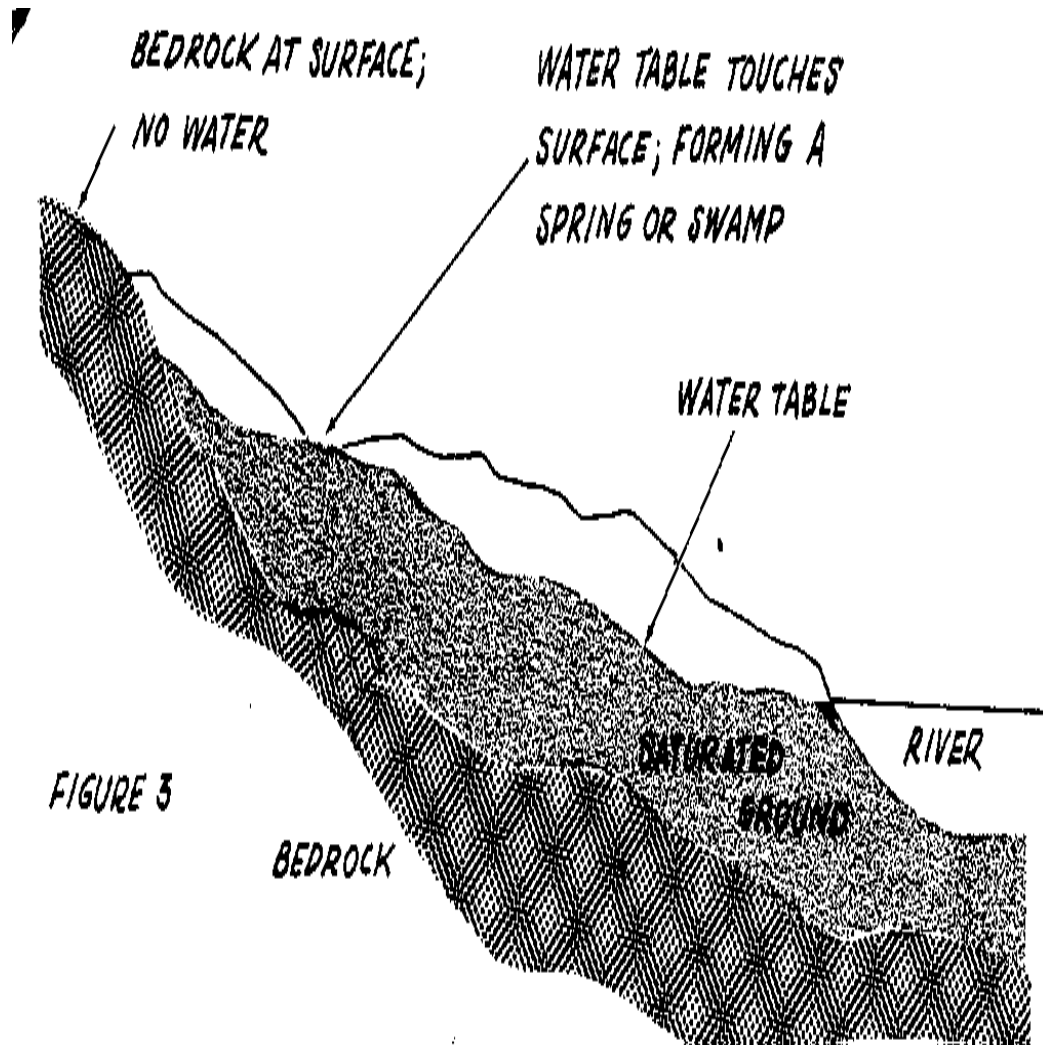
fig3pg5.gif (486x486)

BEDROCK AT SURFACE;
NO WATER

WATER TABLE TOUCHES
SURFACE; FORMING A
SPRING OR SWAMP

WATER TABLE

RIVER

SATURATED
GROUND

FIGURE 3

BEDROCK

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).

fig4pg5.gif (486x486)

ORIGINAL WATER TABLE

THE CONE OF DEPRESSION.
IT'S EXACT SHAPE DEPENDS
ON THE RATE OF PUMPING
AND THE POROSITY OF THE
SEDIMENTS, THE EXTENT OF
THE SEDIMENTS AND NEAR-
NESS TO A RIVER OR LAKE.

DRAWDOWN IN A PUMPED WELL
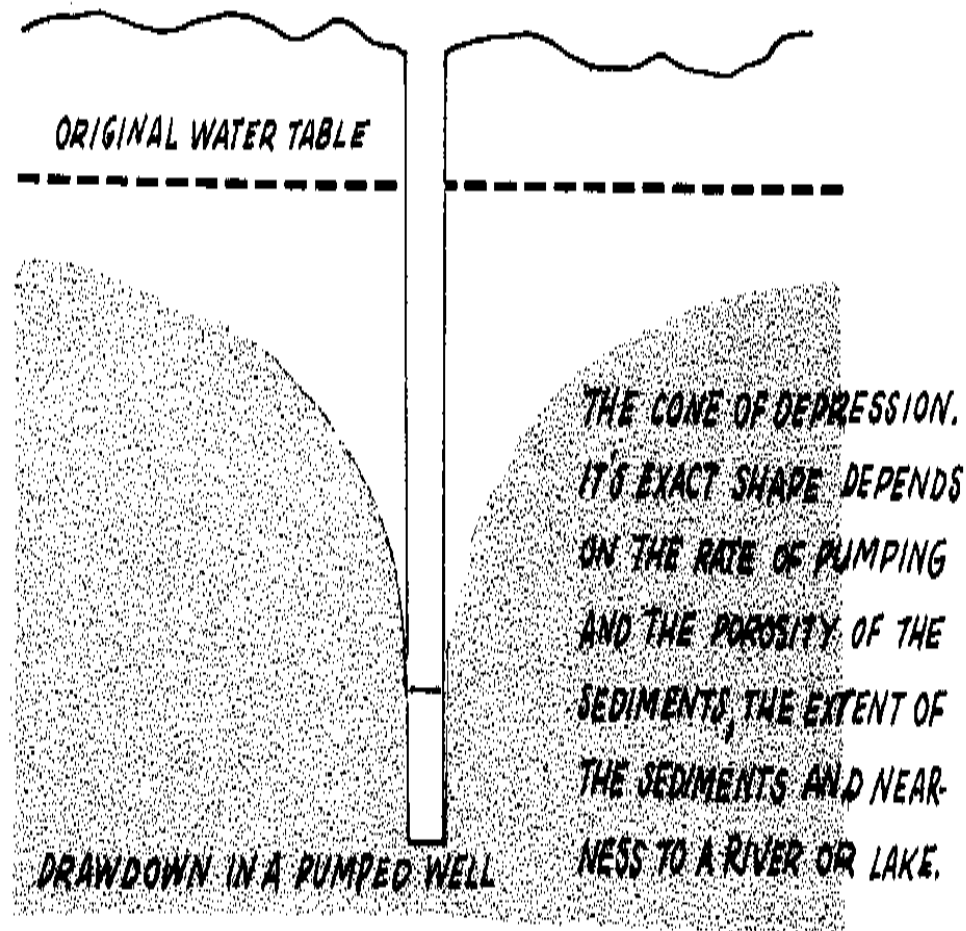
FIGURE 4

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 the water that 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. 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.

Where to Dig a Well

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

o Nearness to Surface Water
o Topography
o Sediment Type
o Nearness to Pollutants

Nearness to Surface Water

If there is surface water nearby, such as a lake or a river, locate the well as
near to 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 (see Figure 5). The

fig5pg6.gif (540x540)

A. NATURAL CONDITIONS

FIGURE 5

B. SALT INTRUSION CAUSED BY PUMPED WELL.
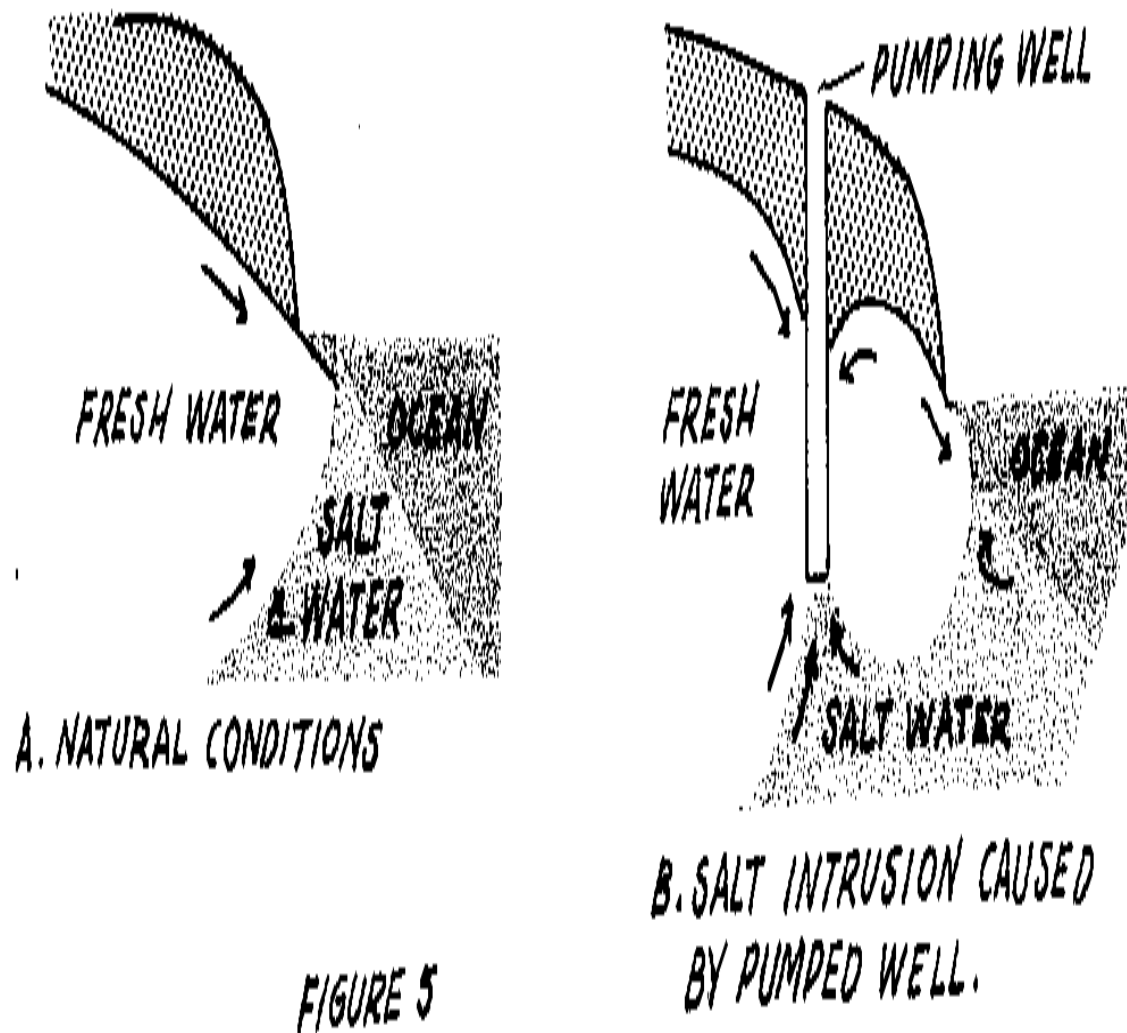
underground boundary between fresh and salt water generally slopes inland: Because salt water is heavier than fresh water, it flows in under it. If a well near the shore is used heavily, salt water may come into the well as shown. This should not occur in wells from which only a moderate amount of water is drawn.

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.

Sediment Type

Ground water occurs in porous or fractured rocks or 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

fig6pg8.gif (540x540)

FIGURE 6: Availability of Ground Water in Water Bearing Sediments or Rock Types
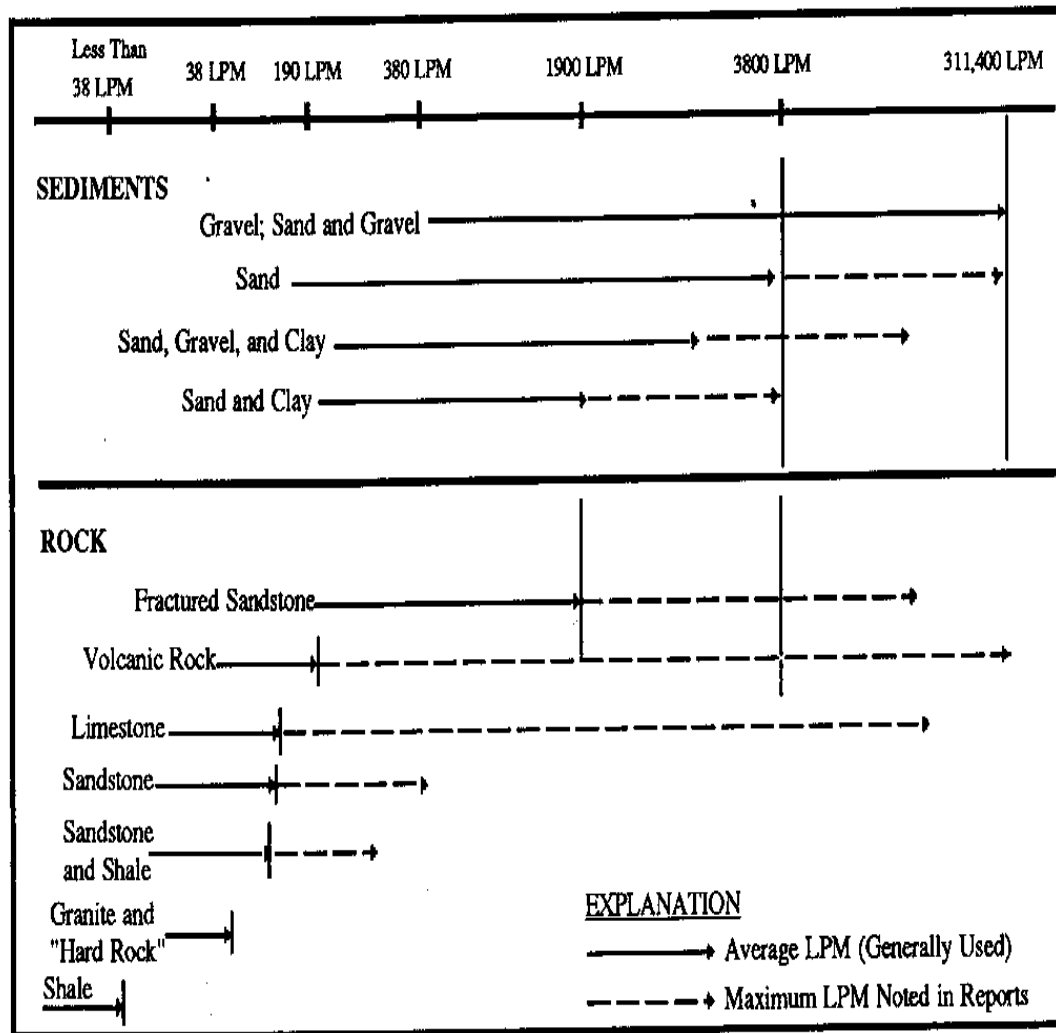
ground water (expressed by typical well discharges) and geologic material (sediments
and various rock types). For planning the well discharge necessary for
irrigating crops, a good rule of thumb for semi-arid climates-37.5cm (15") of
precipitation a year-is a 1500- to 1900-liters (400 to 500 U.S. gallons)-per-

minute
well that will irrigate about 65 hectares (160 acres) for about six 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.

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 and 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

fig7pg90.gif (540x540)

SHALLOW BODY OF POLLUTED WATER

DEEPER BODY OF PURE WATER

CASING TO KEEP OUT POLLUTED WATER

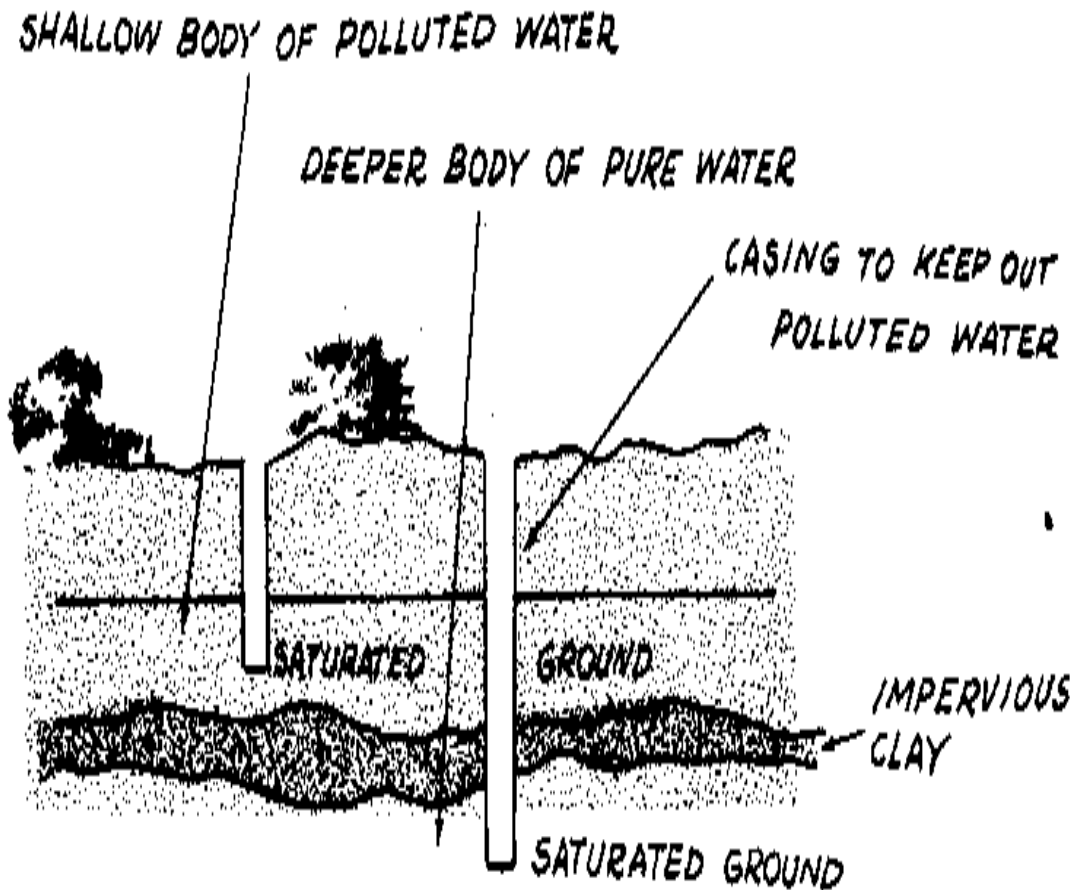SATURATED GROUND

IMPERVIOUS CLAY

SATURATED GROUND

FIGURE 7

how deep to dig wells.

Aquifers (water bearing sediments) of Sand and Gravel. Generally yield 11,400 LPM (300 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 and gpm) if thin and poorly fractured or interbedded with clay or
shale).
Aquifers of Limestone. Generally yield between 38 LPM (10gpm) but have been
known to yield more than 3800 LPM (1000 gpm) due to caverns or nearness
of stream, etc.
Aquifers of Granite and/or "Hard Rock." Generally yield 38 gpm (10gpm) and may
yield less (enough for a small household).
Aquifers of Shale. Yield less than 38 LPM (10gpm), not much good for anything
except as a last resort.

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 the Overview to the Sanitary Latrines section, p. 149. 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 and providing good drainage around the well cover.

Well Casing and Seal

The purpose of casing and seating 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 soil to form a slight hill that will help drain away spilled water and rain water.

Casing is the term for the pipe, concrete or grout ring, or other material that supports the well wall. It is usually impermeable in the upper part of the well to

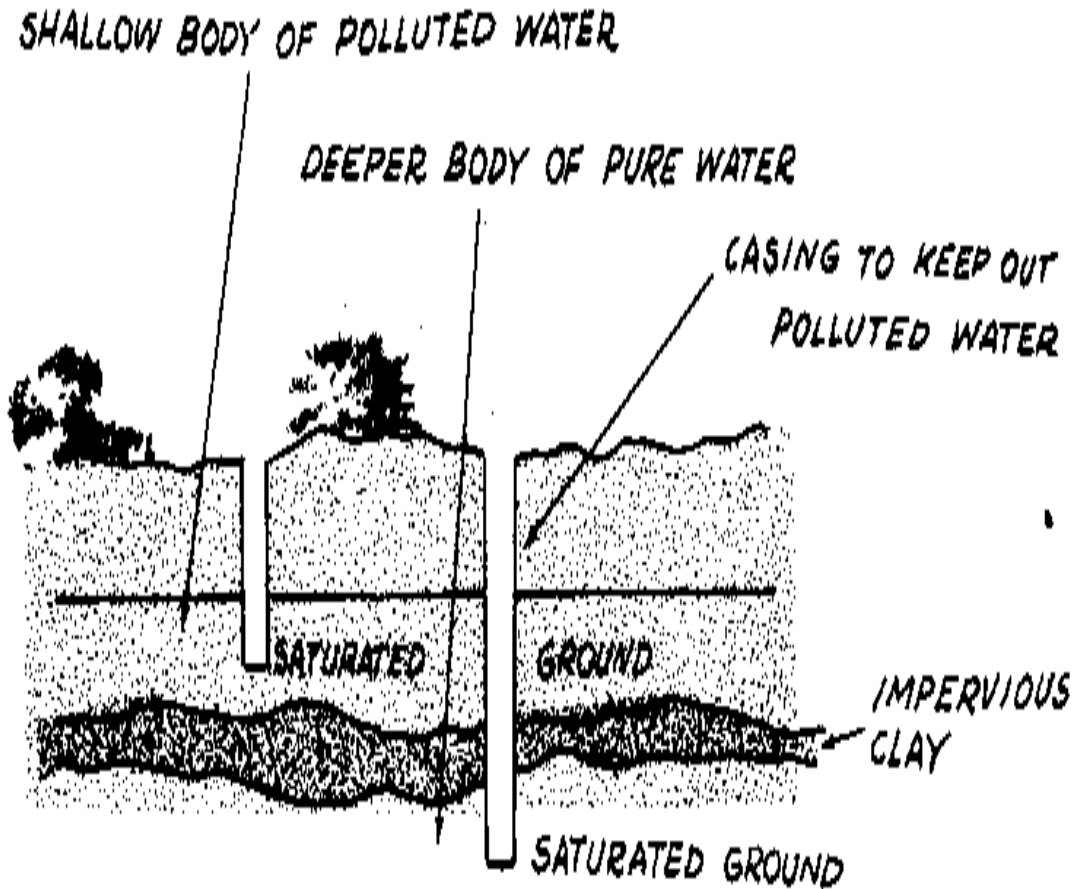**keep out polluted water (see Figure 7) and may be perforated or absent in the**

fig7pg9.gif (540x540)

SHALLOW BODY OF POLLUTED WATER

DEEPER BODY OF PURE WATER

CASING TO KEEP OUT POLLUTED WATER

SATURATED GROUND

IMPERVIOUS CLAY

SATURATED GROUND

FIGURE 7

lower part of the well to let water enter. See also "Well Casing and Platforms,"
p.
12, and "Reconstructing Dug Wells," p. 57.

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

Sources:

Anderson, K.E. Water Well Handbook. Rolla, Missouri: Missouri Water Wells Drillers Association, 1965.

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

Davis, S.N. and DeWiest, R.J.M. Hydrogeology. New York: Wiley & Sons, 1966.

Todd, D.K. Ground Water Hydrology. New York: Wiley & Sons, 1959.

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

Ground Water and Wells. Saint Paul, Minnesota: Edward E. Johnson, Inc., 1966.

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U.S. Army. Wells. Technical Manual 5-297. Washington, D.C.: U.S. Government Printing Office, 1957.

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 lane group, but they would be big enough for a family
of 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 that 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.
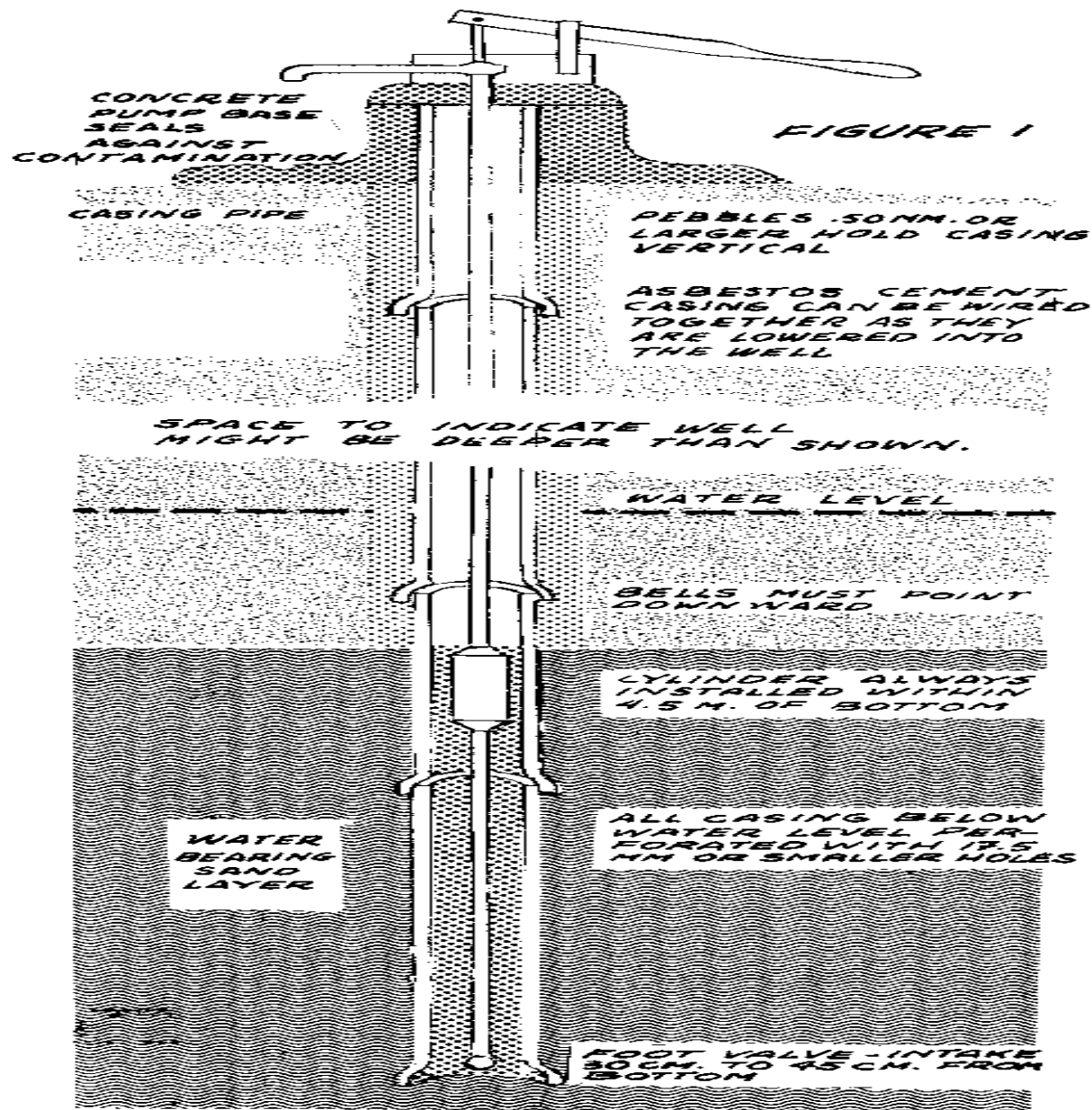
Well Casing and Platforms

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 it.

Two low-cost casing techniques are described here:

1. Method A (see Figure 1), from an American Friends Service Committee (AFSC)

fig1pg13.gif (600x600)

FIGURE 1

CONCRETE PUMP BASE SEALS AGAINST CONTAMINATION.

CASING PIPE

PEBBLES .50MM. OR LARGER HOLD CASING VERTICAL

ASBESTOS CEMENT CASING CAN BE WIRED TOGETHER AS THEY ARE LOWERED INTO THE WELL

SPACE TO INDICATE WELL MIGHT BE DEEPER THAN SHOWN.

WATER LEVEL

BELLS MUST POINT DOWNWARD

CYLINDER ALWAYS INSTALLED WITHIN 4.5 M. OF BOTTOM

WATER BEARING SAND LAYER

ALL CASING BELOW WATER LEVEL PERFORATED WITH 17.5 MM OR SMALLER HOLES

FOOT VALVE - INTAKE 30 CM. TO 45 CM. FROM BOTTOM

team in Rasulia, Madhya Pradesh, India.

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

Method A

Tools and Materials

Casing pipe (from pump to water-bearing layer to below minimum water table)-
Asbestos
cement, tile, concrete, or even galvanized iron pipe will do
Sand
Gravel
Cement
Device for lowering and placing casing (see Figure 2)

fig2pg14.gif (540x540)

FIGURE 2

A   B
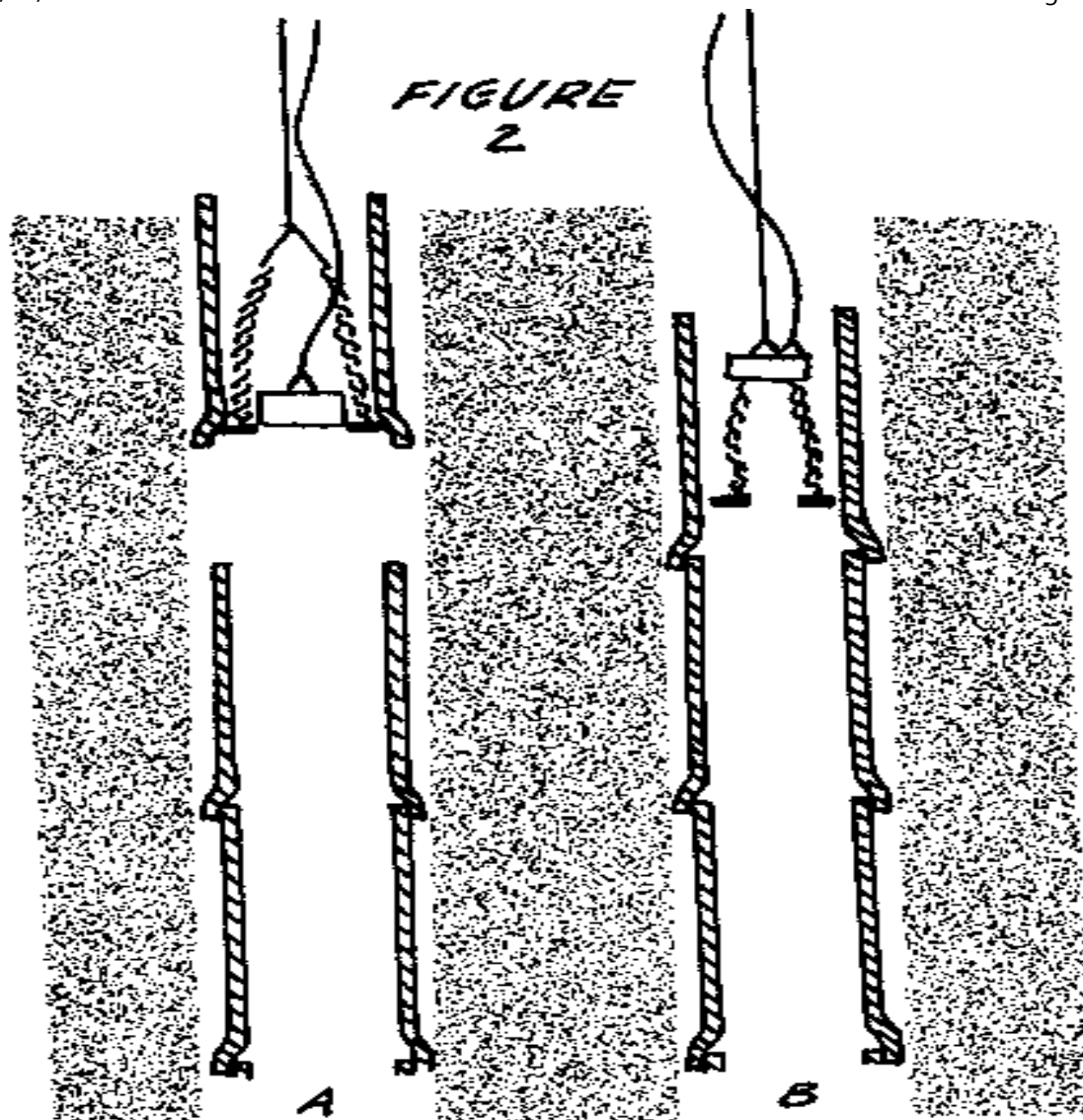
Drilling rig - see "Tubewell Boring"
Foot valve, cylinder, pipe, hand pump
The well hole is dug as deep as
possible into the water-bearing
strata. The diggings are placed near

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.

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 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.

Tools and Materials

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

fig3pg15.gif (145x437)

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 1m x 2m (0.01.6" x 39 1/2" x 79")

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 non-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, then pounding with a wooden mallet to the shape shown in Figure 3.

The seam is made slightly wider at one
end than at the other to give the pipe a
slight taper, 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") V-shaped wooden
block and applying pressure from above with a length of 5cm (2") pipe (see

Figure 4).
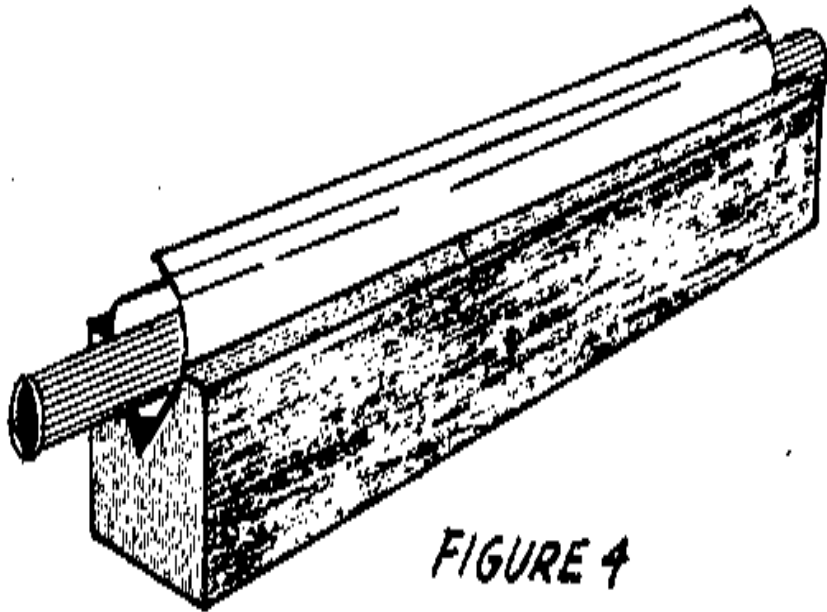
fig4pg15.gif (393x393)

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 5.

fig5pg15.gif (285x285)

FIGURE 5

**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 to 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.**

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 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. If the sections of casing are not assembled perfectly straight, the casing, as a result, is not centered in the well
and the pressure of the grouting is not equal all the way around. The casing may collapse. 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.

This method can be modified for use in areas where the structure of the material through which the well is drilled is such that there is little or no danger of cave-in. In this situation, the casing serves only one purpose, as a sanitary seal.

The well will be cased only about 8 meters (26 feet) down from the ground surface. To do this, the well is drilled to the desired depth with a diameter roughly the same as that of the casing. The well is then 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 is then poured as in the original method. This modification (1) saves considerable
costly material, (2) allows the well to be made a smaller diameter except near the
top, (3) lessens grouting difficulties, and (4) still provides 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 tiles 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 better than 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 that 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 that would take the water a considerable
distance from the well. It is worth noting that in Sudan and other very arid
areas

such spillage from community wells is used to water vegetable gardens or community nurseries.

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:

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

Mott, Wendell. Explanatory Notes on Tubewells. Philadelphia: American Friends Service Committee, 1956. (Mimeographed.)

Hand-Operated Drilling Equipment

Two methods of drilling a shallow tubewell with hand-operated equipment are described here: Method A, which was used by an American Friends Service Committee (AFSC) team in India, operates by turning an earth-boring auger. Method B, developed by an International Voluntary Services (IVS) team in Vietnam, uses a ramming action.

Earth Boring Auger

This simple hand-drilling rig can be used 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

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 hexagonal head machine steel bolts 5cm (2")
long, with nuts
9 10mm (3/8") steel hexagonal nuts

For Toggle Bolt:

1 3mm (1/8") diameter countersink head iron rivet, 12.5mm (1/2") long
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, hacksaw, 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 (Figures 1 and 2) is a simple method for attaching new

fig1x200.gif (600x600)

FIGURE 1

JOINT A

PLATFORM

JOINT A

JOINT B

JOINT A

JOINT C

AUGER
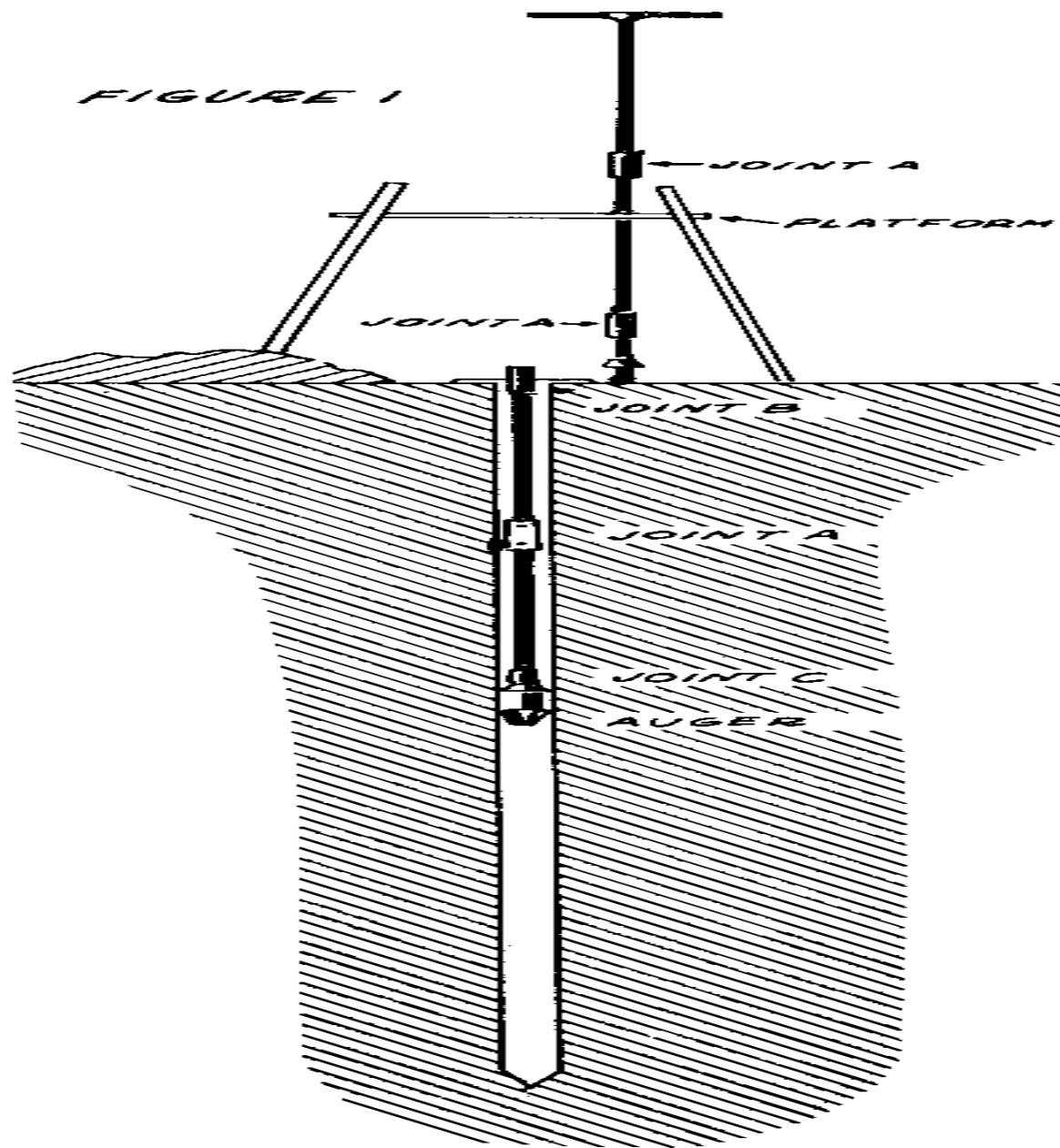
sections.

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.

fig3x200.gif (600x600)

FIGURE 1

JOINT A

PLATFORM

JOINT A

JOINT B

JOINT A
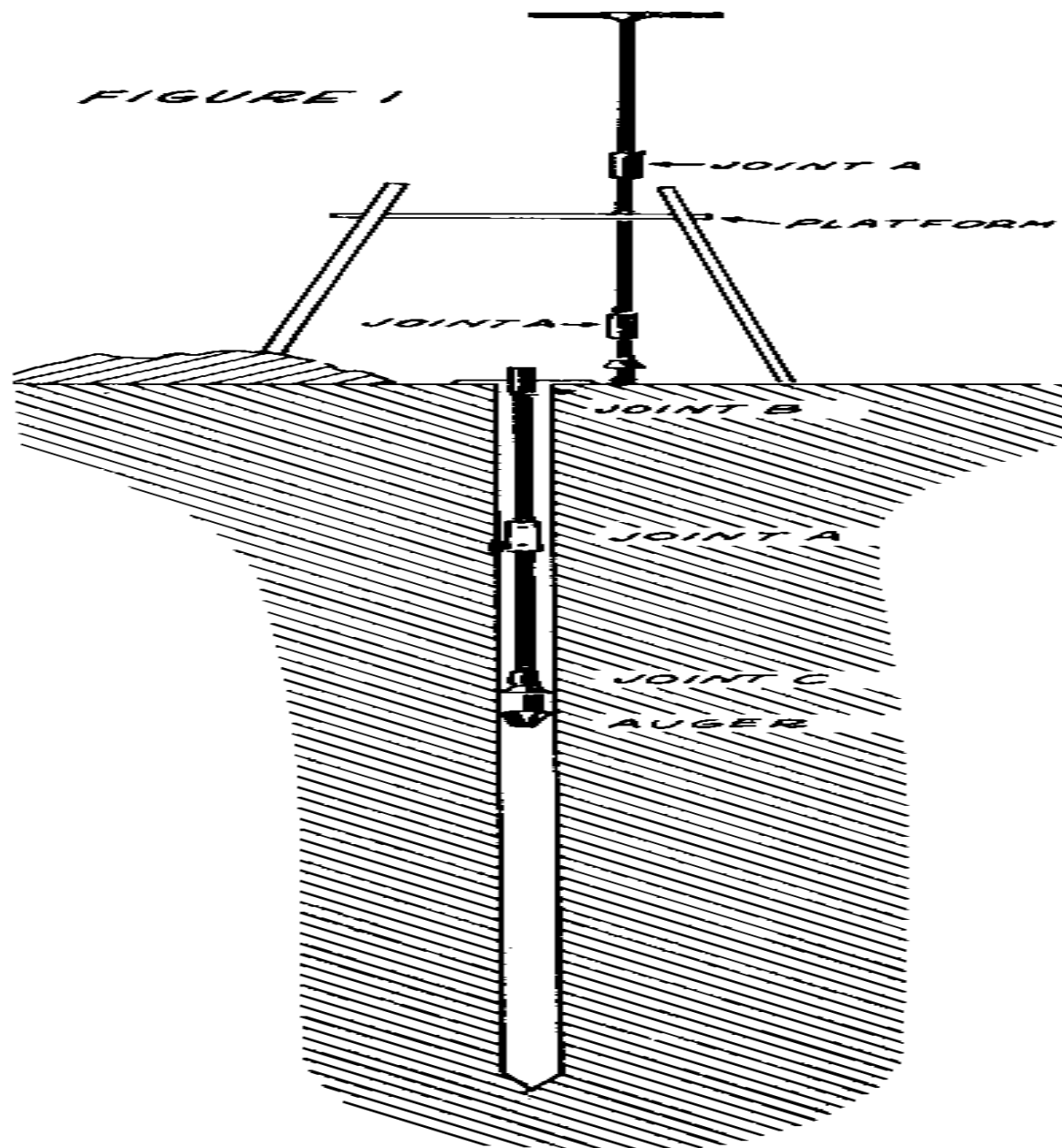
JOINT C

AUGER

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. These troubles can be avoided by using a sleeve pipe fastened
with two 10mm (3/8") bolts. 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.

fig2x20.gif (600x600)

Drill pipe
(be sure 32mm
pipe will fit
over this)

8.75mm

(clear
hole for
10mm bolt)

5cm

20cm

FIGURE2

JOINT A

32mm
Standard weight
steel galvanized
pipe

5cm
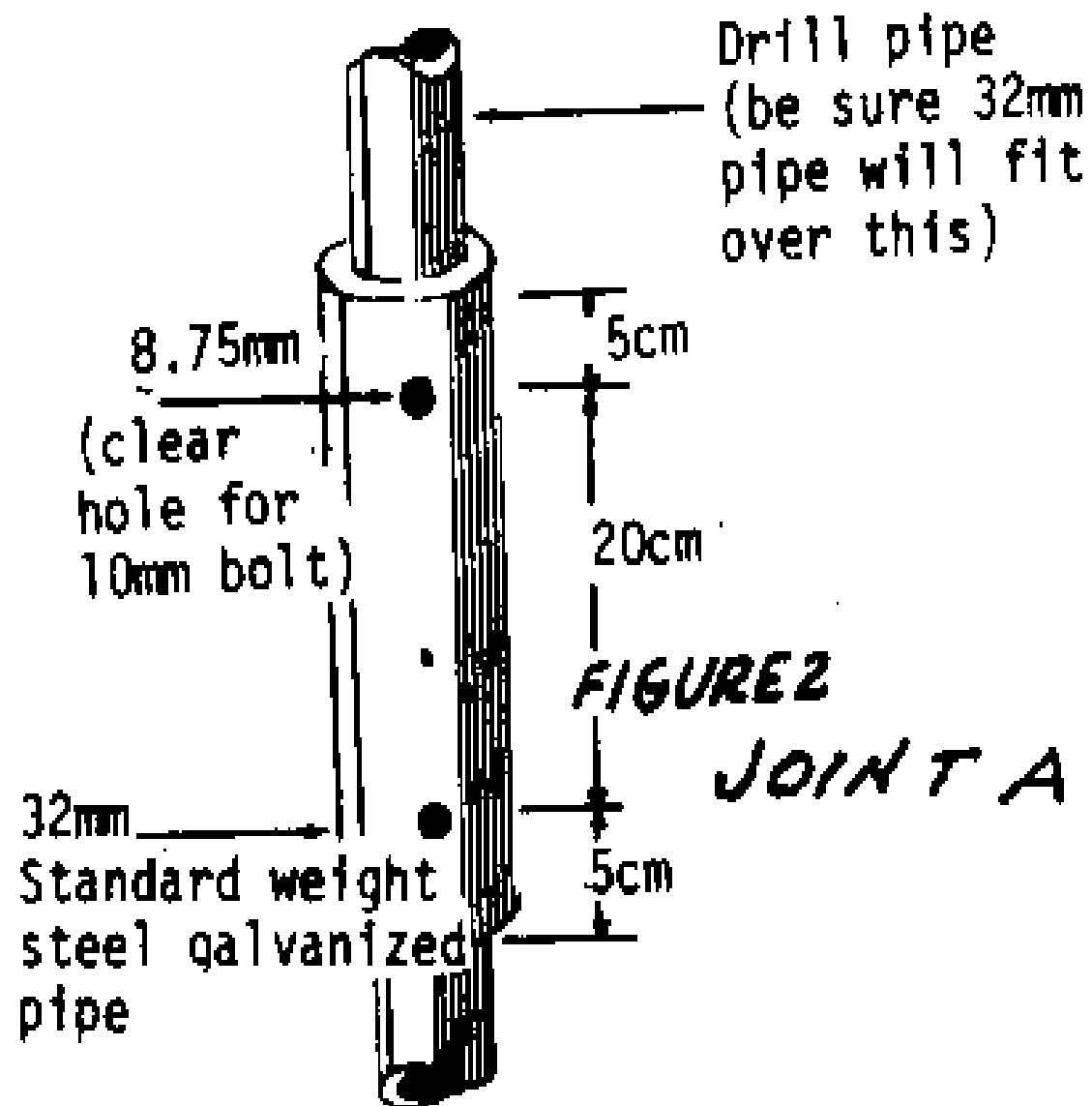
**Four 3-meter (10') sections and two 107cm (3 1/2') sections of pipe are the most
convenient lengths for drilling a 15-meter (50') well. Drill an 8.75mm (13/32")**

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, pull up the full auger

fig4x200.gif (600x600)

25mm pipe
drill line

32mm to 25mm
reducer coupling

32mm pipe 23cm long

7.5cm

38mm pipe
shown
cut away

10mm
toggle bolt

17.5mm
holes
clear
10mm
bolts

17.5mm hole about
in the middle of
32mm pipe to clear
the 10mm toggle
bolt--mark loca-
tion thru 38mm pipe

10cm

stop bolt
10mm steel bolt
5cm long

17.5mm
hole
clears
19mm
rod

10cm

support rod
shown in place

7.5cm

38mm to 25mm
reducer coupling

FIG.5 JOINT B

until Joint B appears at the surface. See Figure 4A. Then put a 19mm (3/4")

fig4x21.gif (600x600)

TOGGLE BOLT

SUPPORT ROD

A   B   C
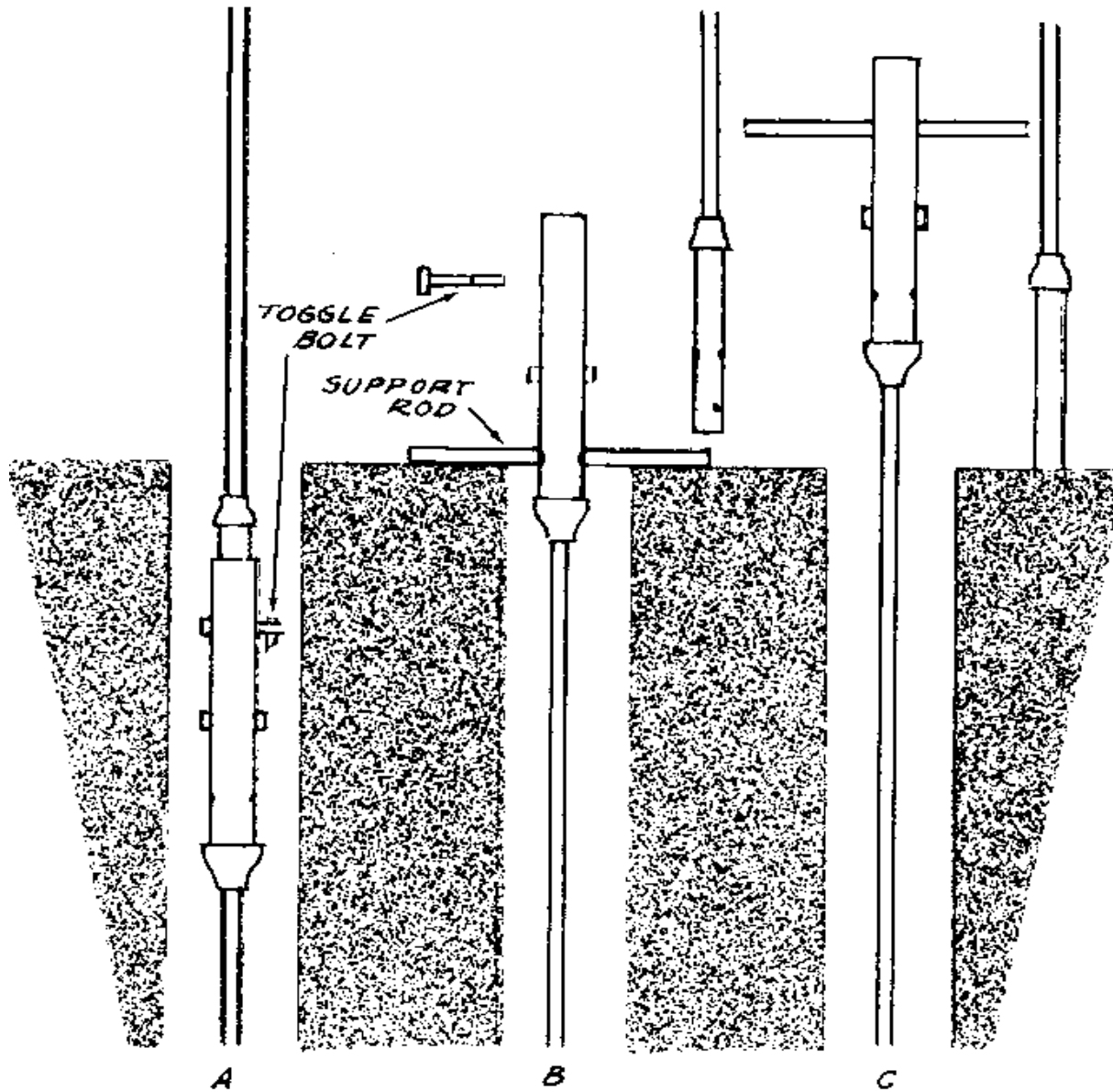
FIGURE 4   JOINT B IN OPERATION

diameter rod 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 that 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.

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 three feet-one meter).
Ten feet (three meters) of perforated casing embedded in such a sandy layer will
provide a very good flow of water.

Tubewell Earth Auger

This earth auger (Figure 5), which is similar to designs used with power drilling
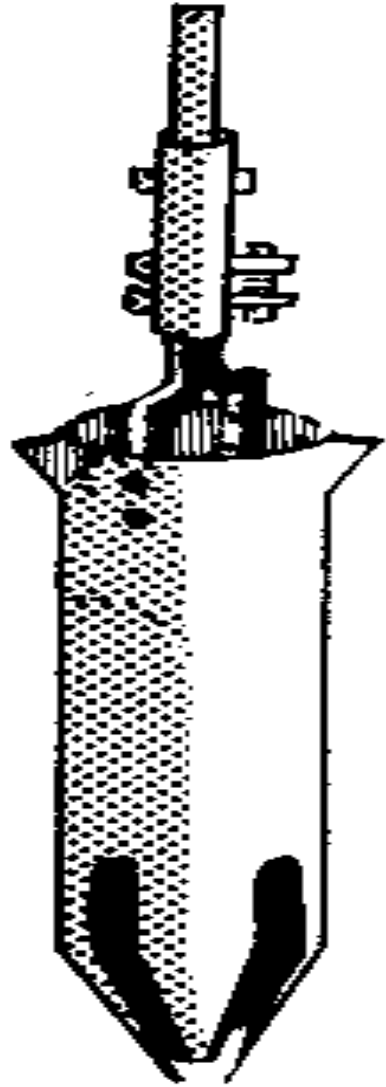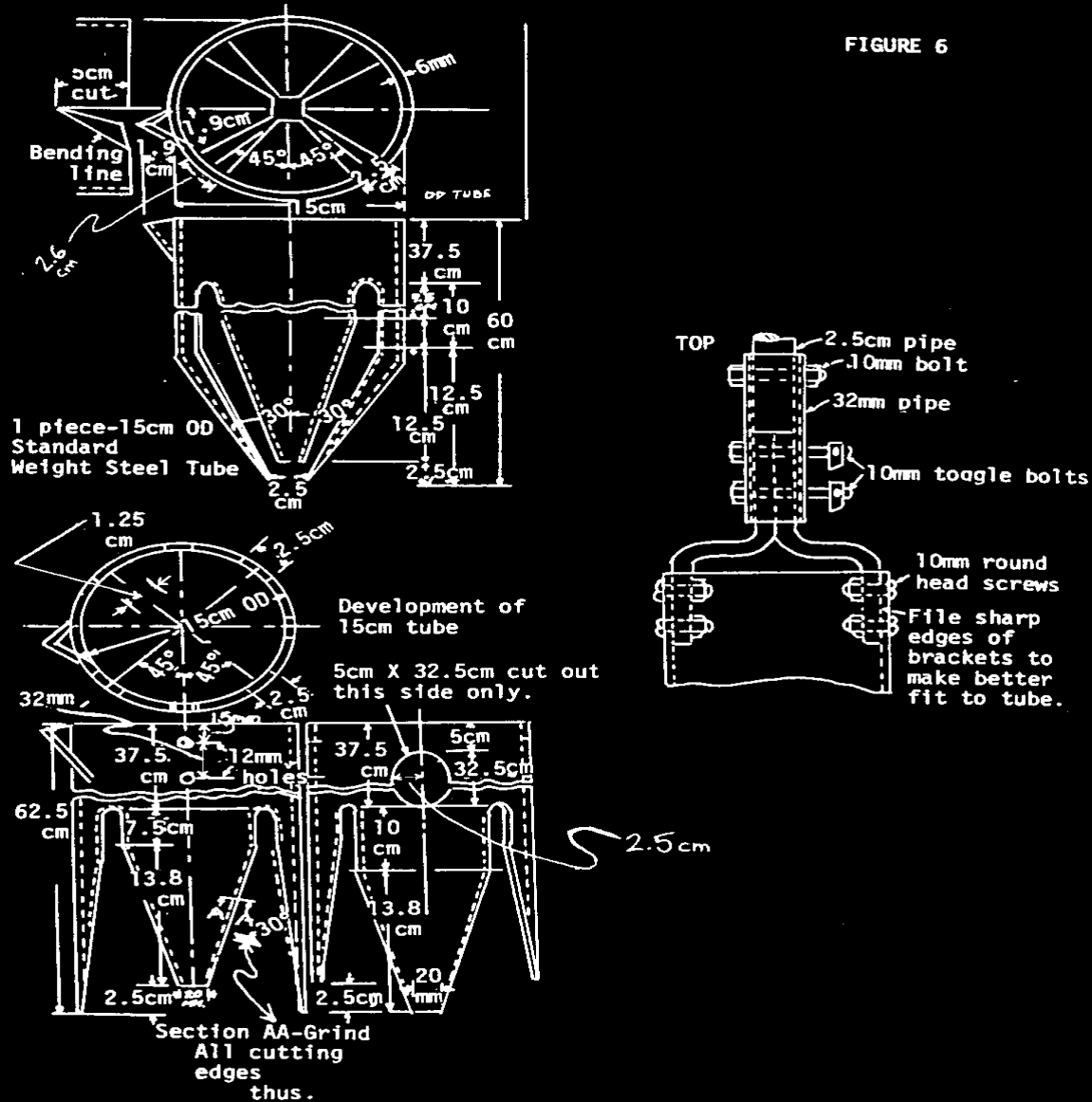
fig5x22.gif (600x600)

FIGURE 5
TUBEWELL EARTH AUGER

equipment, is made from a 15cm (6") steel tube.

The 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).

fig6x23.gif (600x600)

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 hexagonal 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:

U.S. Army and Air Force. Wells. Technical Manual 5-297, AFM 85-23. Washington,
D.C.: U.S. Government Printing Office, 1957.

Tubewell Sand Auger

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

A smaller version of the sand auger made to
fit inside the casing pipe can be used to

remove loose, wet sand.

The tubewell sand auger is illustrated in
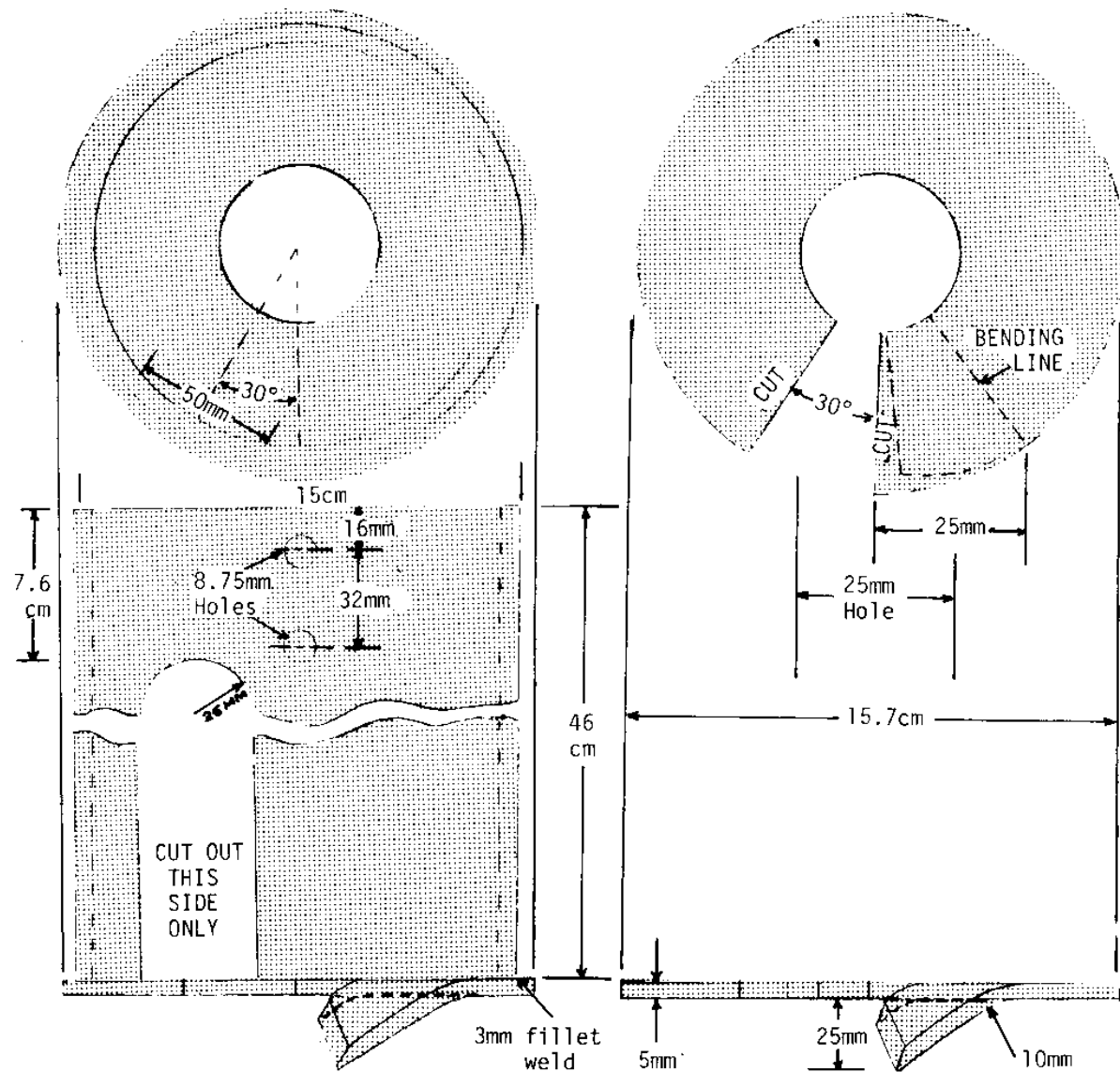Figure 7. Construction diagrams are given in

fig7x24.gif (600x600)

PREVIOUS ENTRY DETAILS PARTS TO CONNECT WITH DRILL LING.
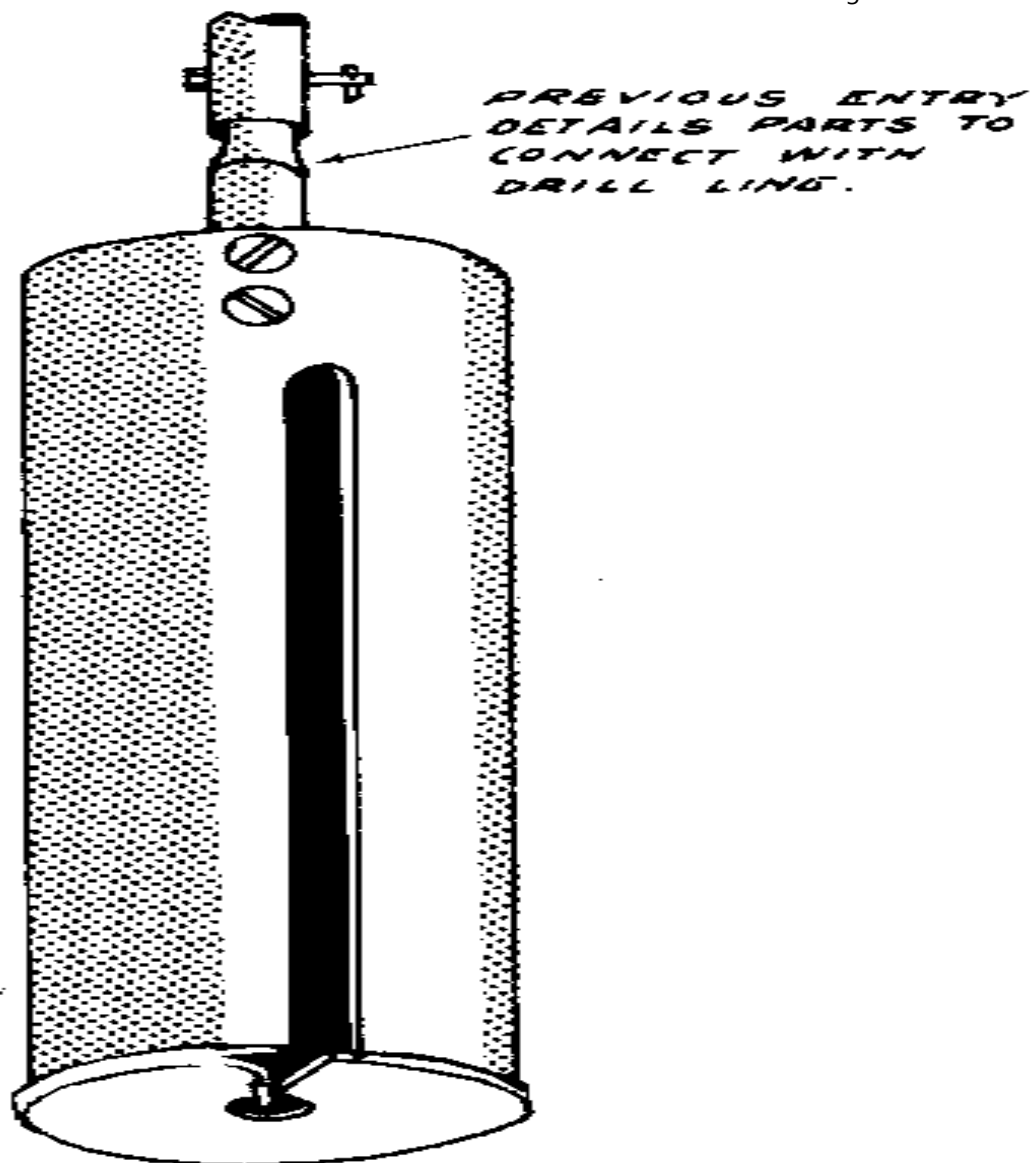
FIGURE 7

TUBEWELL SAND AUGER

Figure 8.

`fig8x25.gif (600x600)`

15cm

7.6 cm

16mm

8.75mm Holes

32mm

26 mm

CUT OUT THIS SIDE ONLY

46 cm

50mm

30°

3mm fillet weld

BENDING LINE

CUT

30°

CUT

25mm

25mm Hole

15.7cm

25mm Hole

15.7cm

5mm

25mm

10mm

DETAIL OF BOTTOM

FIGURE 8

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.

Tubewell Sand Bailer

The sand bailer <see figure 9> can be used to drill from inside a perforated
well casing when a

fig9x26.gif (600x600)

ENTRY ON TUBEWELL EARTH AUGER
DETAILS PARTS TO CONNECT WITH DRILL LINE

NORMAL
SOIL

WET, LOOSE
SAND

PERFORATED CASING
WITH BELL REMOVED

FLAP IS CLOSED AS
BUCKET IS BEING
REMOVED FROM
THE WELL

FLAP OPENS AS
BUCKET IS JAMMED
DOWN INTO SAND

FIGURE 9
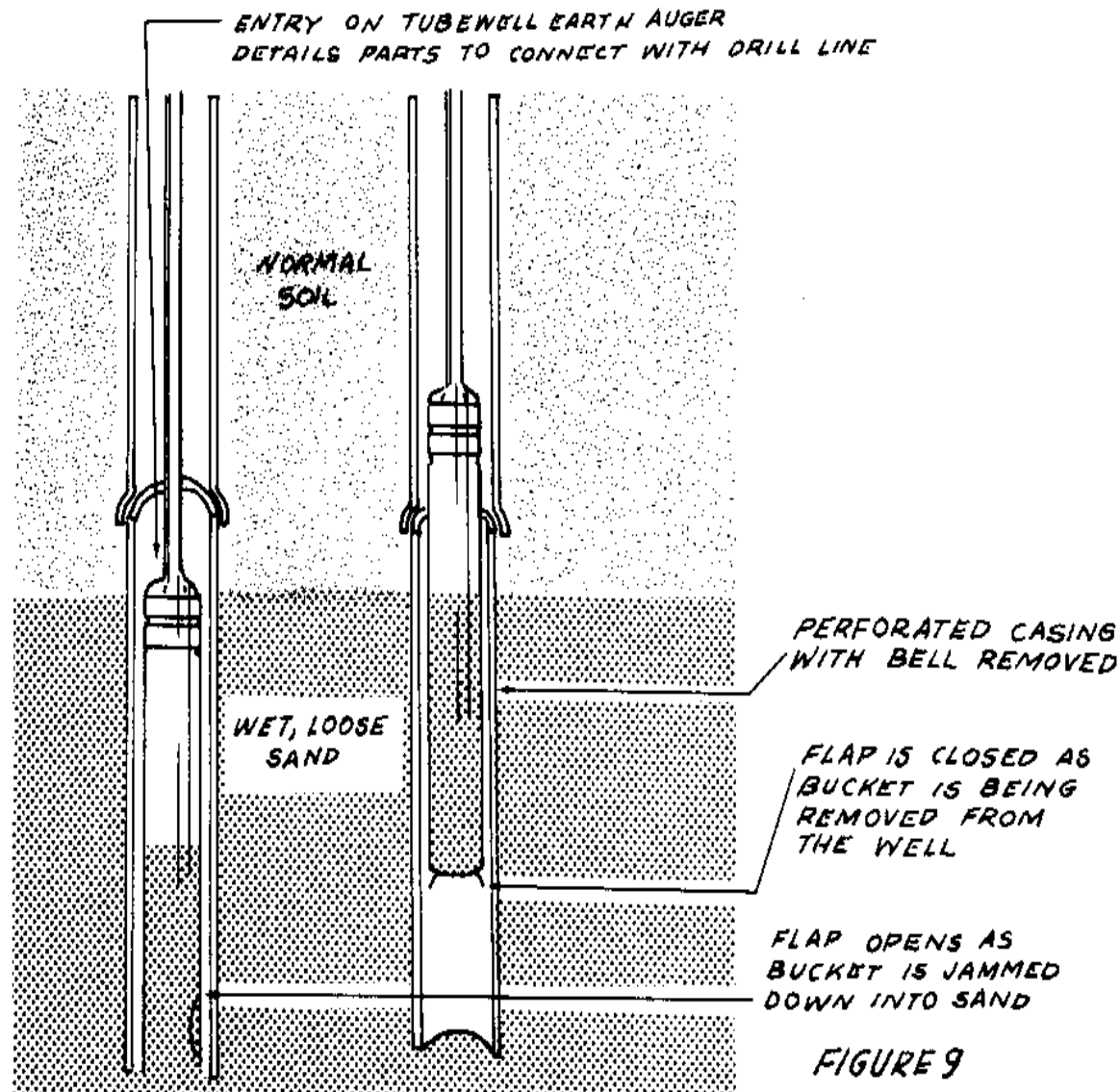
USING A SAND BAILER TO DRILL FROM INSIDE A WELL CASING

bore goes into loose wet sand and the walls start to cave in. It has been used to

make 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

Repeatedly jamming this "bucket" into the well will remove sand from below the
perforated casing, allowing the bucket 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, Wendell Mott, American Friends Service
Committee,
Philadelphia, Pennsylvania, 1956 (Mimeographed).

Ram Auger

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.

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 1/3" 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
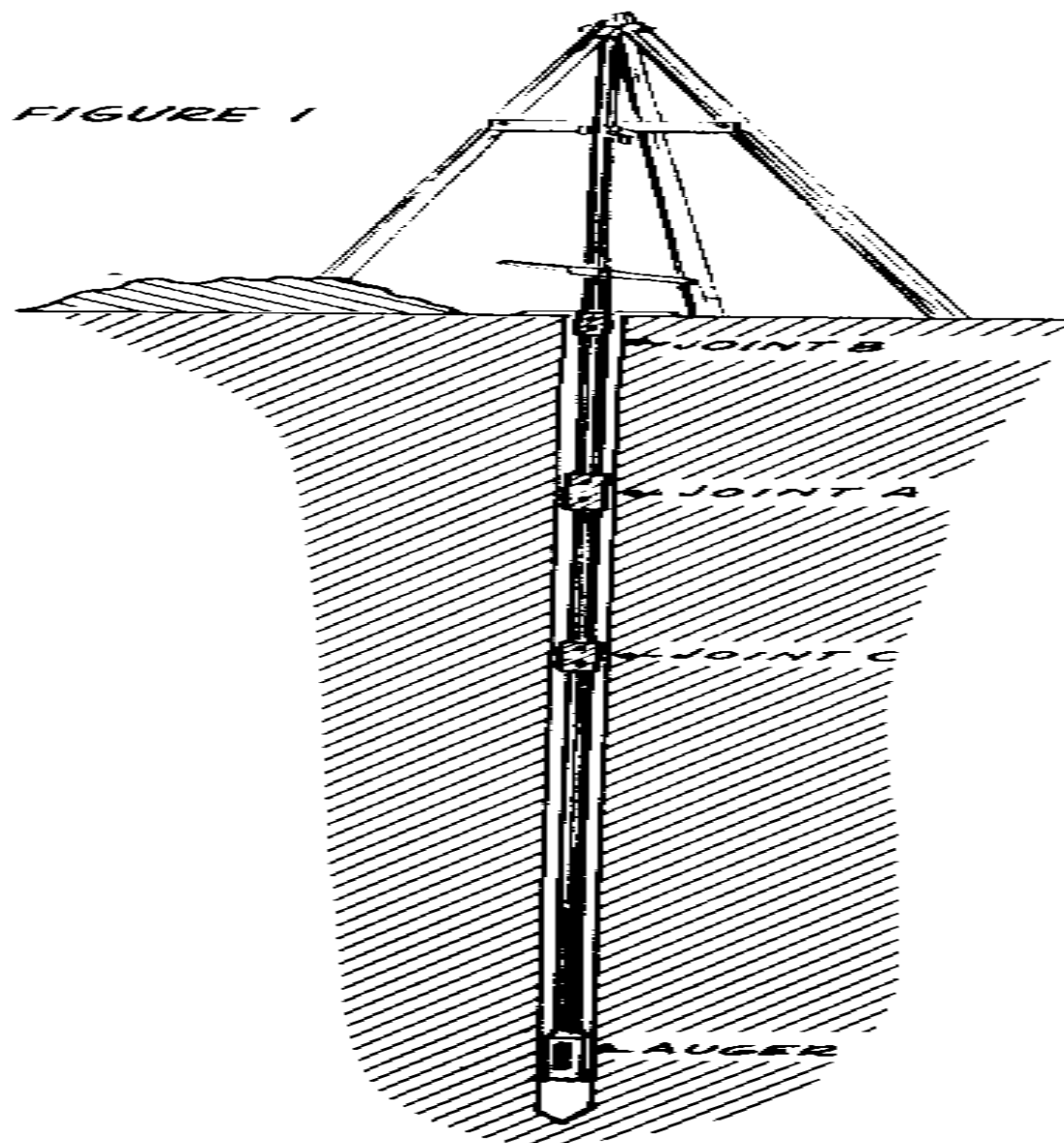the villagers. Water was found in varying quantities at all the sites chosen. (See
"Getting Ground Water from Wells and Springs.")

Starting to Drill

A tripod is set up over the approximate location for the well (see Figure 1). Its

fig1x28.gif (600x600)

FIGURE 1

JOINT B

JOINT A

JOINT C

AUGER

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 hung from the auger guide on the tripod's crossbar to locate the
exact starting point. It is helpful
to dig 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 people work
together with the auger. One
system that worked out quite well
was to use three people, 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 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 part way 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

fig2x290.gif (393x393)
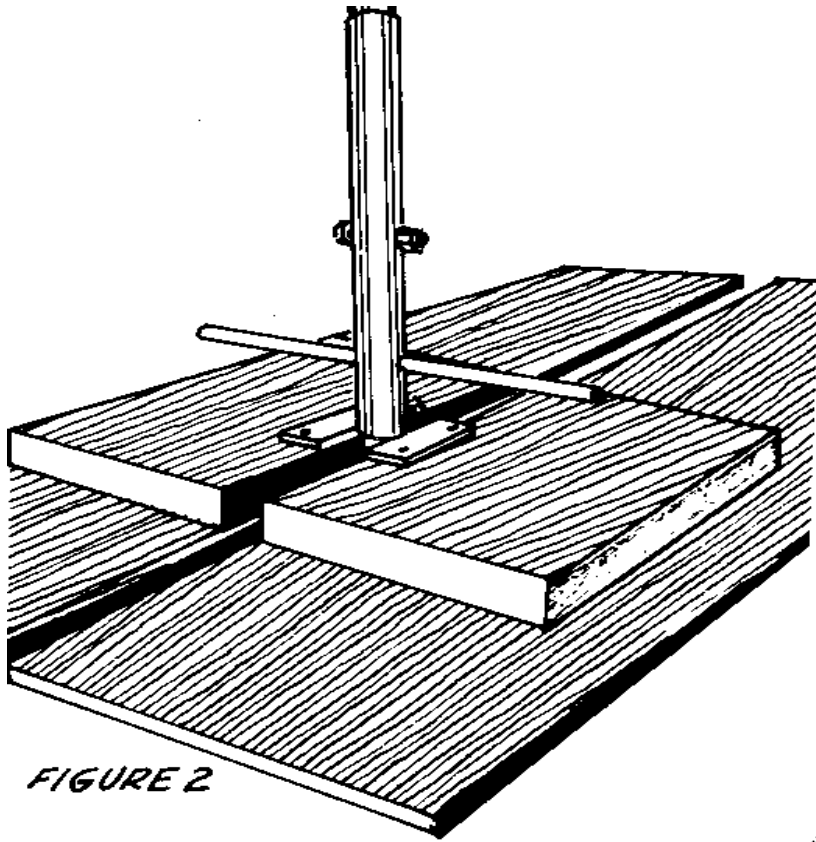
FIGURE 2

the extension so that the bottom of
the coupling can rest on the small
metal plate. The next step is to put
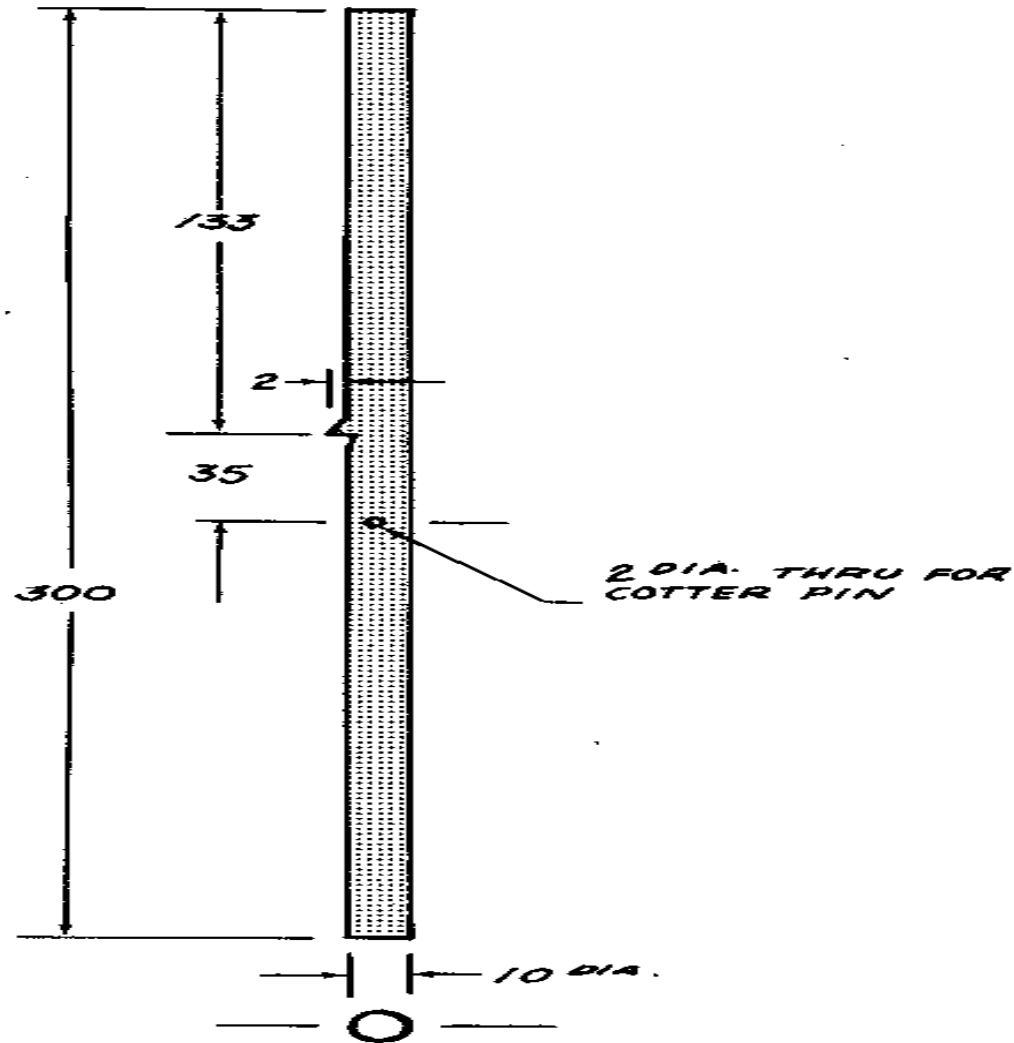the safety rod (see Figure 4)

fig4x30.gif (594x594)

FIGURE 4   SAFETY ROD

MAT'L: MILD STEEL

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.

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 on the tool
tray (see Figures 5 and 6). The reason for putting the extensions on the tool
tray

fig5x310.gif (393x393)
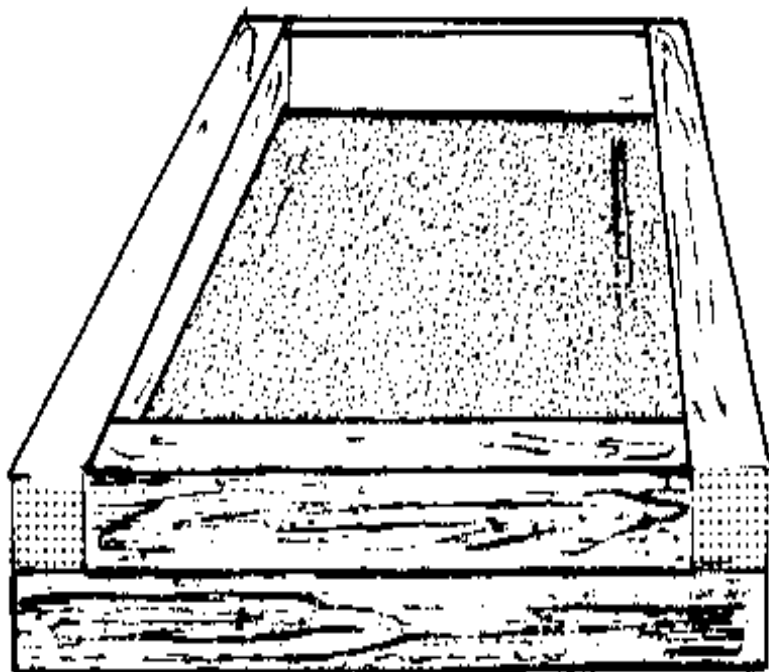
FIGURE 5 TOOL TRAY

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.

Drilling Rock

When stone or other substances 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 the well keeps going into water-bearing ground. However, in village wells where water can only be raised slowly by handpump 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 another 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 (Mimeographed).

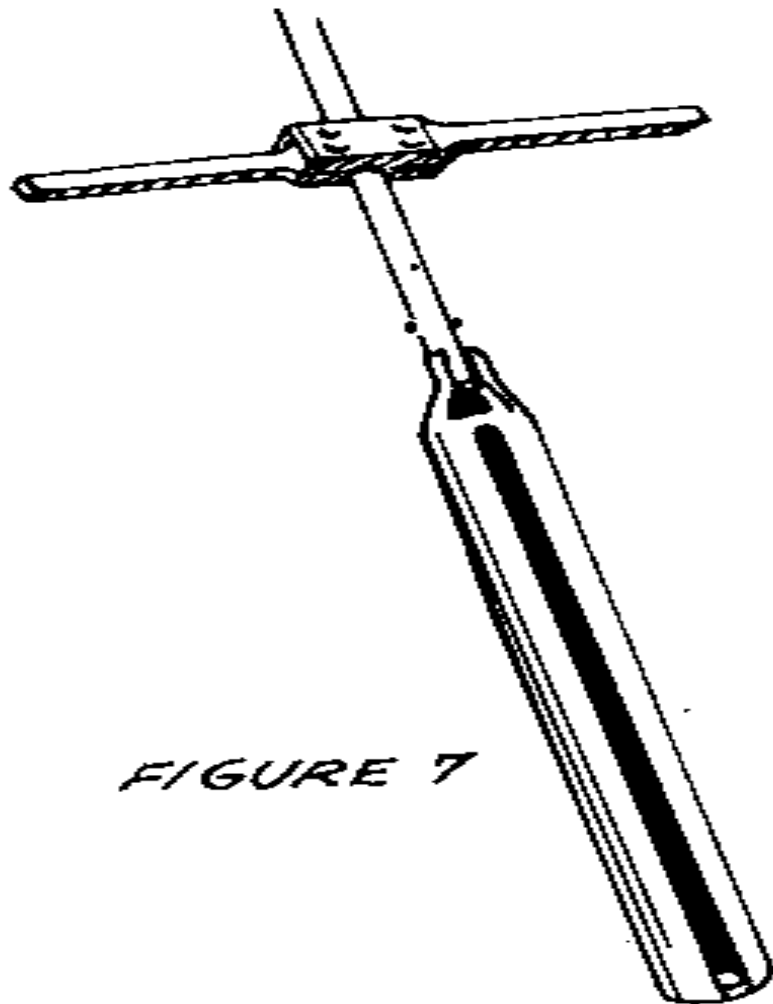**Equipment <see figure 7>**

fig7x32.gif (486x486)

FIGURE 7

The following section gives construction details for the well-drilling equipment used with the ram auger:

o **Auger, Extensions, and Handle**
o **Auger Cleaner**
o **Demountable Reamer**
o **Tripod and Pulley**
o **Bailing Bucket**
o **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

fig8x34.gif (600x600)
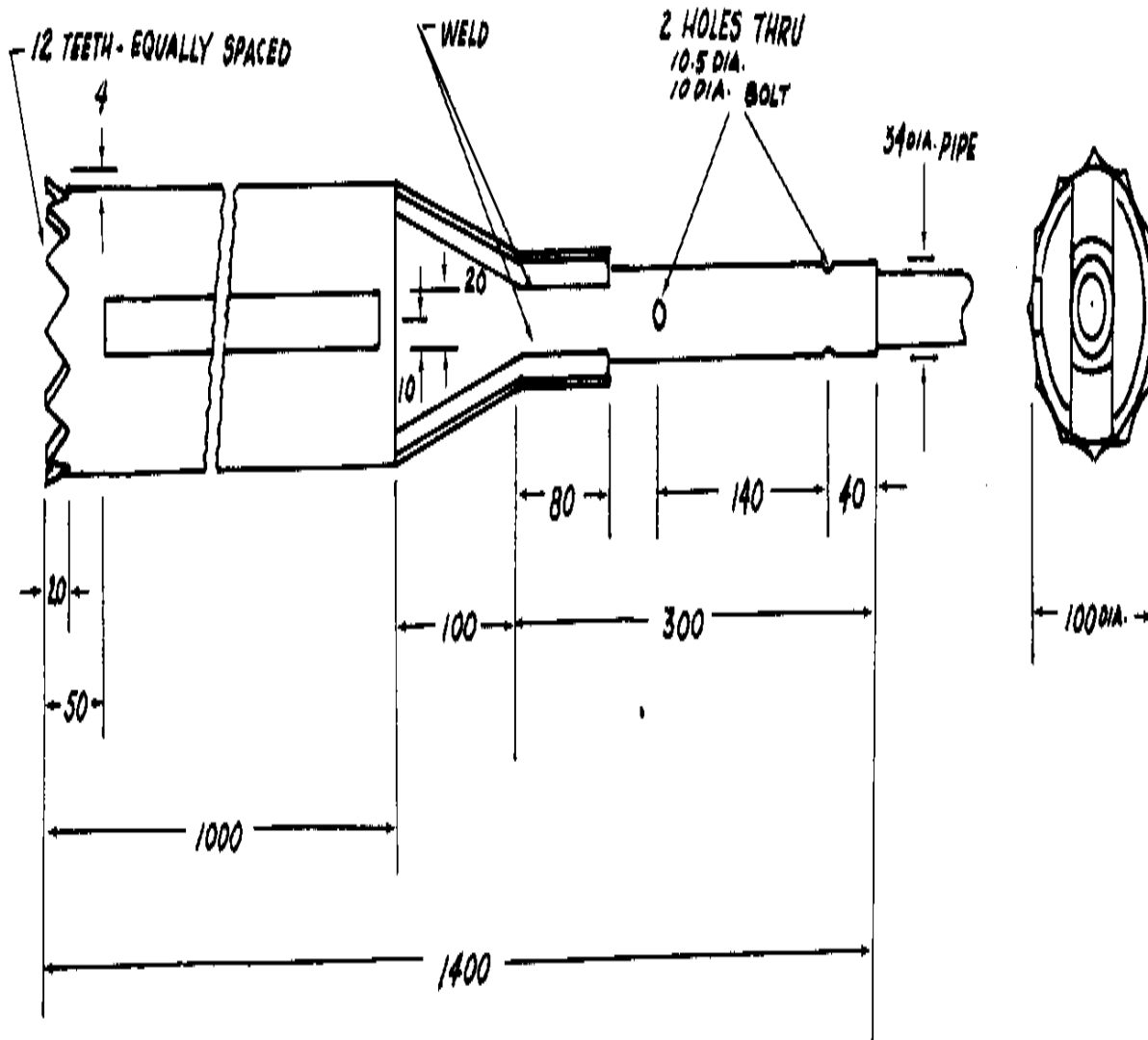
FIGURE 8, CUTTING HEAD, WELL DRILLING AUGER

(see Figure 9) and handle (see Figure 10) make it possible to bore deep holes.
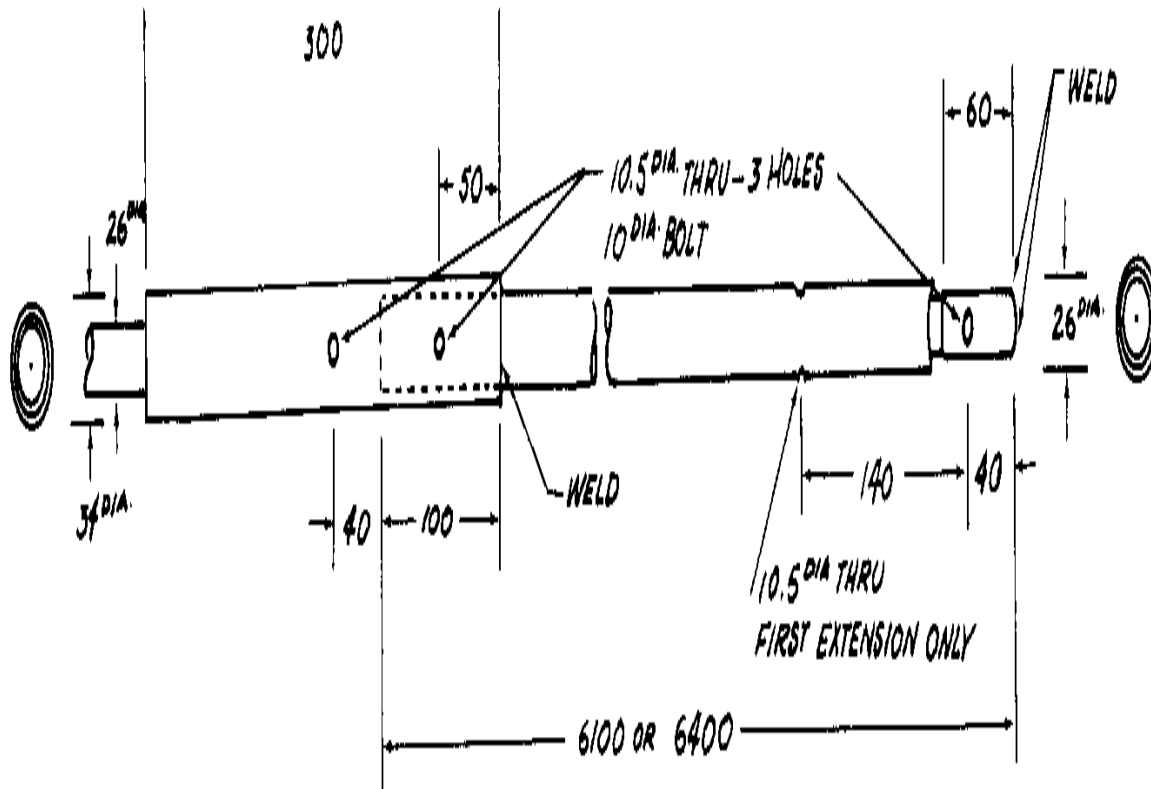
fig9x34.gif (600x600)

FIGURE 9 EXTENSION, WELL DRILLING AUGER

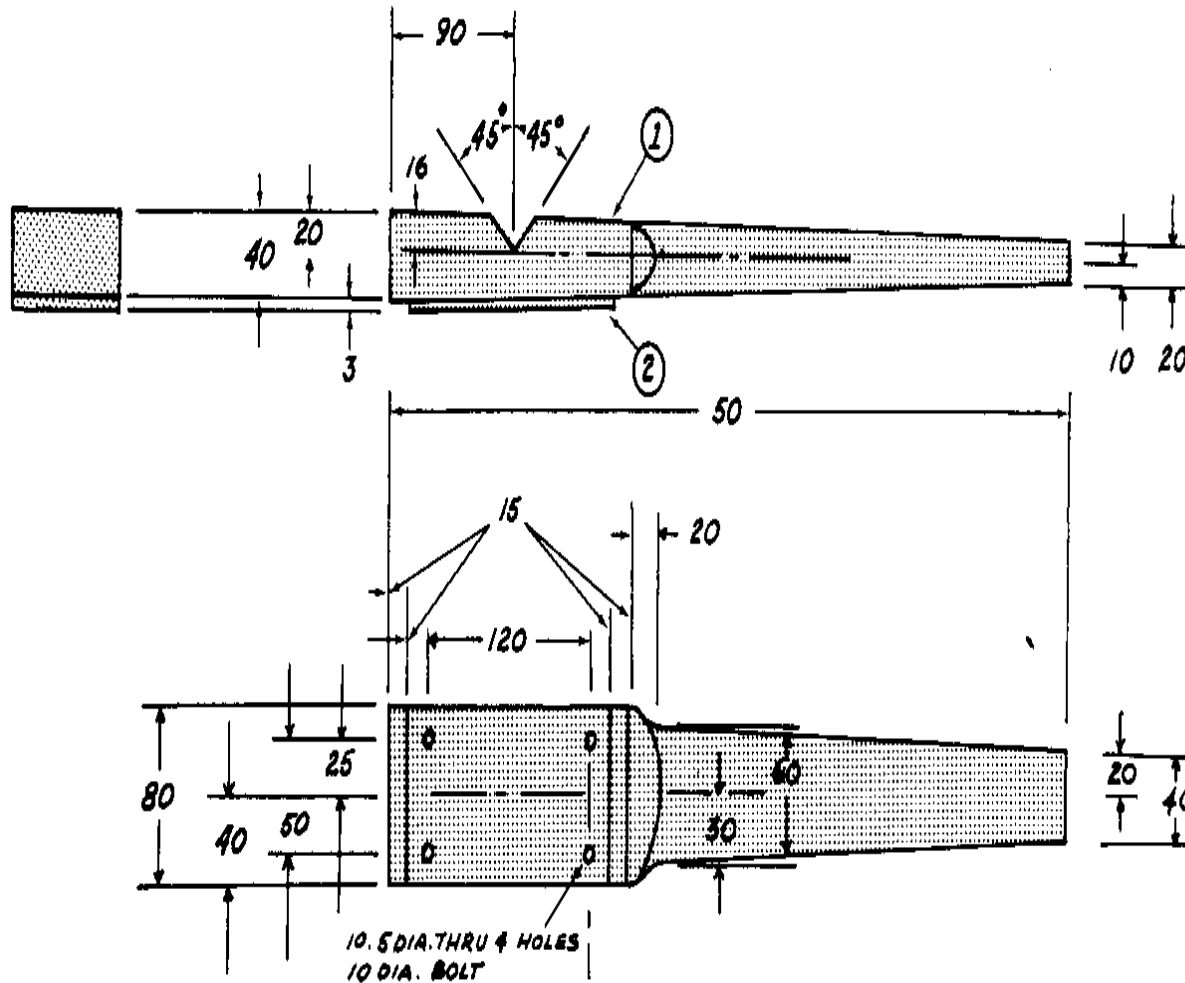NOTE: 34 DIA. COUPLING MAY BE OMITTED ON LAST EXTENSION

fig10x35.gif (600x600)

FIGURE 10, HANDLE, WELL DRILLING AUGER

NOTE: 2 REQUIRED PER SET

SCALE: ¼ SIZE   MAT'L: ① HARDWOOD
                             ② MILD STEEL

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: 10mm 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 that 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,
however, this type of auger may be more effective.

Auger Cleaner

Soil can be removed rapidly from the auger with this auger cleaner (see Figure 11).
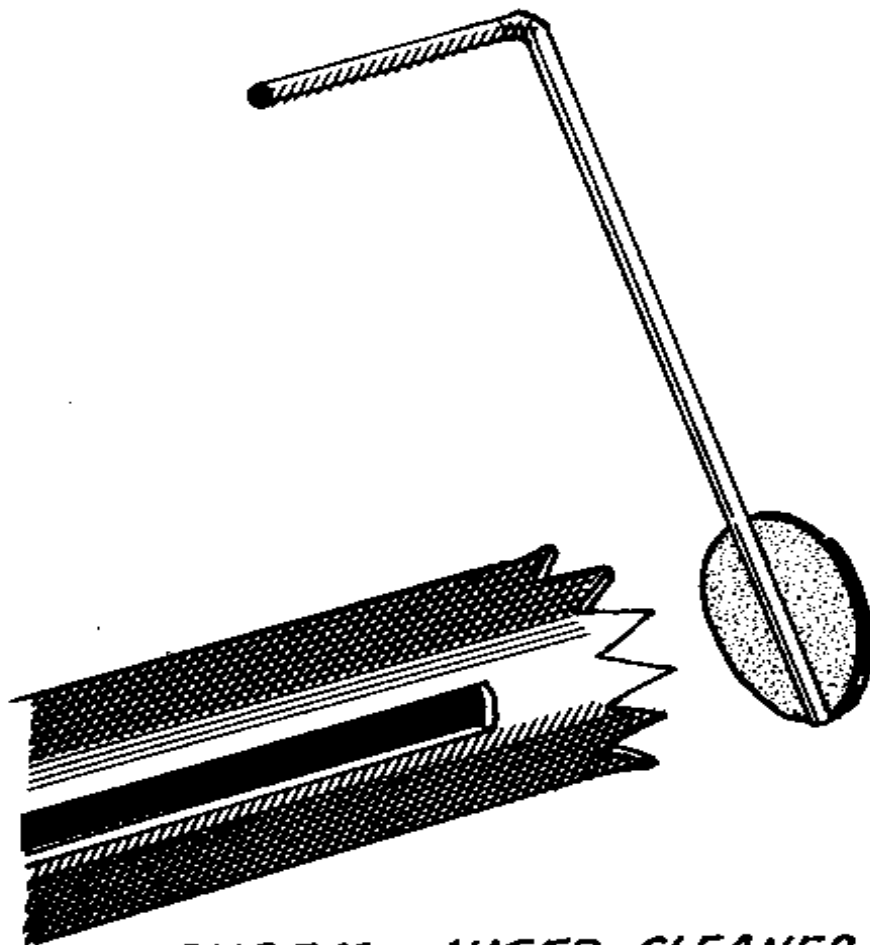
fig11x36.gif (486x486)

FIGURE 11 AUGER CLEANER

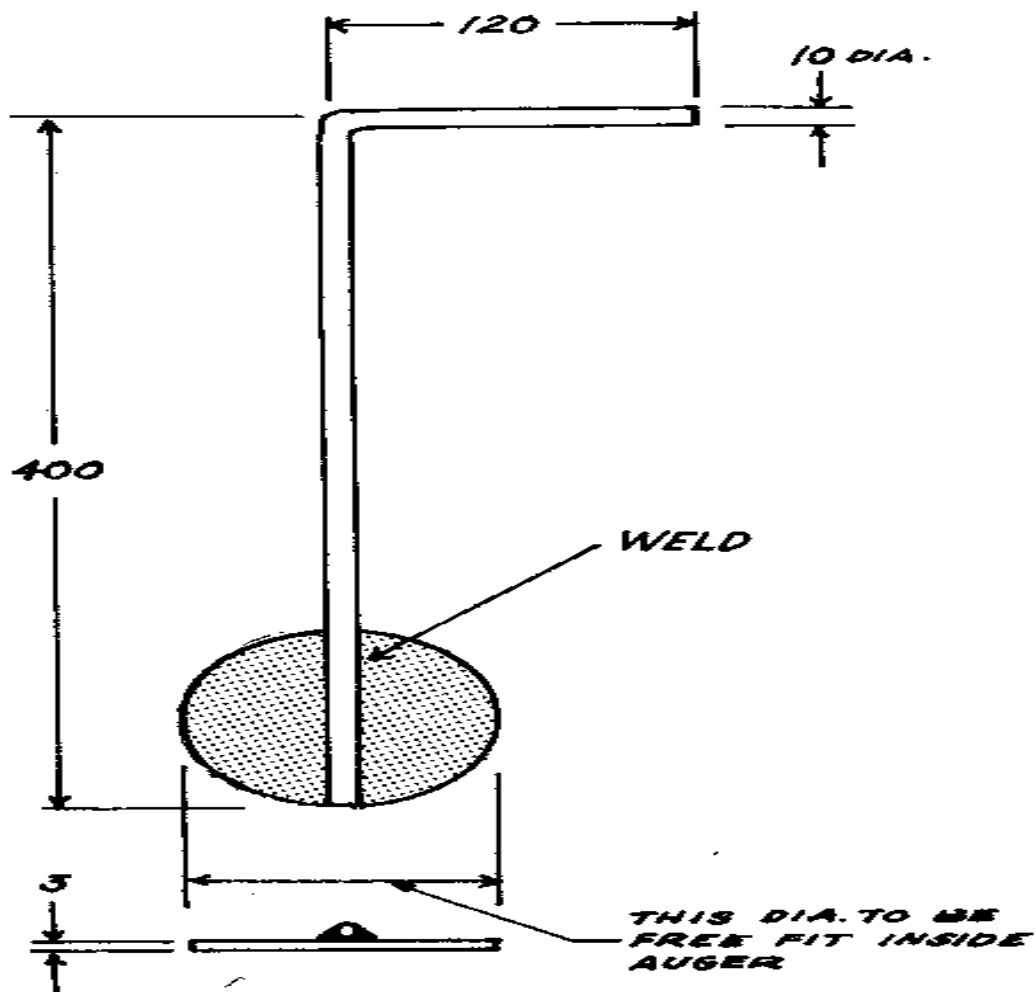Figure 12 gives construction details.

fig12x36.gif (600x600)

120

10 DIA.

400

WELD

3

THIS DIA. TO BE
FREE FIT INSIDE
AUGER

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 (6" 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).
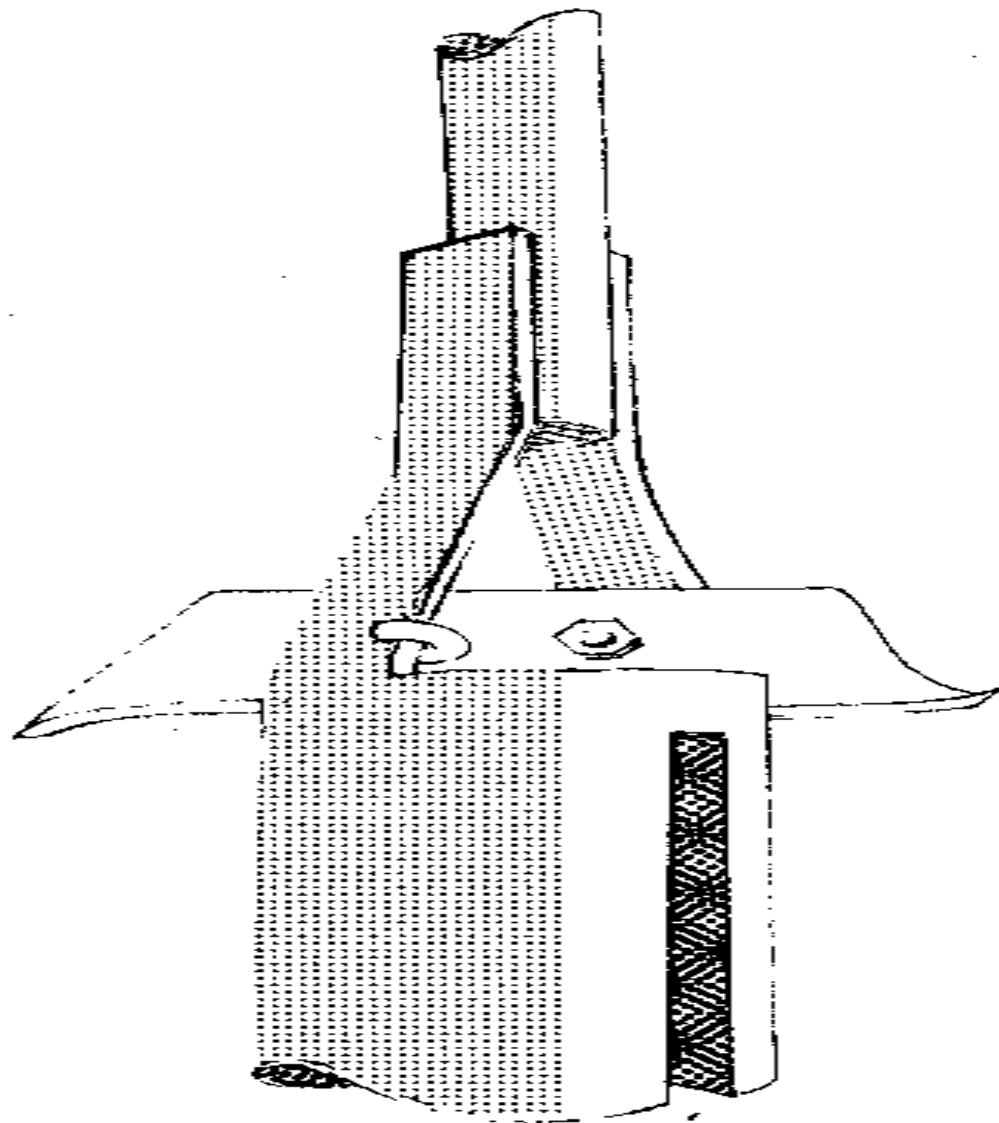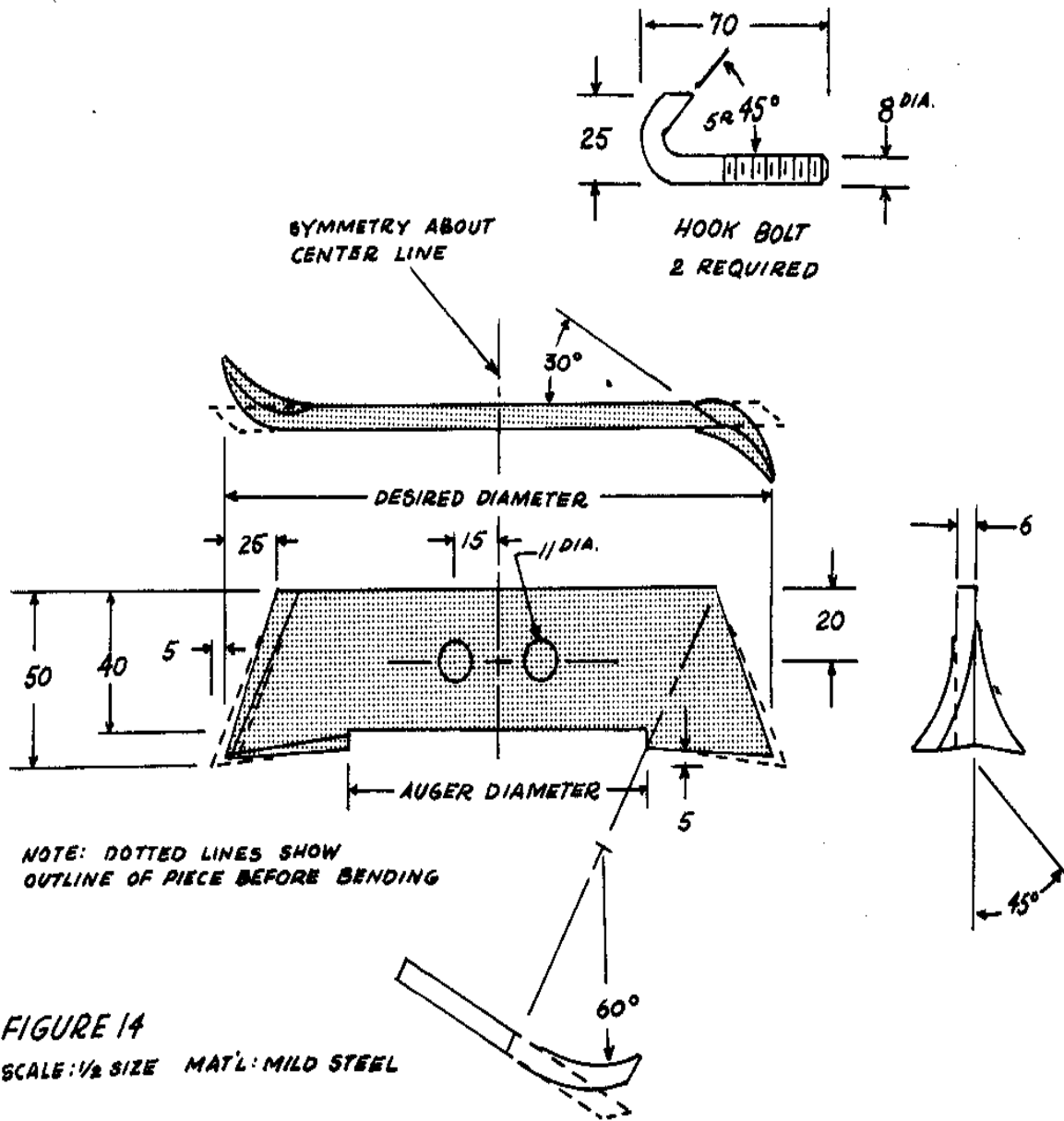
fig13x37.gif (600x600)

FIGURE 13

It is made from a piece of steel 1cm (1/2") larger than the desired well diameter (see Figure 14).

fig14x38.gif (600x600)

SYMMETRY ABOUT
CENTER LINE

70

25   5R   45°

8 DIA.

HOOK BOLT
2 REQUIRED

30°

DESIRED DIAMETER

25   15   11 DIA.

20

50   40   5

6

AUGER DIAMETER

5

45°

NOTE: DOTTED LINES SHOW
OUTLINE OF PIECE BEFORE BENDING

60°

FIGURE 14

SCALE: ½ SIZE   MAT'L: MILD STEEL

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.)

Tripod and Pulley

The tripod (see Figures 15 and 16), which is made of poles and assembled with
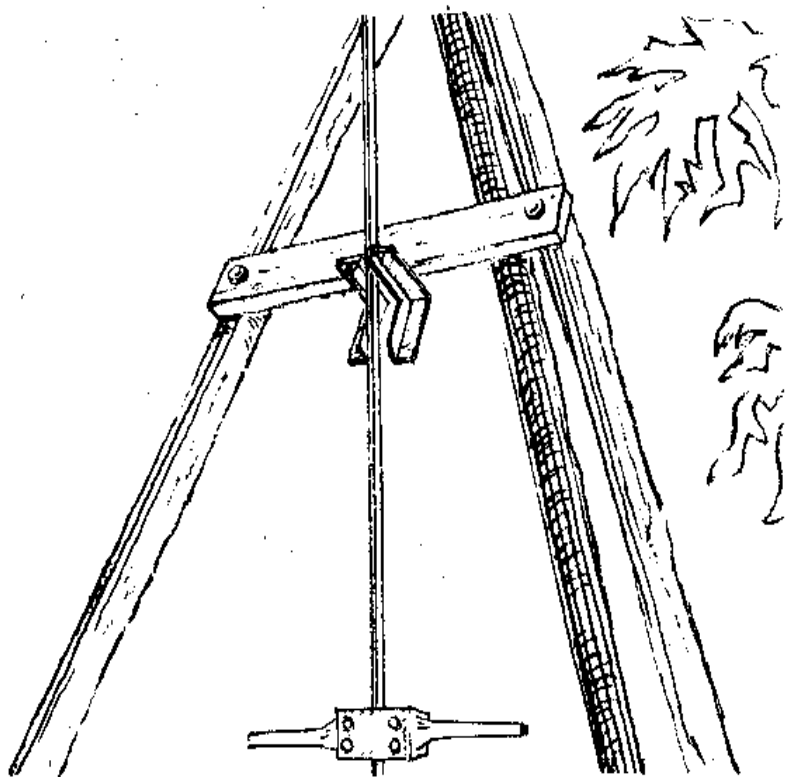
fig15390.gif (393x393)

FIGURE 15

when it extends far above ground; (2) to provide a mounting for the pulley (see Figures 17 and 19)
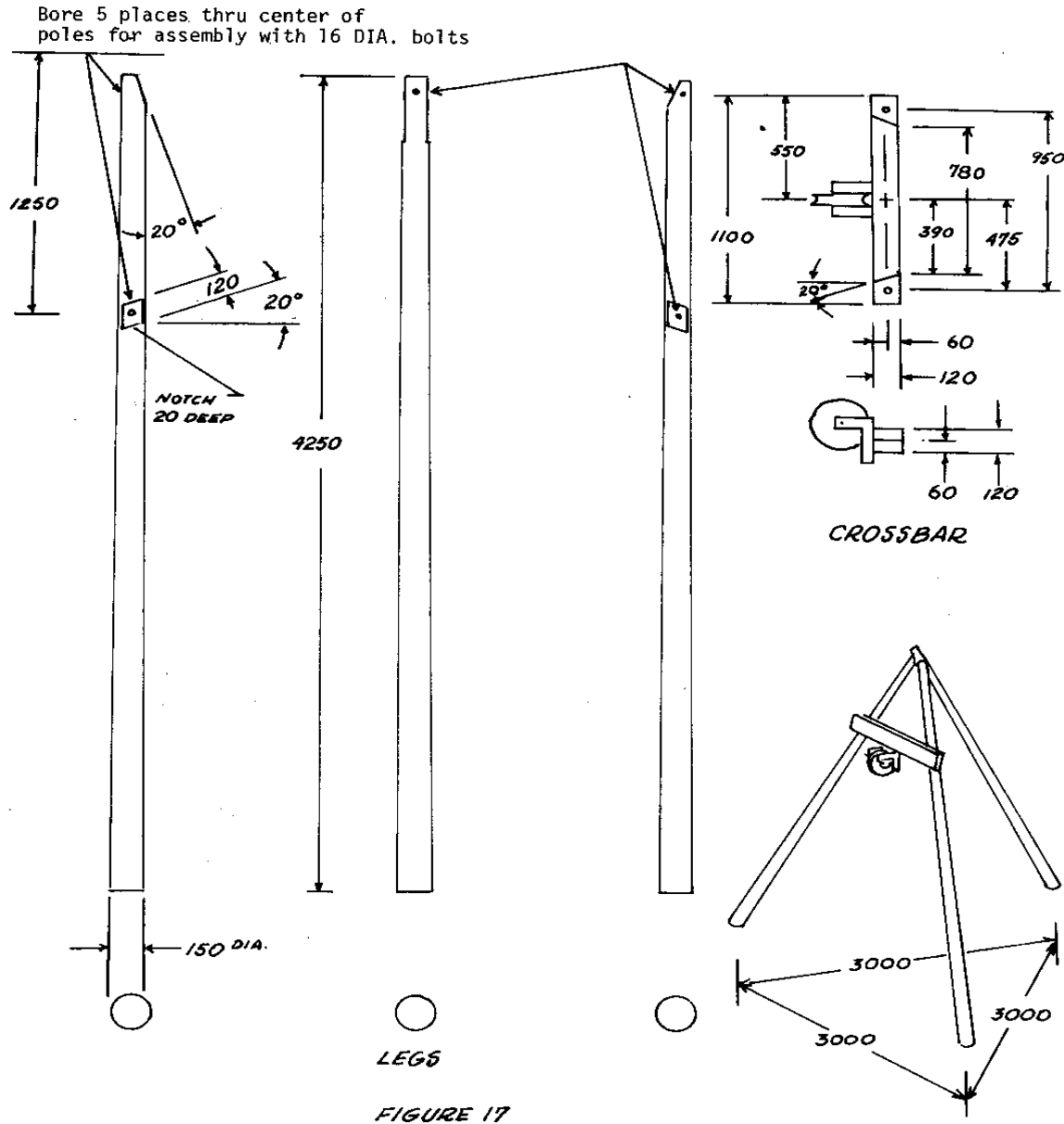
fig17400.gif (600x600)

Bore 5 places thru center of
poles for assembly with 16 DIA. bolts

1250

20°

120

20°

NOTCH
20 DEEP

4250

150 DIA.

LEGS

550

1100

780

950

390

475

20°

60

120

60   120

CROSSBAR

3000

3000

3000

FIGURE 17

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) that extend horizontally beyond the front
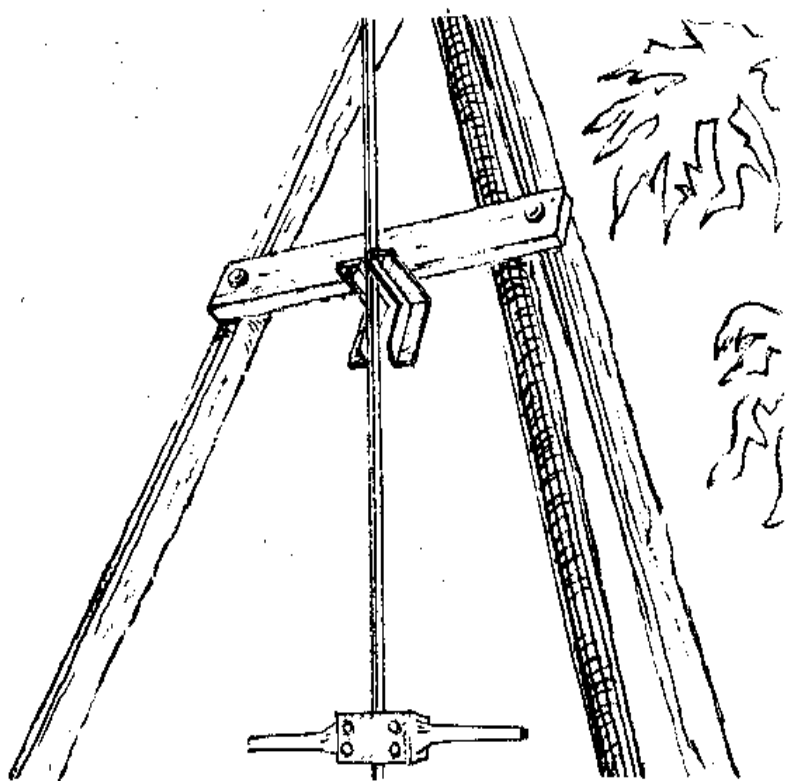
fig18390.gif (393x393)

FIGURE 15

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).

fig19x41.gif (600x600)

WELD

50

10

10

10.5 DIA.

180

160

NOTE: Two pieces, this and its mirror image, make one pulley bracket. (See tripod drawing.) Attach to crossbar with 12DIA. Bolts.
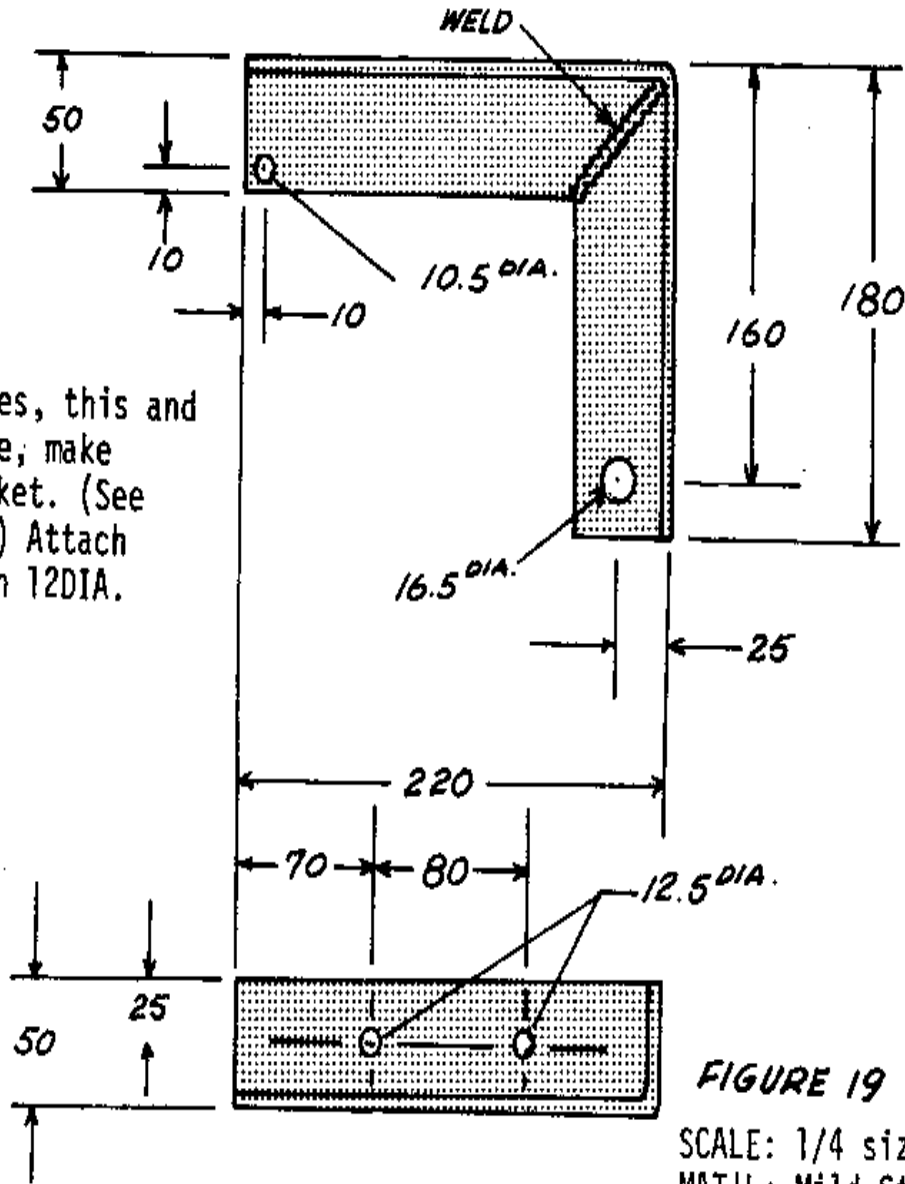
16.5 DIA.

25

220

70

80

12.5 DIA.

25

50

FIGURE 19

SCALE: 1/4 size
MAT'L: Mild Steel

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 washer
2 Bolts: 16mm (5/8") in diameter and 25cm (9 7/8") long; nuts and washers
Bore 5 places through center of poles for assembly with 16mm bolts

Bailing Bucket

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

Tools and Materials

Pipe: about 8.5cm (3 3/8") in diameter, 1 to 2cm (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") diameter by 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).
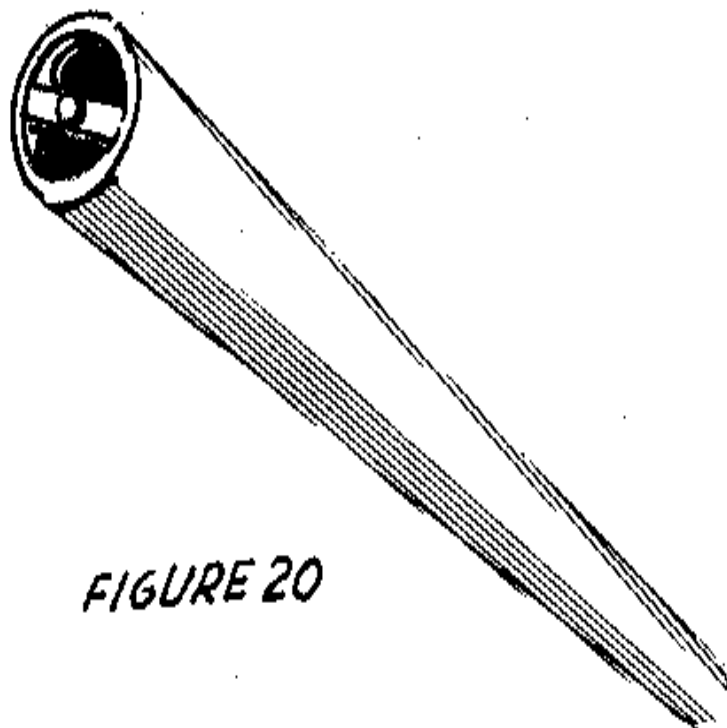
fig20420.gif (393x393)

FIGURE 20

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 people 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 people 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.

Bit for Drilling Rock

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

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**
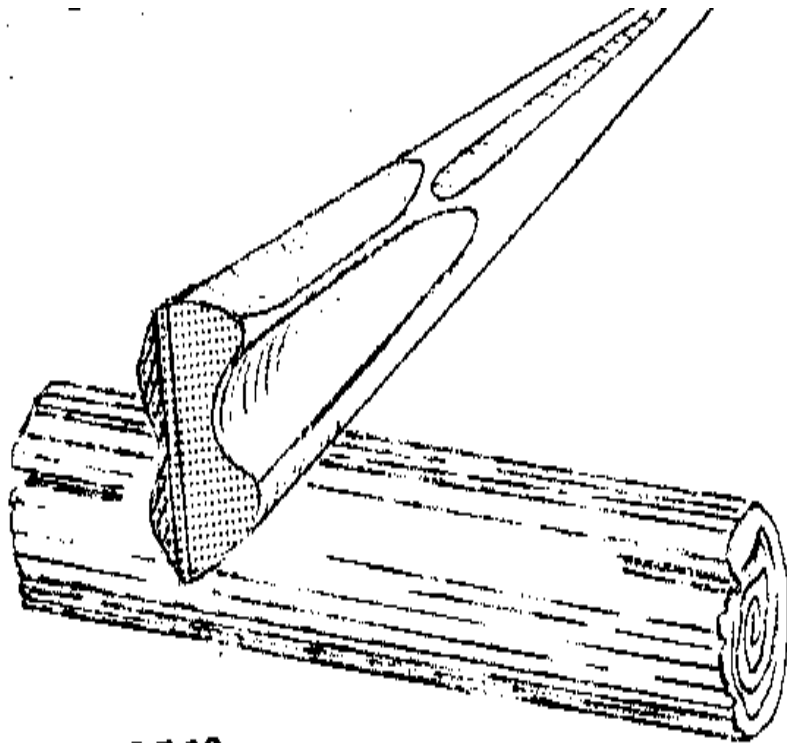
fig22440.gif (393x393)

FIGURE 22
HEAVY BIT FOR DRILLING ROCK

**handle) for attaching a rope or
cable 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 may be possible,
depending on the circumstances, 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.

In using the drilling bit, put the pulley in place as with the bailing bucket, attach
the bit to its rope or cable, and lower it 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 to raise and drop the bit is to
run the rope through the pulley and then straight back to a tree or post where it
can be 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

fig24x46.gif (393x393)

FIGURE 24
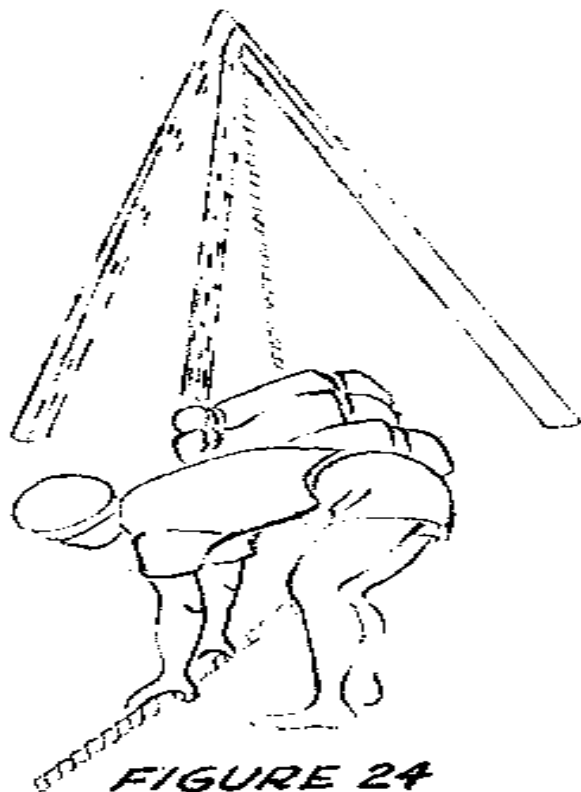
to seven workers, occasionally more. Frequent rests are necessary, usually after
every 50 to 100 strokes. Because
the work is harder near the ends
of the rope than in the middle, the
positions of the workers should be
rotated to distribute the work
evenly.

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

The speed of drilling, of course,
depends 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.

Occasionally the bit may become stuck in the well and it will be necessary to
use
a lever arrangement consisting of a long pole attached to the rope to free it
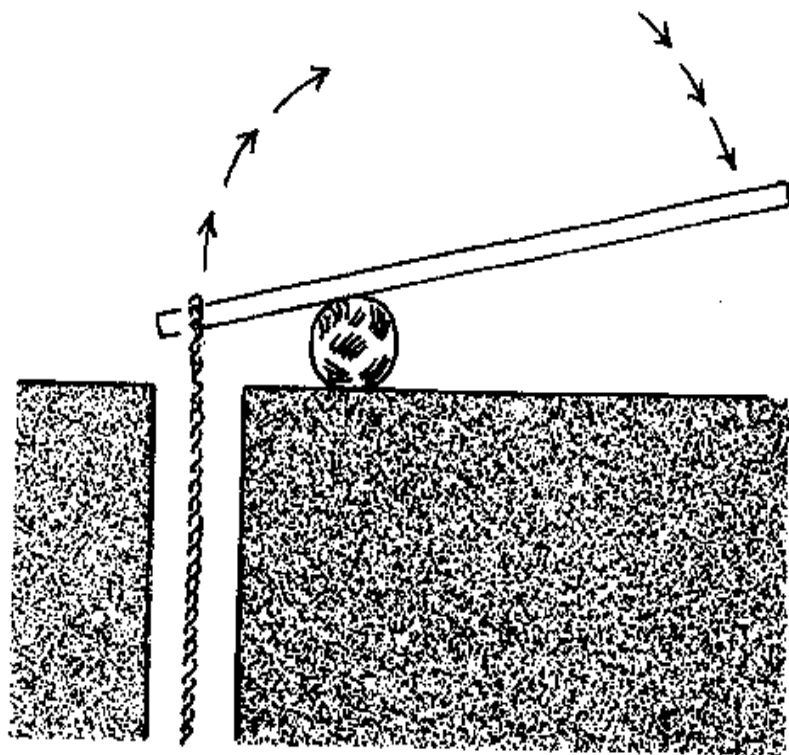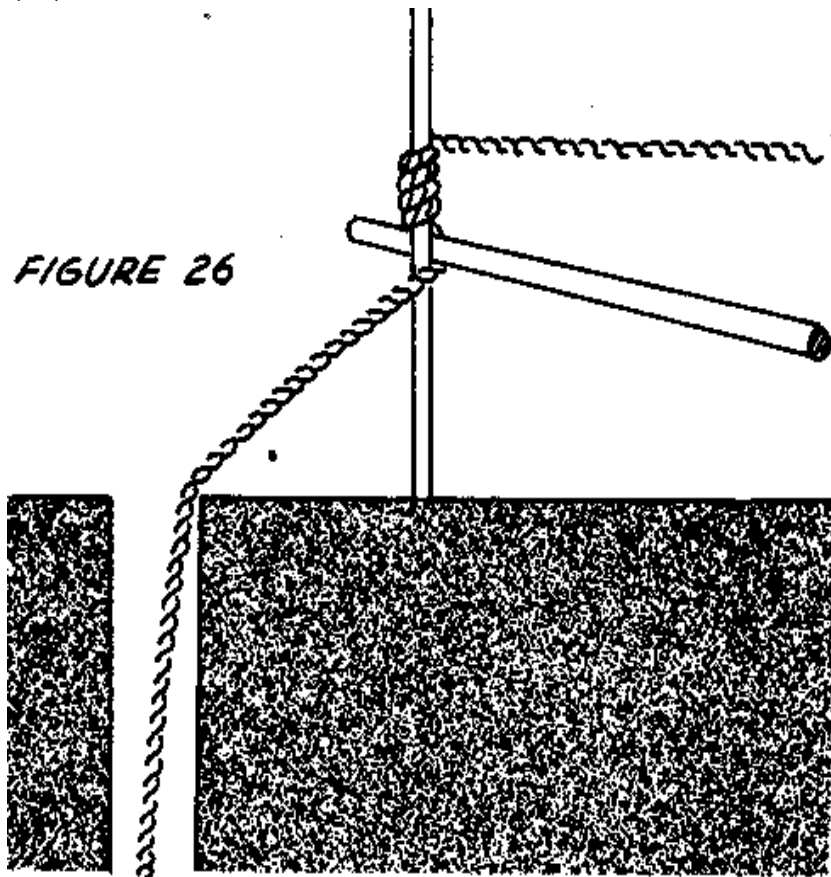(see Figure 25).

fig25x47.gif (437x437)

FIGURE 25

Alternatively, a windlass may be used, consisting of a horizontal pole
used to wrap the rope around a vertical pole pivoted on the ground and held in
place by several workers (see Figure 26). If these fail, it may be necessary to

fig26x47.gif (437x437)

FIGURE 26

rent or borrow a chain hoist. A worn rope or cable may break when trying to
retrieve a stuck bit. If this happens, fit a hook to one of the auger
extensions,
attach enough extensions together to reach the desired depth, and after hooking
the bit, pull with the chain hoist. A rope or cable may also be used for this
purpose, but are considerably more difficult to hook onto the bit.

Drilling Mechanically

The following method can be used for raising and dropping the bit

mechanically:

o Jack up the rear wheel of a car and replace the wheel with a small
drum (or use the rim as a pulley).
o Take the rope that is attached to the bit, come from the tripod on
the pulley, and wrap the rope loosely around the drum.
o 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.
o 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
that 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 that 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 can be dug in less than three hours with this method,
which works best in sandy soil, according to the author of this entry, who has
drilled 30 wells with it.

Tools and Materials

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: 20cm (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)

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.

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

fig1x49.gif (600x600)

BOLT

CHAIN

ROPE

TRIPOD

PULLEY

DRY BUCKET

FIGURE 1
DRY BUCKET
FOR WELL
DRILLING
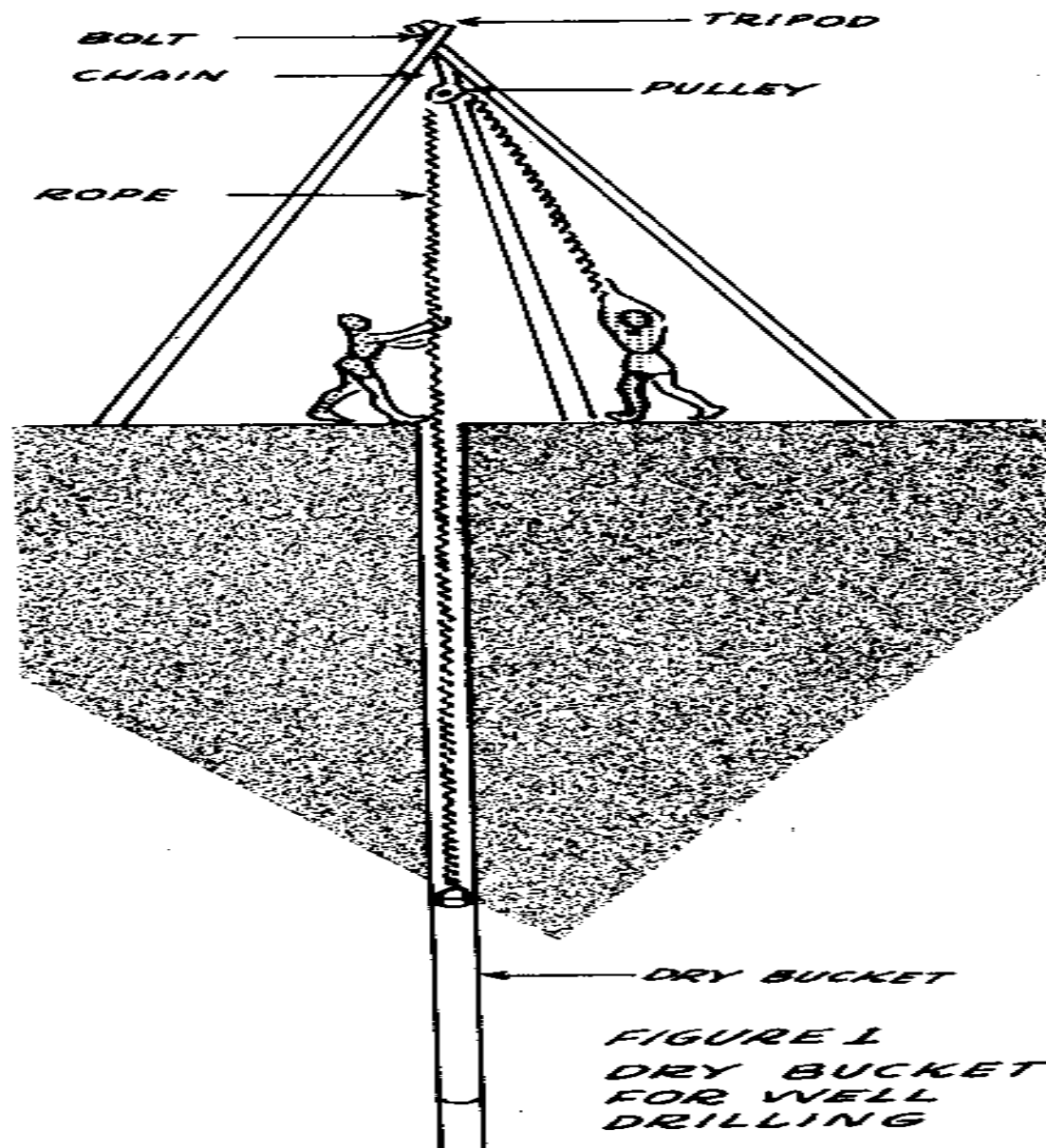
amount of soil up into the bucket. After this is repeated two or three times, the

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.

To make the dry bucket, you will need the following 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

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

fig2x49.gif (486x486)
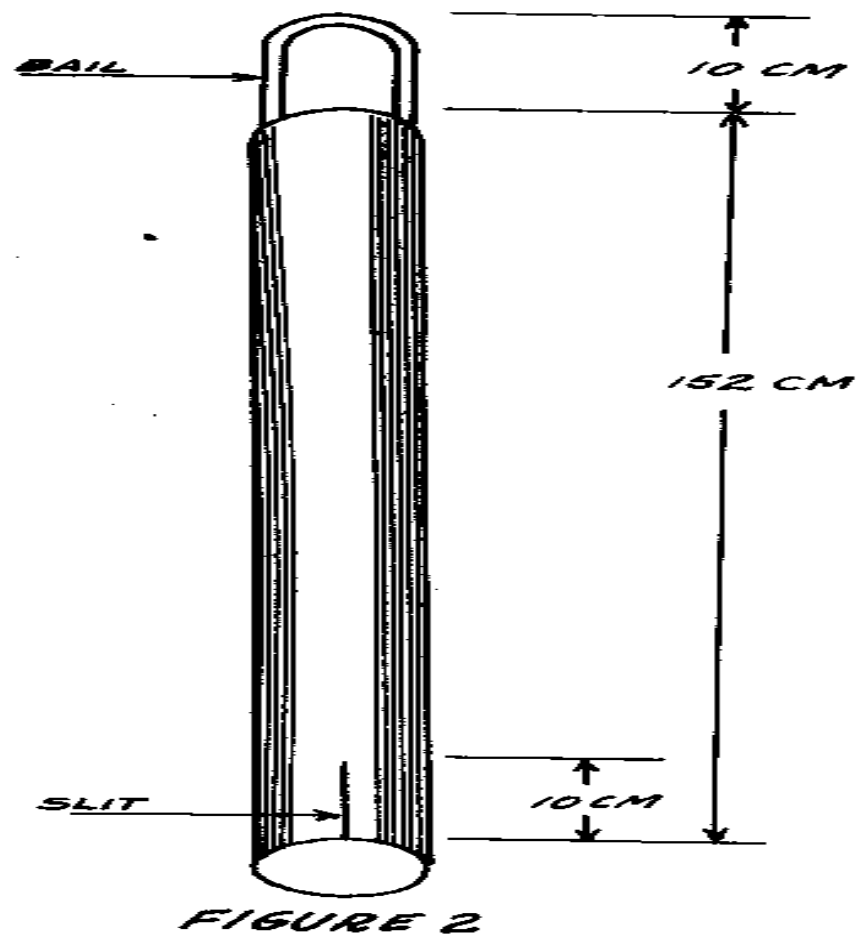
FIGURE 2

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

fig3x49.gif (393x393)

38 MM
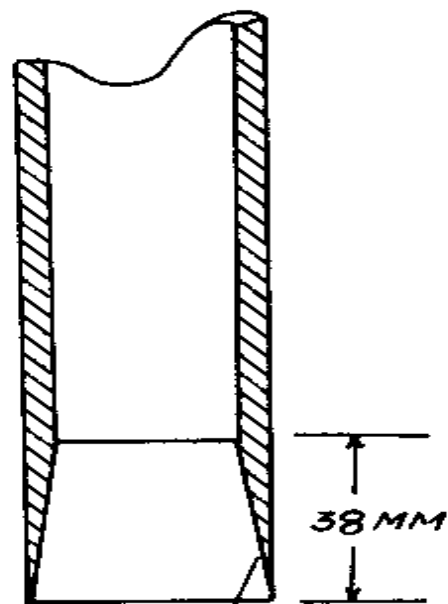
FILED
CUTTING EDGE

FIGURE 3

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

Source:

John Brelsford, VITA Volunteer, New Holland, Pennsylvania

Driven 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 (see Figure 1):

fig1x50.gif (486x486)
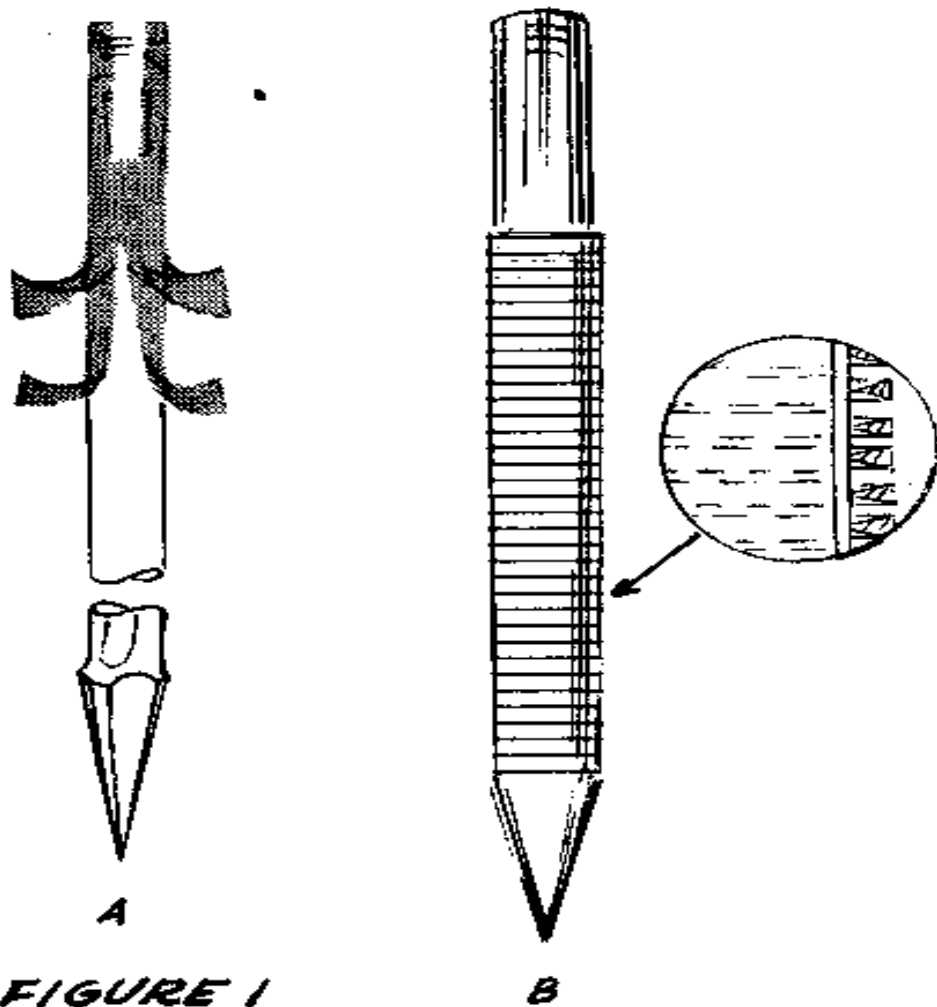
FIGURE 1

usually obtainable through mail order houses
from the United States and elsewhere
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 - 15 meters (33'
to 49'). (Note that suction pumps generally cannot raise water beyond 10 meters.)

The most common types of well points are:

o 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;

o a slotted steel pipe with no covering screen, which allows more water to enter but is less rugged.

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

The joints of the drive pipe must be carefully made to prevent thread breakage and assure airtight operation. Clean and oil the threads carefully and use joint compound and special drive couplings when available. To ensure 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).

fig2x51.gif (600x600)

FIGURE 2

Cold Rolled Shafting Weight 20 to 25 lbs.

Welded Joint

Vent Hole

Pipe - Weight 25 to 30 lbs

Drive Cap

Riser Pipe

Riser Pipe

Driving Bar

Coupling

Sand Screen

Driving Point

Supporting Cable

Falling Weight 40 to 50 lbs

Guide Rod

Drive Head

Coupling

Riser Pipe
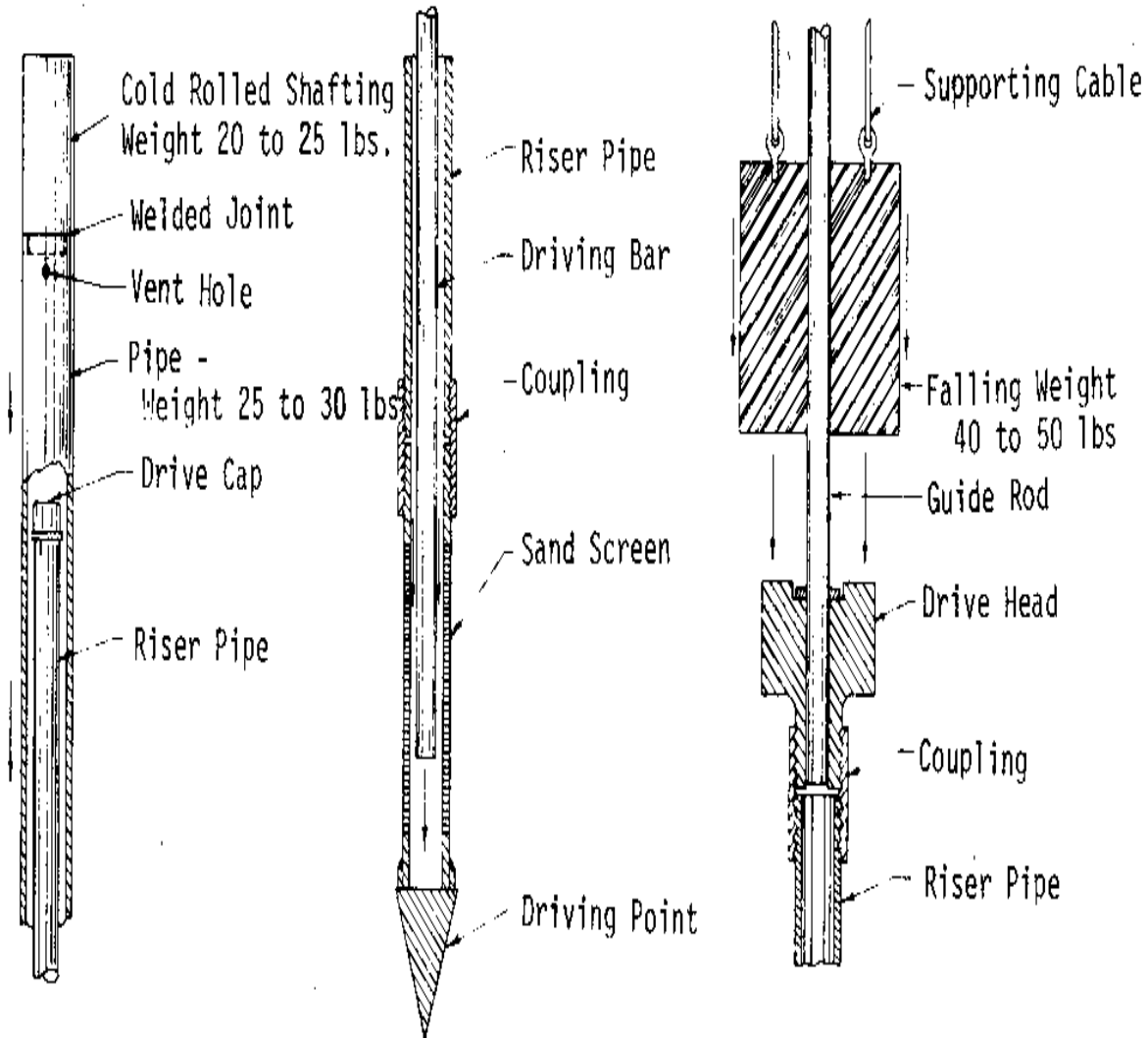
check with a plumb bob to see that the pipe is vertical. Test it occasionally and keep it straight by pushing on the pipe while driving. Hit the drive cap squarely each time or you may damage the equipment.

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 weight dropped over
it, or the pipe itself can be used to guide a falling weight that strikes a
special
drive clamp.

The table in Figure 3 will help identify the formations being penetrated.
Experience

fig3x52.gif (600x600)

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

From: Wells, TM5-297/AFM 85-23, 1957
Army Technical Manual, p.24.

FIGURE 3

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 puddle clay or, if clay is not available, with well-tamped earth. Make a solid, water-proof pump platform (concrete is best) and provide a place for spilled water to drain away.

Source:

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

DUG WELLS <see figure 1>

fig1x54.gif (600x600)

FIGURE I

PUMP ON
CONCRETE
PLATFORM

CASING
EXTENDS
AT LEAST 30 CM
ABOVE GROUND

CASING MADE OF
CONCRETE HUME
PIPE

EXCAVATED SOIL
FILLED AROUND
CASING

SPACE TO INDICATE
WELL MIGHT BE
DEEPER THAN SHOWN

CEMENT MORTAR
PACKED INSIDE
CONCRETE COLLAR

CYLINDER

SAND 61 CM

GRAVEL 30.5 CM

REINFORCED
CONCRETE
COVER

CONCRETE
RINGS

HOOKS FOR
LOWERING
RINGS

FOOT VALVE   GRAVEL

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 demand 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 dug wells,
and should be used if your region
allows their construction and an
adequate amount of water can be
drawn from them during the busy
hours (see section on Tubewells).

Deep dug wells have several
disadvantages. The masonry lining

needed is very expensive. Construction
is potentially very dangerous;
workers should not dig deeper than
one and a half meters without
shoring up the hole. An open well
is very easily contaminated by
organic matter that 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 dug well.

Sealed Dug Well

The well described here has an
underground concrete tank that 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.

Many of these wells were installed in India by an American Friends Service
Committee team there; they perform well unless they are not deep enough or
sealed and capped properly.

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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 that they 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:
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o It provides pure water, safe for drinking.
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o It presents no hazard of children falling in.
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o Drawing water is easy, even for small children.

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

o The cost of installation is greatly reduced.

o The labor involved is much reduced.

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

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

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

On the other hand, compared to a well where people draw their own buckets or other containers of water, there are three minor disadvantages: only one person can pump at a time, the pump requires regular maintenance, 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 dropped to its lowest
level. There should be a full 3 meter (10') reaccumulation of water within 24 hours after the well has been bailed or pumped dry. Greater depth is, of course, desirable.

Spread 15cm (6") of clean, washed gravel or small rock over the bottom of the well. 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.

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 the shaft is 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 soil that 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. Philadelphia: American Friends Service Committee, 1956 (Mimeographed).

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, in many places these wells are dug by people unfamiliar with good sanitation methods and become 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.
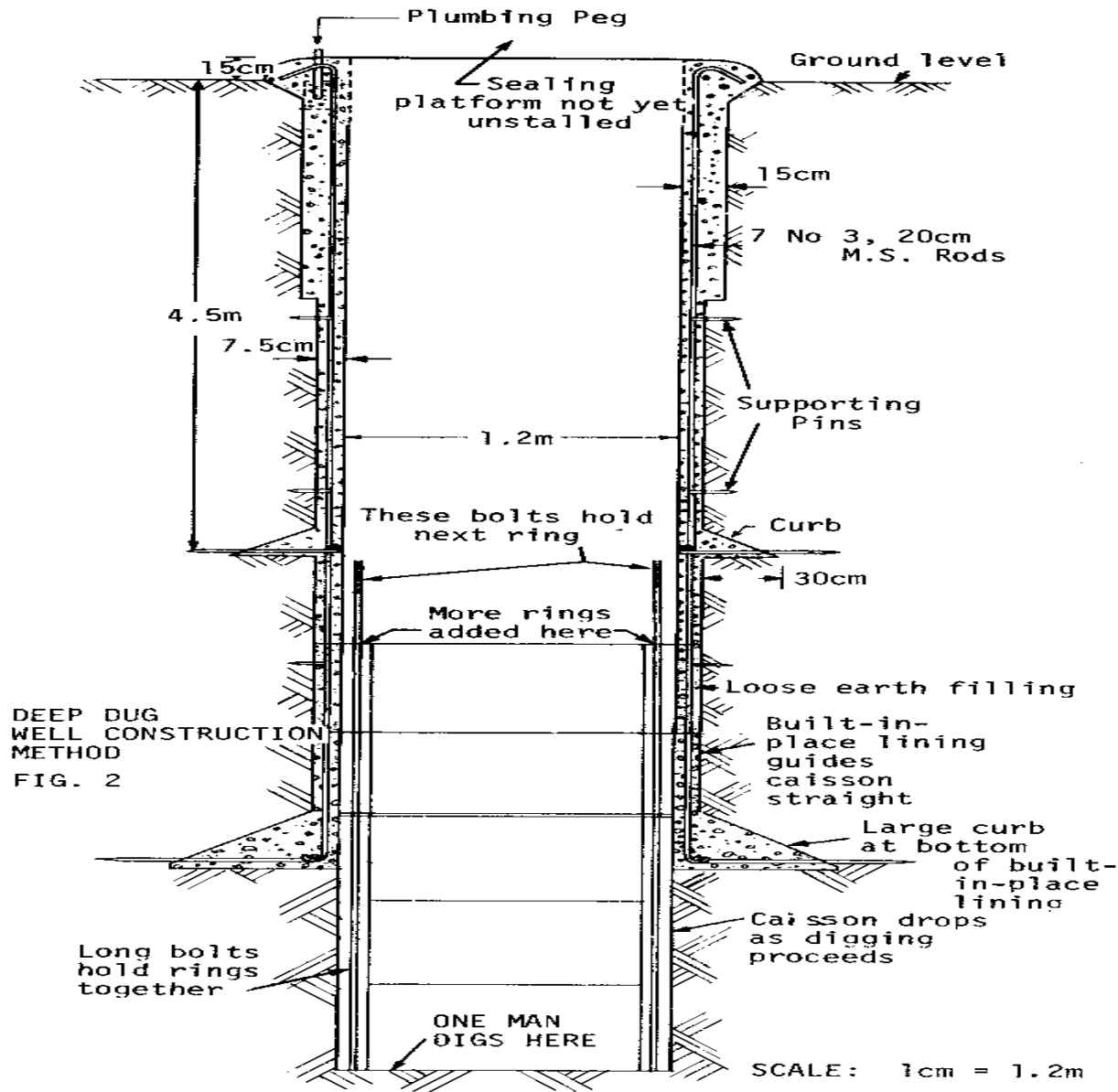
Experience has shown that for one person, the average width of a round well for best digging speed is 1 meter (3 1/4'). However, 1.3 meters (4 1/4') is best for two workers digging together and they dig more than twice as fast as one person. Thus, two workers in the larger hole is usually best.

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 (Figure 2.)

fig2x58.gif (600x600)

Plumbing Peg

Ground level

15cm

Sealing platform not yet unstalled

15cm

7 No 3, 20cm M.S. Rods

4.5m

7.5cm

Supporting Pins

1.2m

These bolts hold next ring

Curb

30cm

More rings added here

Loose earth filling

DEEP DUG WELL CONSTRUCTION METHOD FIG. 2

Built-in-place lining guides caisson straight

Large curb at bottom of built-in-place lining

Caisson drops as digging proceeds

Long bolts hold rings together

ONE MAN DIGS HERE

SCALE: 1cm = 1.2m

If possible, use concrete for the lining because it is strong, permanent, and made

mostly of local materials. It can also 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 mortar has set firmly between the bricks or stones.

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

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

o set up a tripod winch over cleared, level ground and mark reference points for plumbing and measuring the depth of the well.

o have two workers dig the well while another raises and unloads the dirt until the well is exactly 4.6 meters (15') deep.

o trim the hole to size using a special jig mounted on the reference points.

o place the forms carefully and fill 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 that 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; there an extra-deep
curb is constructed. From this point on, caissoning is used.

Caissons are concrete cylinders fitted with bolts to attach 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. As workers dig, 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.

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.

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 involves installation of a buried concrete slab; see
Figure 3

fig3x60.gif (600x600)

NOTE: Concrete well platform to be laid after backfill has sufficiently steeled.

Weep hole to be placed below frost depth to provide antifreeze installation.

CLOSED TOP PUMP

STUFFING BOX

NOTE: Pump stand and base muse be in one piece, joined by flanged or threaded connection.

Cylinder to be placed below point of maximum drawdown.

Asphaltic Seal

Reinforcing Steel

Original Ground Line

Cobble Drain

Platform Drain

10mm MIN.

Earth Backfill Tamped

OR PUDDLED CLAY

CASING

300cm MIN.

PUDDLED CLAY

BACKFILL

WEEP HOLE

ASPHALTIC SEAL

REINFORCING STEEL

12.5mm MIN.

15mm MIN.

NOTE:

Embed in concrete one or two strap iron casing clamps of sufficient strength and size to rigidly support casing and pump.

NOTE: Excavate and remove old curbing to point not less than 3mm from surface where existing curbing is found to be solid. Grouting should extend a sufficient depth below this point to provide proper watertight protection for cap.
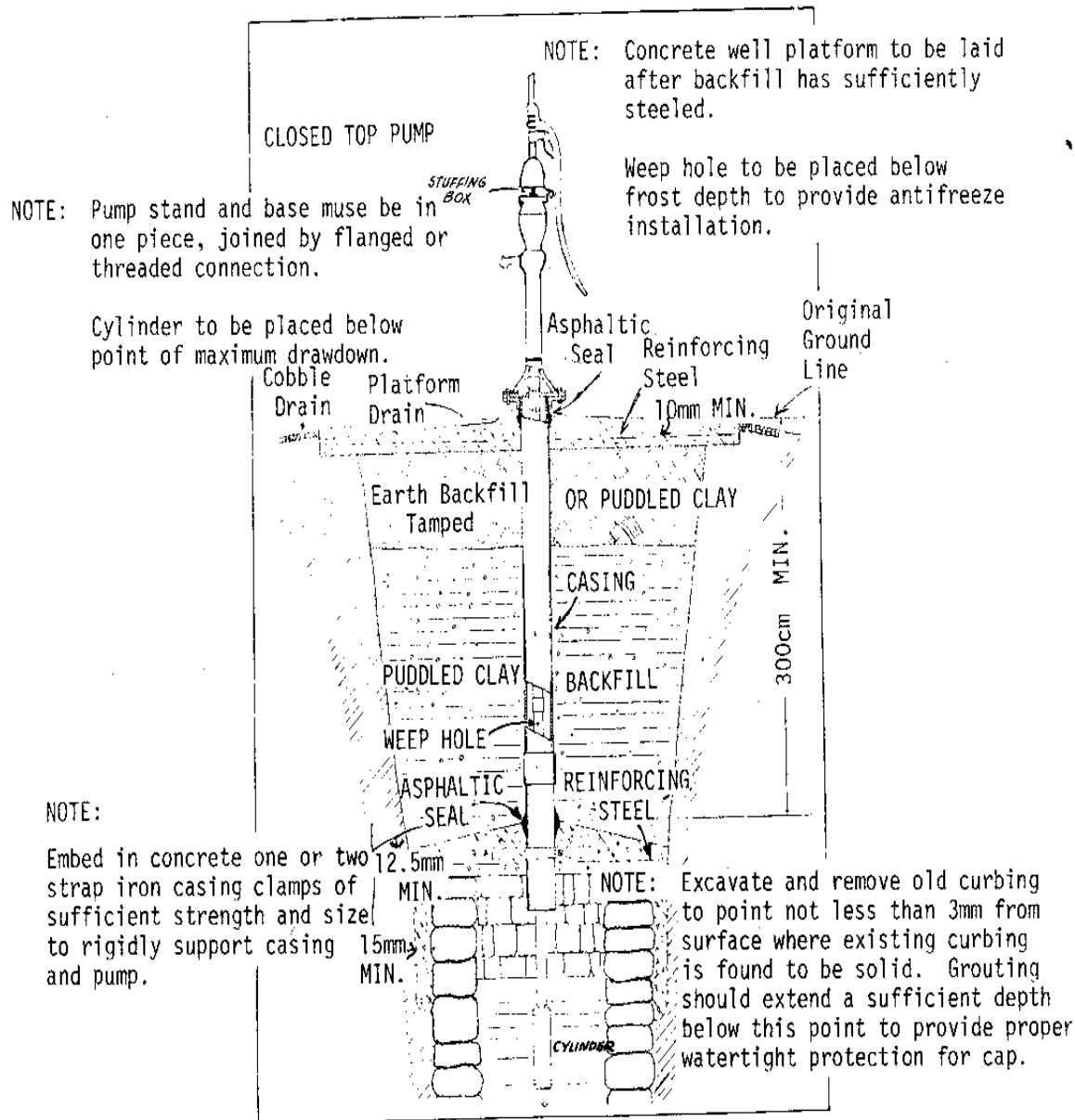
CYLINDER

FIGURE 3

for construction details.

Tools and Materials

Tools and materials for reinforced concrete
A method for entering the well
Pump and drop pipe

Before starting, check the following:

o 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?

o Has the well ever gone dry? Should you deepen it as well as clean it?

o Surface drainage should generally slope away from the well and there should
be effective disposal of spilled water.

o What method will you use to remove the water and what will it cost?

o 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. Tie a rope around the person entering the well and have two
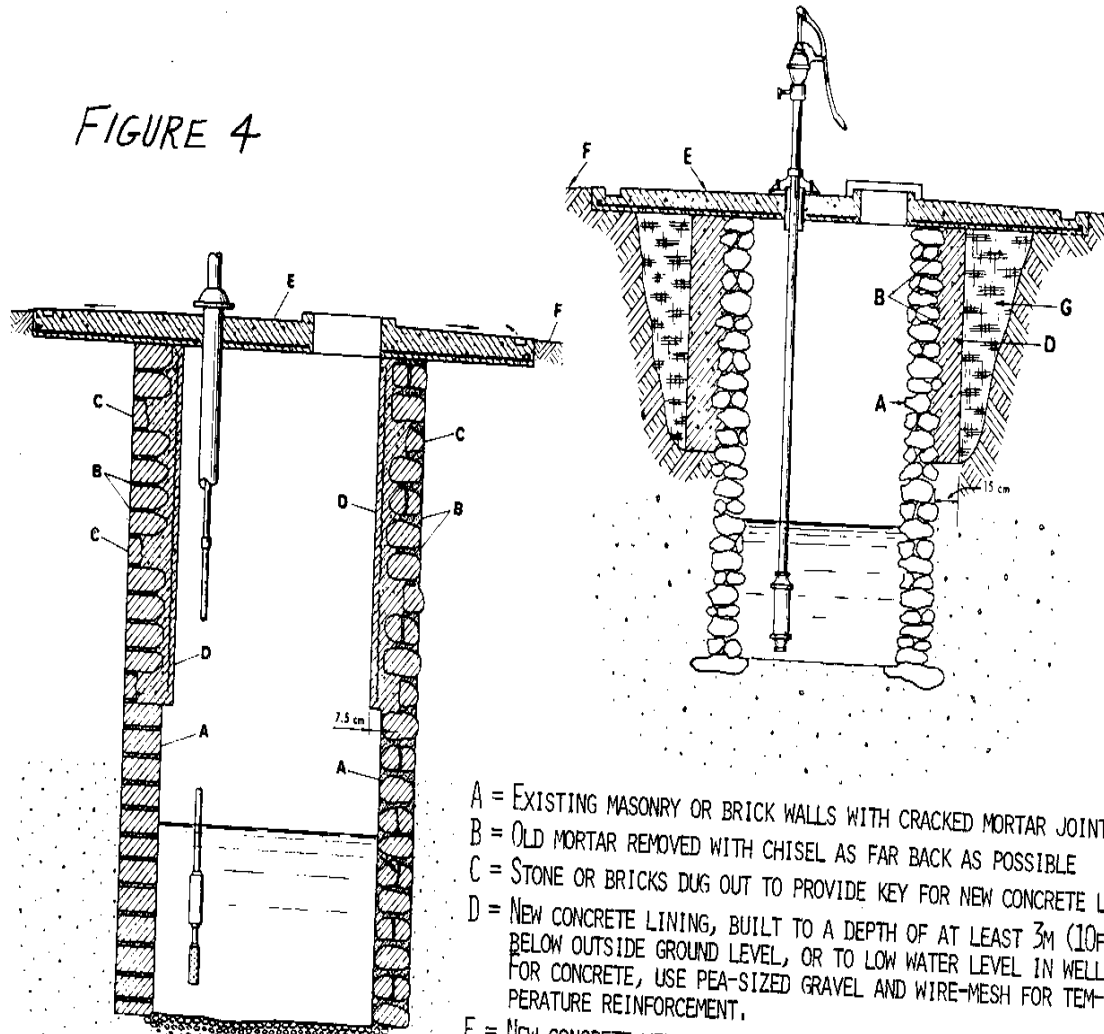strong workers on hand to pull him out in case of accident.

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

fig4x62.gif (600x600)

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 3M (10FT)
BELOW OUTSIDE GROUND LEVEL, OR TO LOW WATER LEVEL IN WELL.
FOR CONCRETE, USE PEA-SIZED GRAVEL AND WIRE-MESH FOR TEM-
PERATURE REINFORCEMENT.
E = NEW CONCRETE WELL TOP, INCORPORATING SANITARY FEATURES (MAN-
HOLE 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 15CM (6IN) THICK

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 "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 opening. Additional soil will usually 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 20-23 liters (5 1/2 to 6 gallons) of water to a
43kg (94 pound) sack of cement. Extend the lining 70cm (27 1/2") 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 drain water 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 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.

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:

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

Manual of Individual Water Supply Systems, Public Health Service Publication No. 24. Washington, D.C.: Department of Health and Human Services.

SPRING DEVELOPMENT

Springs, particularly in sandy soil, often make excellent water sources, but they
should be dug deeper, sealed, protected by a fence, and piped to the home. Proper
development of a spring will increase the flow of ground water and lower the
chances of contamination from surface water. If fissured rock or limestone are
present, get expert advice before attempting to develop the spring.

Springs occur where water, moving through porous and saturated underground
layers of soil (aquifer), emerges at the ground surface. They can be either:

o Gravity seepage, where the water bearing soil reaches the surface over an
impermeable layer, or

o Pressure or artesian, where the water, under pressure and trapped by a hard
layer of soil, finds an opening and rises to the surface. (In some parts of
the world, all springs are called artesian.)

The following steps should be considered in developing springs:

1) Observe the seasonal flow variations over a period of a year if possible.

2) Determine the type of spring-seepage or artesian-by digging a small
hole. An earth auger with extensions is the most suitable tool for that
job. It may not be possible to reach the underlying impermeable layer.

3) Have chemical and biological tests made on samples of the water.

Dig a small hole near the spring to learn the depth of the hard layer of soil and
to find out whether the spring is gravity seepage or pressure. Check uphill and
nearby for sources of contamination. Test the water to see if it must be purified
before being used for drinking. A final point: Find out if the spring runs during
long dry spells.

For gravity-fed springs, the soil is usually dug to the hard, underlying layers and
a tank is made with watertight concrete walls on all but the uphill side (see
Figures 1 and 2).

fig1x650.gif (600x600)

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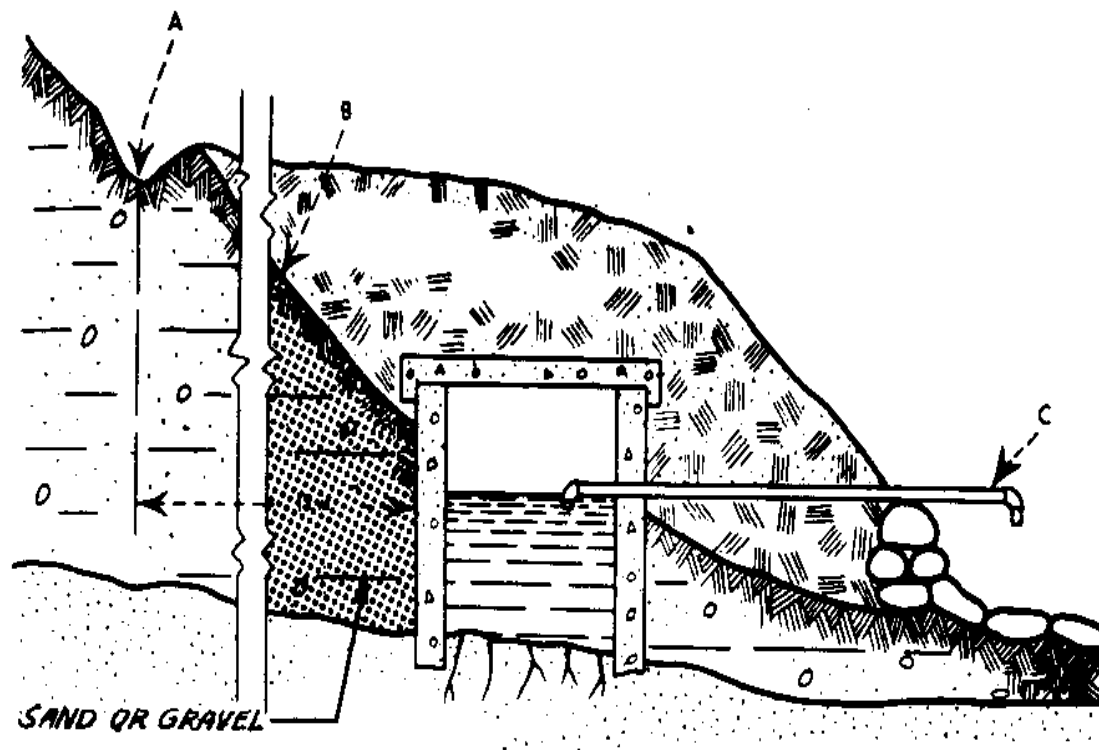
A = Protective drainage ditch to keep drainage water a safe distance from spring
B = Original slope and ground line
C = Screened outlet pipe : can discharge freely or be piped to village or residence

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

The opening on the uphill side should be lined with porous concrete or stone without mortar, so that it will admit the gravity seepage water.

It can be backfilled with gravel and sand, which helps to keep fine materials in the water-bearing soil from entering the spring. If the hard soil cannot be reached easily, a concrete cistern is built that can be fed by a perforated pipe placed in the water-bearing layer of earth. With a pressure spring, all sides of the tank are made of watertight reinforced concrete, but the bottom is left open.
The water enters through the bottom.

Read the section in this handbook on cisterns before developing your spring. No matter how the water enters your tank, you must make sure the water is pure by:

o building a complete cover to stop surface pollution and keep out sunlight, which causes algae to grow.

o installing a locked manhole with at least a 5cm (2") overlap to prevent entrance of polluted ground water.

o installing a screened overflow that discharges at least 15cm (6") above the ground. The water must land on a cement pad or rock surface to keep the water from making a hole in the ground and to ensure proper drainage away from the spring.

o arranging the spring so that surface water must filter through at least 3 meters (10') of soil before reaching the ground water. Do this by making a diversion ditch for surface water about 15 meters (50') or more from the spring. Also, if necessary, cover the surface of the ground near the spring with a heavy layer of soil or clay to increase the distances that rainwater must travel, thus ensuring that it has to filter through 3 meters (10') of soil.

o making a fence to keep people and animals away from the spring's immediate surroundings. The suggested radius is 7.6 meters (25').

o installing a pipeline from the overflow to the place where the water is to be used.

Before using the spring, disinfect it thoroughly by adding chlorine or chlorine compounds. Shut off the overflow to hold the chlorine solution in the well for 24
hours. If the spring overflows even though the water is shut off, arrange to add chlorine so that it remains strong for at least 30 minutes, although 12 hours would be much safer. After the chlorine is flushed from the system have the water tested. (See section on "Superchlorination.")

Sources:

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

Manual of Individual Water Supply Systems, Public Health Service Publication No. 24. Washington, D.C.: U.S. Department of Health and Human Services.

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Water Lifting and Transport

OVERVIEW

Once a source of water has been found and developed, four basic questions must be answered:

1. What is the rate of flow of the water in your situation?
2. Between what points must the water be transported?
3. What kind and size of piping is needed to transport the required flow?
4. What kind of pump, if any, is necessary to produce the required flow?

The information in this section will help you to answer the third and fourth questions, once you have determined the answers to the first two.

Moving Water

The first three entries in this section discuss the flow of water in small streams,
partially filled pipes, and when the height of the reservoir and size of pipe are
known. They include equations and alignment charts (also called nomographs) that give simple methods of estimating the flow of water under the force of gravity, that is, without pumping. The fourth tells how to measure flow by observing the spout from a horizontal pipe.

Four entries follow on piping, including a discussion of pipes made of bamboo.

You will note that in the alignment charts here and elsewhere, the term "nominal
diameter, inches, U.S. Schedule 40" is used along with the alternate term,
"inside
diameter in centimeters," in referring to pipe size.

Pipes and fittings are usually manufactured to a standard schedule of sizes.
U.S.
Schedule 40, the most common in the United States, is also widely used in other
countries. When one specifies "2-inch Schedule 40," one automatically specifies
the
pressure rating of the pipe and its inside and outside diameters (neither of
which,
incidentally, is actually 2"). If the schedule is not known, measure the inside
diameter and use this for flow calculations.

Lifting Water

Next, several entries follow the steps required to design a water-pumping system
with piping. The first entry in this group, "Pump Specifications: Choosing or
Evaluating a Pump," presents all the factors that must be considered in
selecting
a pump. Fill out the form included there and make a piping sketch, whether you
plan to send it to a consultant for help or do the design and selection
yourself.

The first pieces of information needed for selecting pump type and size are: (1)
the flow rate of water needed and (2) the head or pressure to be overcome by
the pump. The head is composed of two parts: the height to which the liquid must
be raised, and the resistance to flow created by the pipe walls (friction-loss).

The friction-loss head is the most difficult factor to measure. The entry "Determining
Pump Capacity and Horsepower Requirements" describes how to select the
economic pipe size(s) for the flow desired. With the pipe(s) selected one must
then calculate the friction-loss head. The entry "Estimating Flow Resistance of
Pipe Fittings" makes it possible to estimate extra friction caused by constrictions
of pipe fittings. With this information and the length of pipe, it is possible to
estimate the pump power requirement using the entry, "Determining Pump Capacity
and Horsepower Requirements."

These entries have another very important use. You may already have a pump and
wonder "Will it do this job?" or "What size motor should I buy to do this job
with the pump I have?" The entry "Pump Specifications: Choosing or Evaluating a
Pump" can be used to collect all the information on the pump and on the job you
want it to do. With this information, you can ask a consultant or VITA if the
pump can be used or not.

There are many varieties of pumps for lifting water from where it is to where it
is to be delivered. But for any particular job, there are probably one or two kinds
of pumps that will serve better than others. We will discuss here only two broad
classes of pumps: lift pumps and force pumps.

A lift or suction pump is located at the top of a well and raises water by
suction. Even the most efficient suction pump can create a negative pressure of
only 1 atmosphere: theoretically, it could raise a column of water 10.3m (34')

at
sea level. But because of friction losses and the effects of temperature, a suction
pump at sea level can actually lift water only 6.7m to 7.6m (22' to 25'). The entry
"Determining Lift Pump Capability" explains how to find out the height a lift
pump will raise water at different altitudes with different water temperatures.

When a lift pump is not adequate, a force pump must be used. With a force pump,
the pumping mechanism is placed at or near the water level and pushes the water
up. Because it does not depend on atmospheric pressure, it is not limited to a
7.6m (25') head.

Construction details are given for two irrigation pumps that can be made at the
village level. An easy-to-maintain pump handle mechanism is described. Use of
the
hydraulic ram, a self-powered pump, is described.

Finally, there are entries on Reciprocating Wire Power Transmission for Water
Pumps, and on Wind Energy for Water Pumping. Further details on pumps can be
found in the publications listed below and in the Reference section at the back
of
the book.

Margaret Crouch, ed. Six Simple Pumps. Arlington, Virginia: Volunteers in
Technical Assistance, 1982.

Molenaar, Aldert. Water Lifting Devices for Irrigation. Rome: Food and
Agriculture

Organization, 1956.

Small Water Supplies. London: The Ross Institute, The London School of Hygiene and Tropical Medicine, 1967.

WATER TRANSPORT

Estimating Small Stream Water Flow

A rough but very rapid method of estimating water flow in small streams is given here. In looking for water sources for drinking, irrigation, or power generation, one should survey all the streams available. If sources are needed for use over a long period, it is necessary to collect information throughout the year to determine flow changes-especially high and low flows. The number of streams that must be used and the flow variations are important factors in determining the necessary facilities for utilizing the water.

Tools and Materials

Timing device, preferably watch with second hand
Measuring tape
Float (see below) <see figure 1>

fig1x69.gif (393x393)

FIGURE 1

Stick for measuring depth

The following equation will help you to measure flow quickly:

Q = KxAxV,

where:

Q (Quantity) = flow in liters per minute

A (Area) = cross-section of stream, perpendicular to flow, in square meters

V (Velocity) = stream velocity, meters per minute

K (Constant) = a corrected conversion factor. This is used because surface flow is normally faster than average flow. For normal stages use K = 850; for flood states use]K = 900 to 950.

To Find Area of a Cross-Section

The stream will probably have different depths along its length so select a place
where the depth of the stream is average.

o Take a measuring stick and place it upright in the water about one-half meter (1 1/2') from the bank.

o Note the depth of water.

o Move the stick 1 meter (3') from the bank in a line directly across the stream. Note the depth.

o Move the stick 1.5 meters (4 1/2') from the bank, note the depth, and continue moving it at half-meter (1 1/2') intervals until you cross the stream.

Note the depth each time you place the stick upright in the stream. Draw a grid, like the one in Figure 2, and mark the varying depths on it so that a cross-section
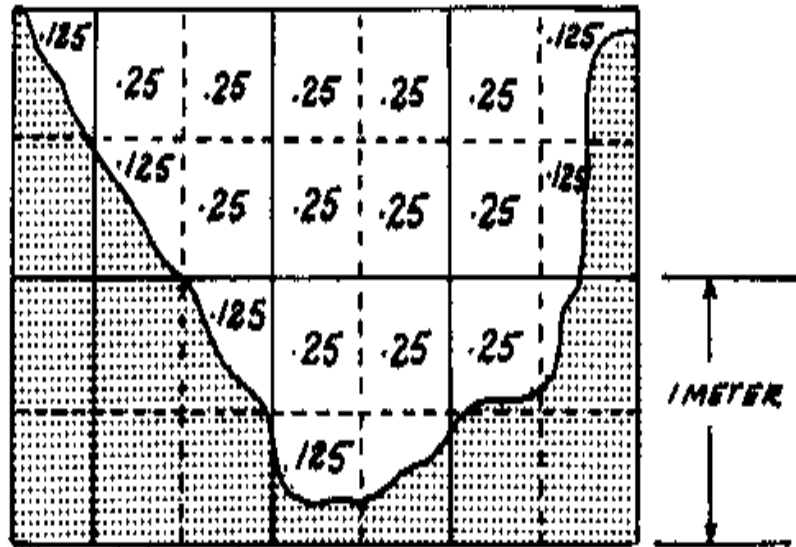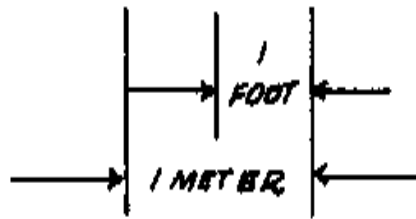
fig2x70.gif (437x437)

FIGURE 2

of the stream is shown. A
scale of 1cm to 10cm is often used
for such grids. By counting the
grid squares and fractions of
squares, the area of the water can
be estimated. For example, the grid
shown here has a little less than 4
square meters of water.

To Find Velocity

Put a float in the stream and measure the distance of travel in one minute (or
fraction of a minute, if necessary.) The width of the stream where the velocity
is
being measured should be as constant as possible and free of rapids.

A light surface float, such as a chip, will often change course because of wind
or
surface currents. A weighted float, which sits upright in the water, will not
change course so easily. A lightweight tube or tin can, partly filled with water
or
gravel so that it floats upright with only a small part showing above water,
makes a good float for measuring.

Measuring Wide Streams

For a wide, irregular stream, it is better to divide the stream into 2- or 3-
meter
sections and measure the area and velocity of each. Q is then calculated for
each
section and the Qs added together to give a total flow.

Example (see Figure 2):

Cross section is 4 square meters

Velocity of float = 6 meters traveled in 1/2 minute

Stream flow is normal

$$Q = \frac{850 \times 4 \times 6 \text{ meters}}{.5 \text{ minute}}$$

Q = 40,800 liters per minute or 680 liters per second

Using English Units

If English units of measurement are used, the equation for measuring stream flow is: Q = K x A x V, where:

Q = flow in U.S. gallons per minute

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

V = stream velocity in feet per minute

K = a corrected conversion factor: 6.4 for normal stages; 6.7 to 7.1 for flood stages

The grid used would be like the one in Figure 3; a common scale is 1" to 12".

fig3x72.gif (393x393)
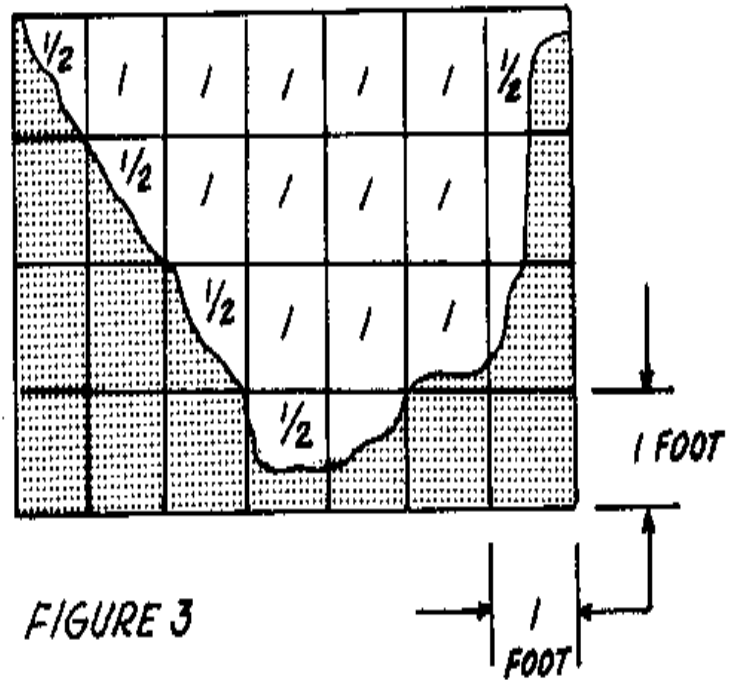
FIGURE 3

Example:

Cross-section is 15 square feet

Float velocity = 20' in 1/2 minute

Stream flow is normal

$$Q = \frac{6.4 \times 15 \times 20 \text{ feet}}{.5 \text{ minute}}$$
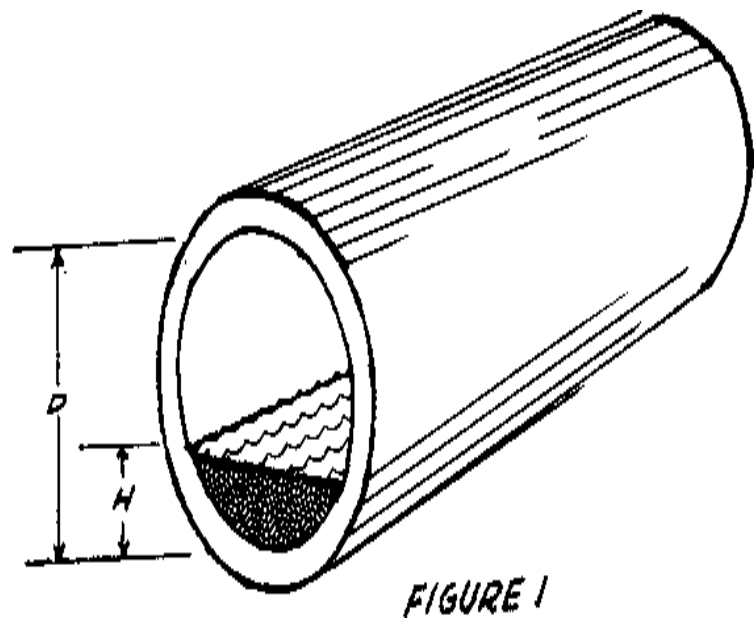
Q = 3,800 gallons per minute

Source:

**Clay, C.H. Design of Fishways and Other Fish Facilities. Ottawa: P.E. Department
of Fisheries of Canada, 1961.**

Measuring Water Flow in Partially-Filled Pipes

The flow of water in partially-filled horizontal pipes (Figure 1) or circular
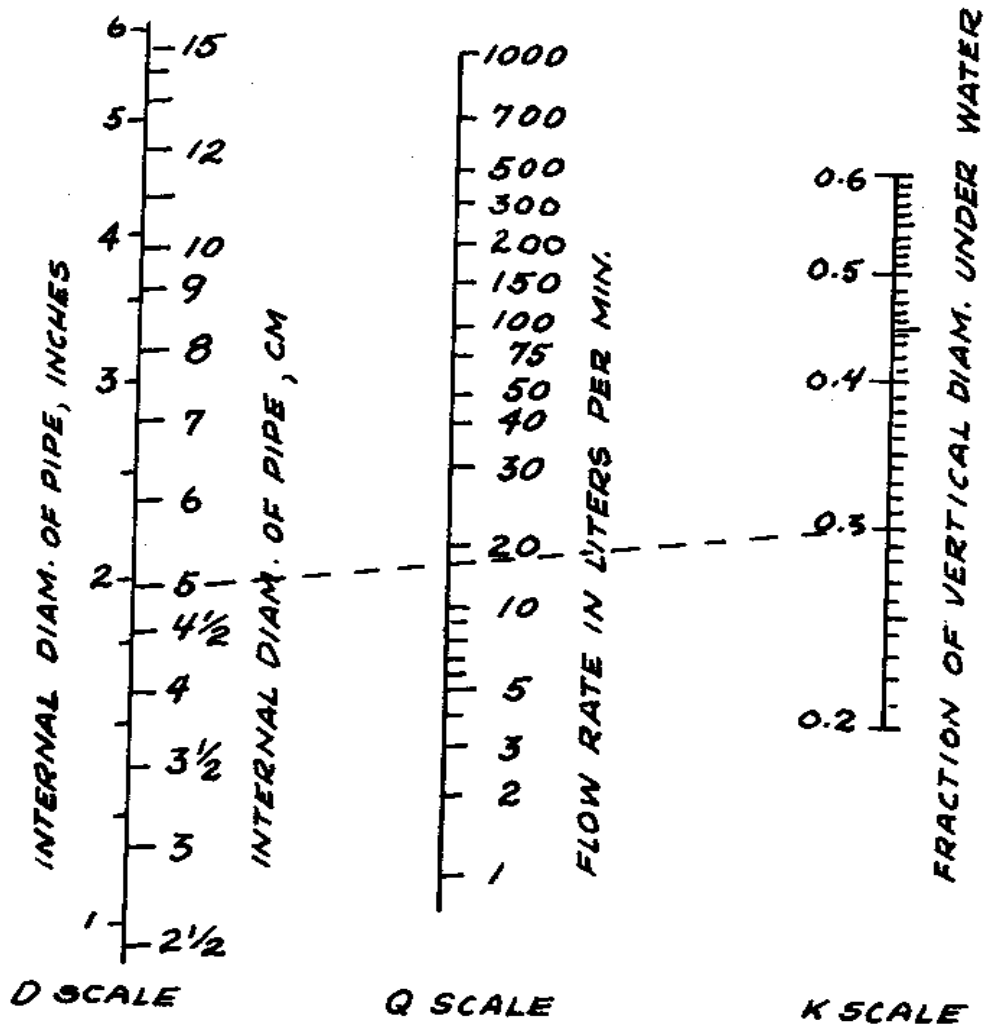
fig1x72.gif (317x393)

FIGURE 1

channels can be determined-if you know the inside diameter of the pipe and the
depth of the water flowing-by using the alignment chart (nomograph) in Figure 2.

fig2x73.gif (540x540)

FIGURE 2

D SCALE   Q SCALE   K SCALE

This method can be checked
for low flow rates and small
pipes by measuring the time
required to fill a bucket or
drum with a weighed quantity
of water. A liter of water
weighs 1kg (1 U.S. gallon of
water weighs 8.33 pounds).

Tools and Materials

Ruler to measure water depth (if ruler units are inches, multiply by 2.54 to
convert to centimeters)
Straight edge, to use with alignment chart

The alignment chart applies to pipes with 2.5cm to 15cm inside diameters, 20 to
60% full of water, and having a reasonably smooth surface (iron, steel, or
concrete sewer pipe). The pipe or channel must be reasonably horizontal if the
result is to be accurate. The eye, aided by a plumb line to give a vertical
reference, is a sufficiently good judge. If the pipe is not horizontal another
method will have to be used. To use the alignment chart, simply connect the
proper point on the "K" scale with the proper point on the "d" scale with the
straight edge. The flow rate can then be read from the "q" scale.

q = rate of flow of water, liters per minute 8.33 pounds = 1 gallon.

d = internal diameter of pipe in centimeters.

K = decimal fraction of vertical diameter under water. Calculate K by measuring the depth of water (h) in the pipe and dividing it by the pipe diameter (d), or K = h (see Figure 1).

fig1x75.gif (600x600)

FIGURE 1

INDEX SCALE
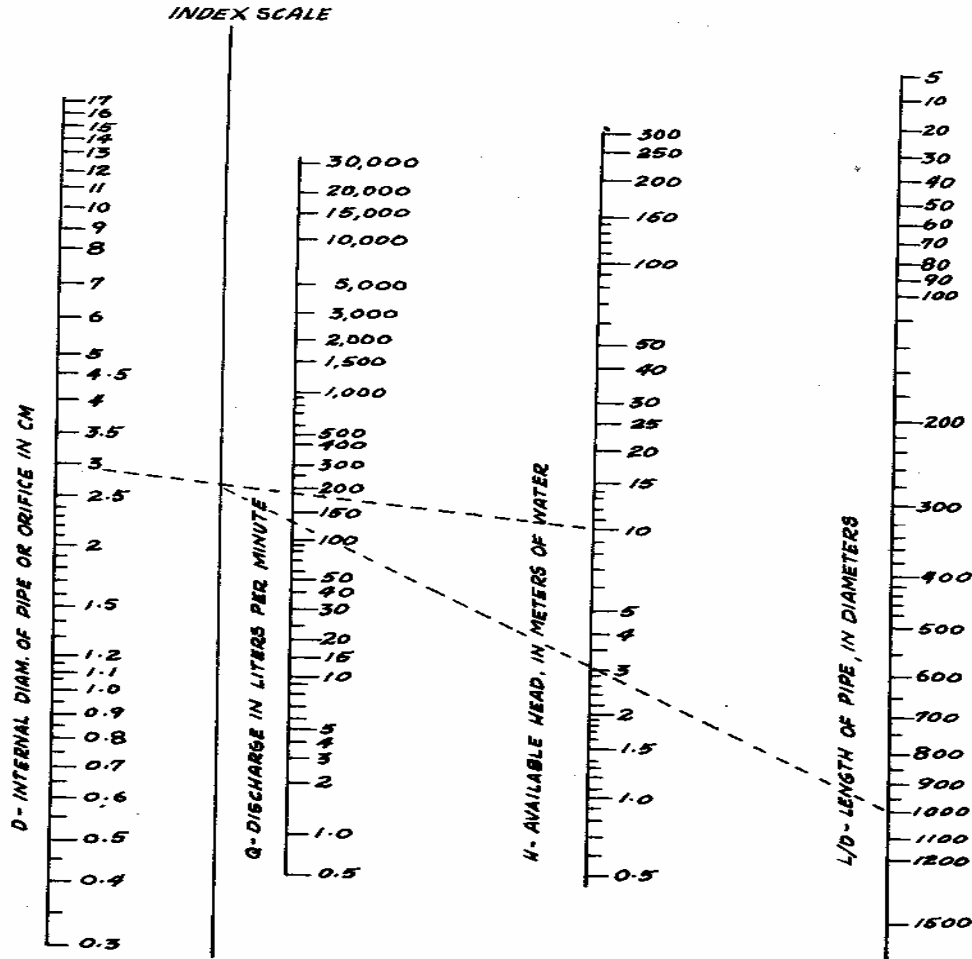
Alignment chart for determining probable water flow with known reservoir height and size and length of pipe.

Source:

Crane Company Technical Paper #407, pages 54-55.

d

Example:

What is the rate of flow of water in a pipe with an internal diameter of 5cm, running 0.3 full? A straight line connecting 5 on the d-scale with 0.3 on the K-scale
intersects the q-scale at flow of 18 liters per minute.

Source:

Greve Bulletin 32, Volume 12, No. 5, Purdue University, 1928.

**Determining Probable Water Flow with Known
Reservoir Height and Size and Length of Pipe**

The alignment chart in Figure 1 gives a reasonably accurate determination of water flow when pipe size, pipe length, and height of the supply reservoir are known. The example given here is for the analysis of an existing system. To design a new system, assume a pipe diameter and solve for flow rate, repeating the procedure with new assumed diameters until one of them provides a suitable flow rate.

Tools and Materials

Straightedge, for use with alignment chart
Surveying instruments, if available

The alignment chart was prepared for clean, new steel pipe. Pipes with rougher surfaces or steel or cast iron pipe that has been in service for a long time may give flows as low as 50 percent of those predicted by this chart.

The available head (h) is in meters and is taken as the difference in elevation between the supply reservoir and the point of demand. This may be crudely estimated by eye, but for accurate results some sort of surveying instruments are
necessary.

For best results, the length of pipe (L) used should include the equivalent lengths
of fittings as described in the section, "Estimating Flow Resistance of Pipe Fittings," p. 76. This length (L) divided by the pipe internal diameter (D) gives
the necessary "L/D" ratio. In calculating L/D, note that the units of measuring both "L" and "D" must be the same, e.g., feet divided by feet; meters divided by meters; centimeters by centimeters.

Example:

Given available head (h) of 10 meters, pipe internal diameter (D) of 3cm, and equivalent pipe length (L) of 30 meters (3,000cm).

Calculate L/D = 3,000cm = 1,000

          3cm

The alignment chart solution is in two steps:

1. Connect internal diameter 3cm to available head (10 meters), and make a mark on the Index Scale. (In this step, disregard "Q" scale)

2. Connect mark on Index Scale with L/D (1,000), and read flow rate (Q) of approximately 140 liters per minute.

Estimating Water Flow from Horizontal Pipes

If a horizontal pipe is discharging a full stream of water, you can estimate the rate of flow from the alignment chart in Figure 2. This is a standard engineering
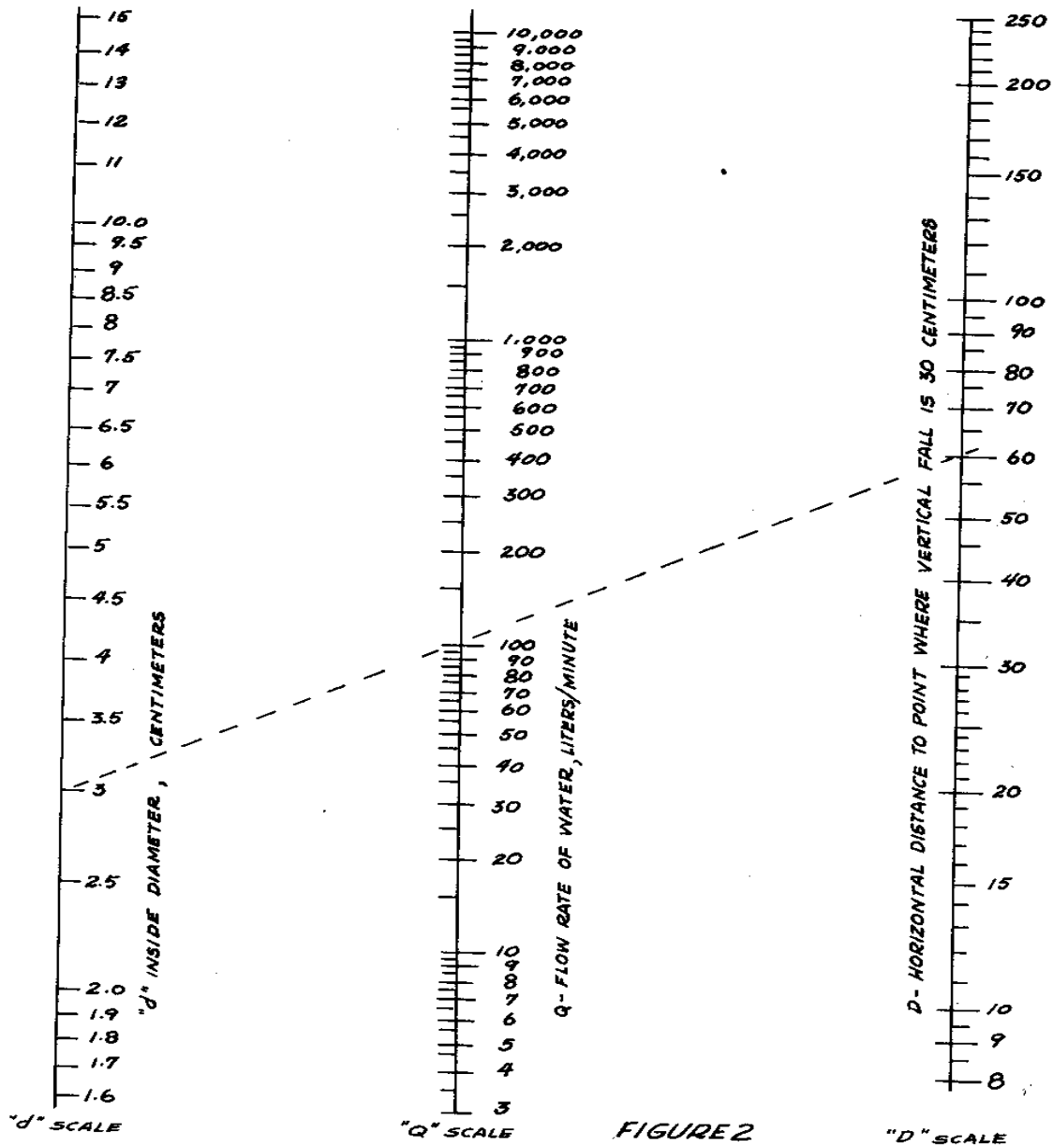
fig2x77.gif (600x600)

FIGURE 2

"d" SCALE — "d" INSIDE DIAMETER, CENTIMETERS

"Q" SCALE — Q - FLOW RATE OF WATER, LITERS/MINUTE

"D" SCALE — D - HORIZONTAL DISTANCE TO POINT WHERE VERTICAL FALL IS 30 CENTIMETERS

technique for estimating flows; its results are usually accurate to within 10 percent of the actual flow rate.

Tools and Materials

Straightedge and pencil, to use alignment chart
Tape measure
Level
Plumb bob

The water flowing from the pipe must completely fill the pipe opening (see Figure 1).
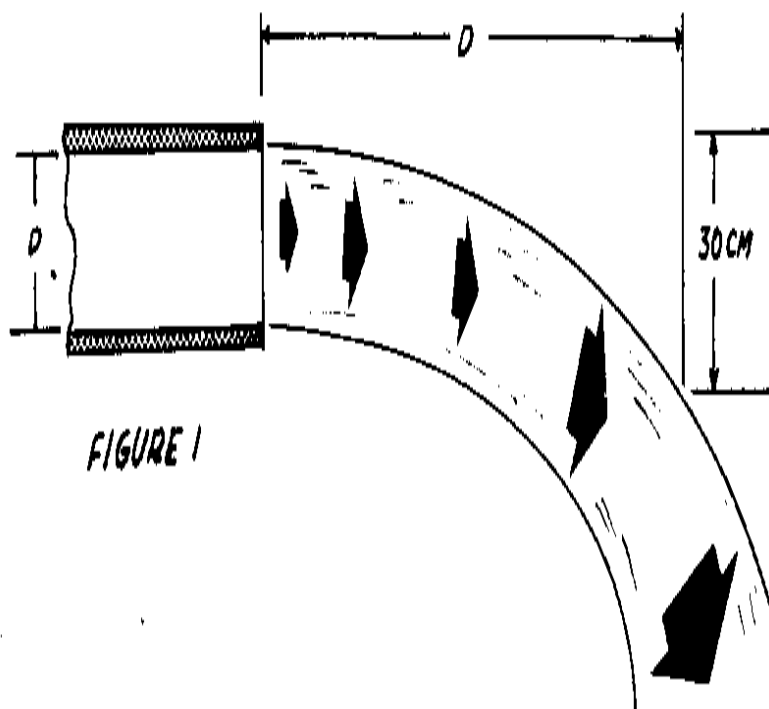
fig1x76.gif (393x393)

FIGURE 1

The results from the chart will be most accurate when there is no constricting or enlarging fitting at the end of the pipe.

Example:

Water is flowing out of a pipe with an inside diameter (d) of 3cm (see Figure 1).
The stream drops 30cm at a point 60cm from the end of the pipe.

Connect the 3cm inside diameter point on the "d" scale in Figure 2 with the 60cm point on the "D" scale. This line intersects the "q" scale

at about 100 liters per minute, the rate at which water is flowing out
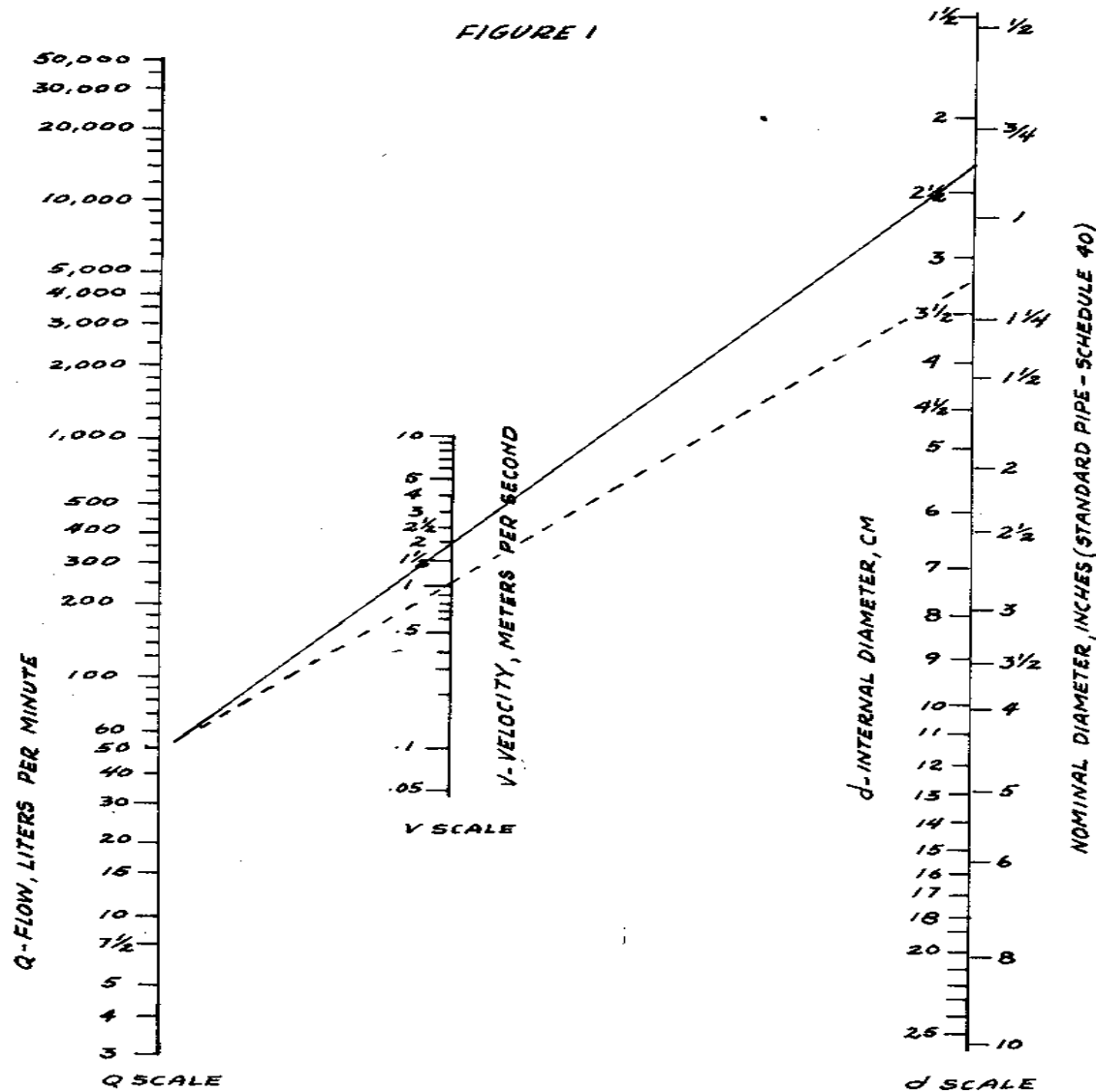of the pipe.

Source:

Duckworth, Clifford C. "Flow of Water from Horizontal Open-end Pipes." Chemical
Processing, June 1959, p. 73.

Determining Pipe Size or Velocity of Water in Pipes

The choice of pipe size is one of the first steps in designing a simple water
system.

The alignment chart in Figure 1 can be used to compute the pipe size needed for

fig1x79.gif (600x600)

FIGURE 1

Q SCALE — Q-FLOW, LITERS PER MINUTE

V SCALE — V-VELOCITY, METERS PER SECOND

d SCALE — d-INTERNAL DIAMETER, CM

NOMINAL DIAMETER, INCHES (STANDARD PIPE - SCHEDULE 40)

a water system when the water velocity is known. The chart can also be used to find out what water velocity is needed with a given pipe size to yield the required rate of flow.

```
Tools and Materials
```

```
Straightedge
Pencil
```

Practical water systems use water velocities from 1.2 to 1.8 meters (3.9 to 5.9 feet) per second. Very fast velocity requires high pressure pumps, which in turn require large motors and use excessive power. Velocities that are too low are expensive because larger pipe diameters must be used.

It may be advisable to calculate the cost of two or more systems based on different pipe sizes. Remember, it is usually wise to choose a little larger pipe if higher flows are expected in the next 5 to 10 years. In addition, water pipes often build up rust and scale, reducing the diameter and thereby increasing the velocity and pump pressure required to maintain flow at the original rate. If extra capacity is designed into the piping system, more water can be delivered by adding to the pump capacity without changing all the piping.

To use the chart, locate the flow (liters per minute) you need on the Q-scale. Draw a line from that point, through 1.8m/sec velocity on the V-scale, to the d-scale.
Choose the nearest standard size pipe.

For example, suppose you need a flow of 50 liters per minute at the time of peak demand. Draw a line from 50 liters per minute on the Q-scale through 1.8m/sec on the V-scale. Notice that this intersects the d-scale at about 2.25. The

correct
pipe size to choose would be the next largest standard pipe size, e.g., 1"
nominal
diameter, U.S. Schedule 40. If pumping costs (electricity or fuel) are high, it
would be well to limit velocity to 1.2m/sec and install a slightly larger pipe
size.

Source:

Crane Company Technical Paper #409, pages 46-47.

Estimating Flow Resistance of Pipe Fittings

One of the forces a pump must overcome to deliver water is the
friction/resistance
of pipe fittings and valves to the flow of water. Any bends, valves,
constrictions, or enlargements (such as passing through a tank) add to friction.

The alignment chart in Figure 1 gives a simple but reliable way to estimate this
resistance: it gives the equivalent length of straight pipe that would have the
same resistance. The sum of these equivalent lengths is then added to the actual
length of pipe. This gives the total equivalent pipe length, which is used in
the
entry, "Determining Pump Capacity and Horsepower Requirements," to determine
total friction loss.

Rather than calculate the pressure drop for each valve or fitting separately,
Figure 1 gives the equivalent length of straight pipe.

Valves

Note the difference in equivalent length depending on how far the valve is open.

1. Gate Valve: full opening valve; can see through it when open; used for complete shut off of flow.

2. Globe Valve: cannot see through it when open; used for regulating flow.

3. Angle Valve: like the globe, used for regulating flow.

4. Swing Check Valve: a flapper opens to allow flow in one direction but closes when water tries to flow in the opposite direction.

Example 1:

Pipe with 5cm inside diameter

Equivalent Length in Meters

a. Gate Valve (fully open) .4
b. Flow into line - ordinary entrance 1.0
c. Sudden enlargement into 10cm pipe 1.0
(d/D = 1/2)
d. Pipe length 10.0

Total Equivalent Pipe Length 12.4

Example 2:

Pipe with 10cm inside diameter

Equivalent Length in Meters

a. Elbow (standard) 4.0
b. Pipe length 10.0

Total Equivalent Pipe Length 14.0

Fittings

Study the variety of tees and elbows: note carefully the direction of flow through
the tee. To determine the equivalent length of a fitting, (a) pick proper dot on
"fitting" line, (b) connect with inside diameter of pipe, then using a straight edge
read equivalent length of straight pipe in meters, and (c) add the fitting
equivalent length to the actual length of pipe being used.

Source:

Crane Company Technical Paper #409, pages 20-21.

Bamboo Piping

Where bamboo is readily available, it seems to be a good substitute for metal
pipe. Bamboo pipe is easy to make with unskilled labor and local materials. The
important features of the design and construction of a bamboo piping system are

given here.

Bamboo pipe is extensively used in Indonesia to transport water to villages. In many rural areas of Taiwan, bamboo is commonly used in place of galvanized iron for deep wells up to a maximum depth of 150 meters (492'). Bamboos of 50mm (2") diameter are straightened by means of heat, and the inside nodes knocked out. The screen is made by punching holes in the bamboo and wrapping that section with a fibrous mat-like material from a palm tree, Chamaerops humilis. In fact, such fibrous screens are also used in many galvanized iron tube wells.

Bamboo piping can hold pressure up to two atmospheres (about 2.1kg per square centimeter or 30 pounds per square inch). It cannot, therefore, be used as pressure piping. It is most suitable in areas where the source of supply is higher
than the area to be served and the flow is under gravity.

Figure 1 is a sketch of a bamboo pipe water supply system for a number of
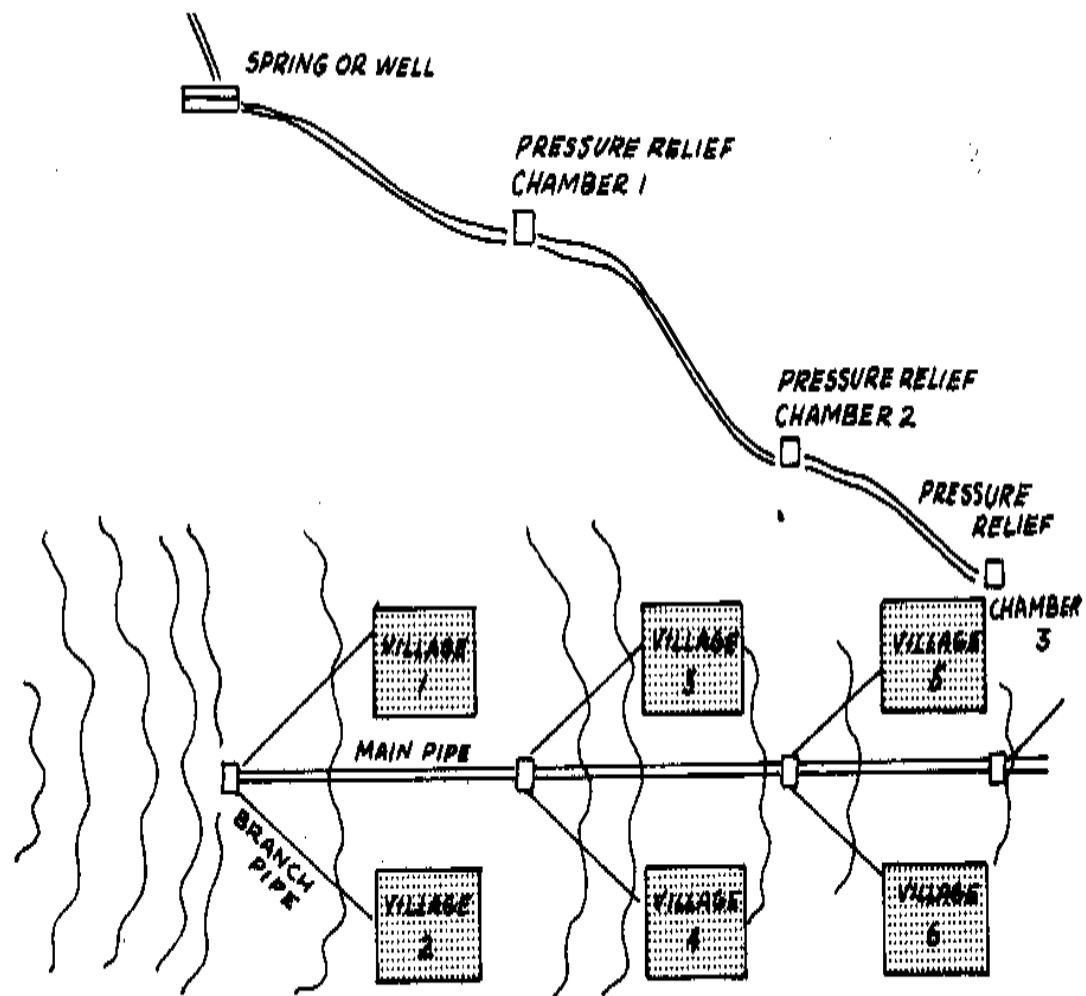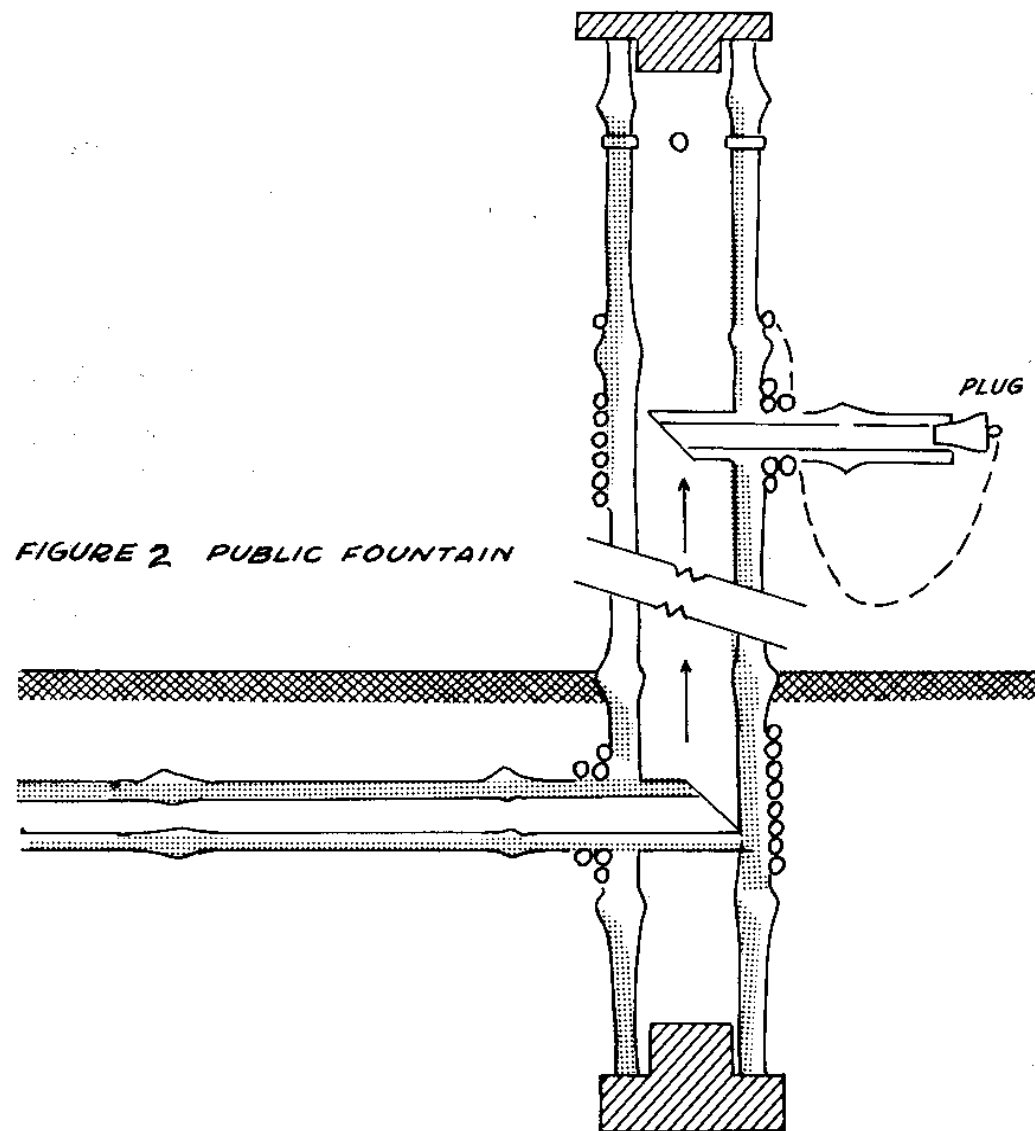
fig1x83.gif (540x540)

SPRING OR WELL

PRESSURE RELIEF
CHAMBER 1

PRESSURE RELIEF
CHAMBER 2

PRESSURE
RELIEF
CHAMBER
3

VILLAGE
1

VILLAGE
3

VILLAGE
5

MAIN PIPE

BRANCH
PIPE

VILLAGE
2

VILLAGE
4

VILLAGE
6

FIGURE 1

villages. Figure 2 shows a public water fountain.

fig2x83.gif (540x540)

PLUG

FIGURE 2 PUBLIC FOUNTAIN

Health Aspects

If bamboo piping is to carry water for drinking purposes, the only preservative treatment recommended is boric acid: borax in a 1:1 ratio by weight. The

recommended
treatment is to immerse green bamboo completely in a solution of 95
percent water and 5 percent boric acid.

After a bamboo pipe is put into operation it gives an undesirable odor to the
water. This, however, disappears after about three weeks. If chlorination is
done
before discharge to the pipe, a reservoir giving sufficient contact time for
effective disinfection is required since bamboo pipe removes chlorine compounds
and no residual chlorine will be maintained in the pipe. To avoid possible
contamination
by ground water, an ever present danger, it is desirable to maintain
the pressure within the pipe at a higher level than any water pressure outside
the
pipe. Any leakage will then be from the pipe, and contaminated water will not
enter the pipe.

Design and Construction

Tools and Materials

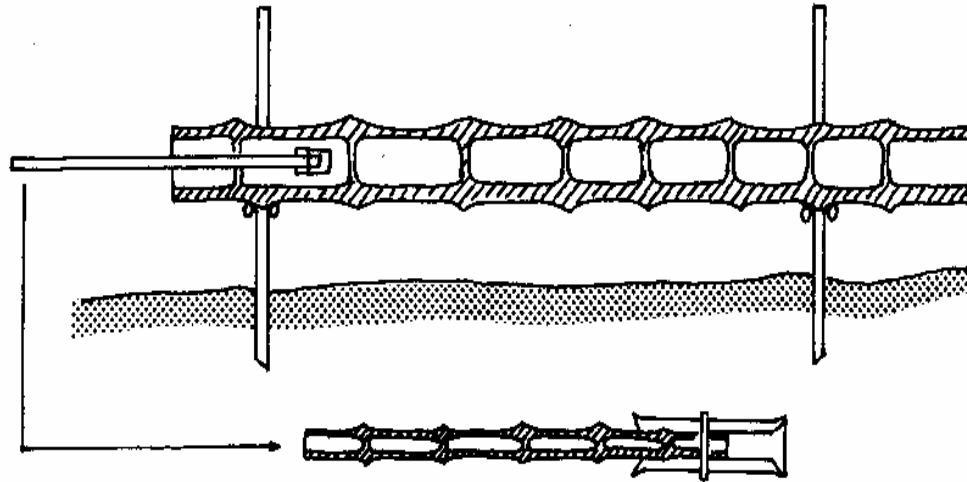Chisels (see text and Figure 3)

fig3x84.gif (270x540)

FIGURE 3

Nail, cotter pin, or linchpin
Caulking materials
Tar
Rope

Bamboo pipe is made of lengths of bamboo of the desired diameter by boring out
the dividing membrane at the joints. A circular chisel for this purpose is shown
in Figure 3. One end of a short length of steel pipe is belled out to increase
the
diameter and the edge sharpened. A length of bamboo pipe of sufficiently small
diameter to slide into the pipe is used as a boring bar and secured to the pipe
by
drilling a small hole through the assembly and driving a nail through the hole.
(A
cotter pin or linchpin could be used instead of the nail.) Three or more chisels
ranging from smallest to the maximum desired diameter are required. At each
joint the membrane is removed by first boring a hole with the smallest diameter

chisel, then progressively enlarging the hole with the larger diameter chisels.

Bamboo pipe lengths are joined in a number of ways, as shown in Figure 4. Joints

fig4x85.gif (600x600)

FIGURE 4

TAR SOAKED ROPE   TAR MIXED WITH COTTON
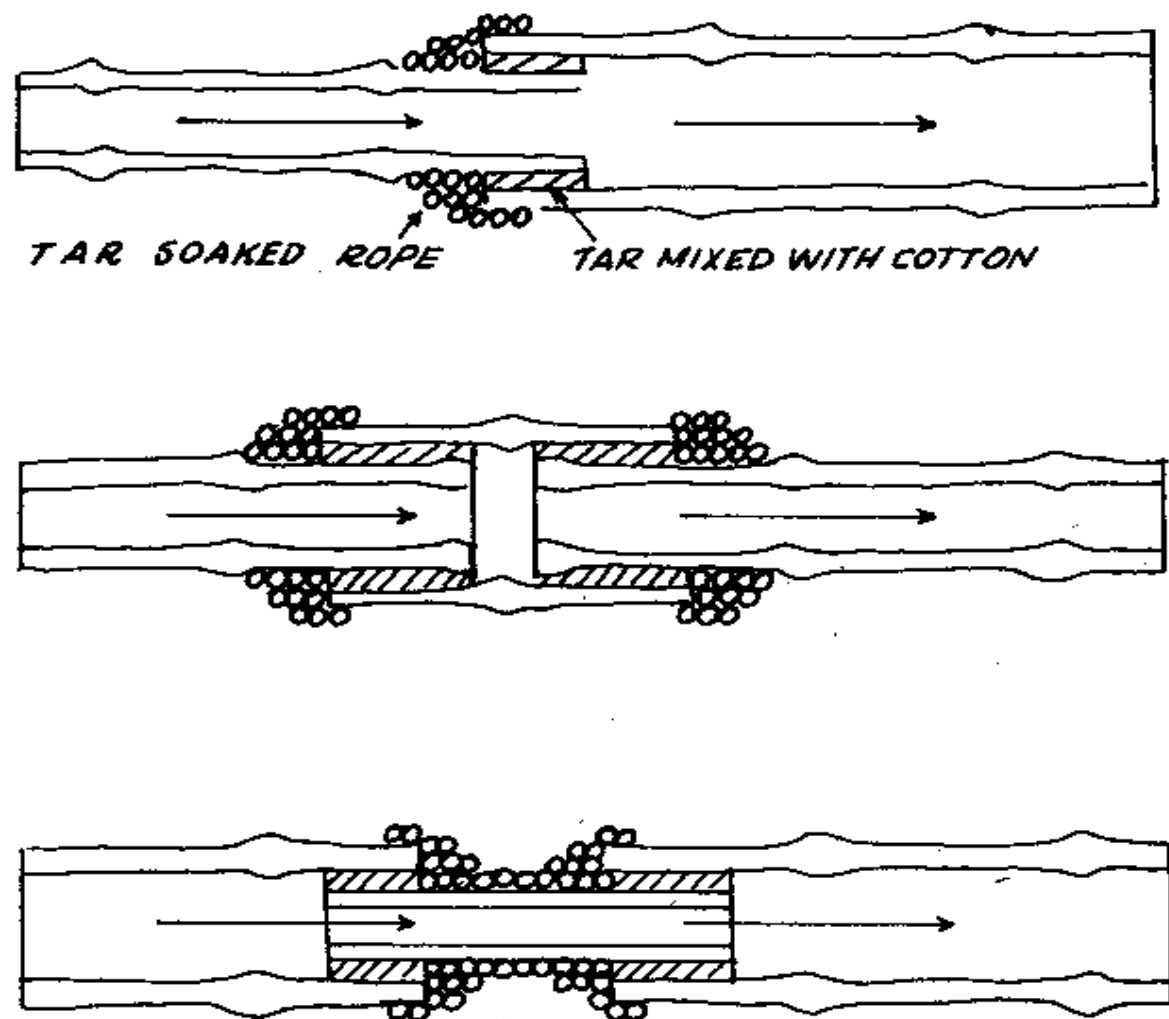
are made watertight by caulking with cotton wool mixed with tar, then tightly binding with rope soaked in hot tar.

Bamboo pipe is preserved by laying the pipe below ground level and ensuring a continuous flow in the pipe. Where the pipe is laid above ground level, it is protected by wrapping it with layers of palm fiber with soil between the layers. This treatment will give a life expectancy of about 3 to 4 years to the pipe; some
bamboo will last up to 5-6 years. Deterioration and failure usually occur at the natural joints, which are the weakest parts.

Where the depth of the pipe below the water source is such that the maximum pressure will be exceeded, pressure relief chambers must be installed. A typical chamber is shown in Figure 5. These chambers are also installed as reservoirs for
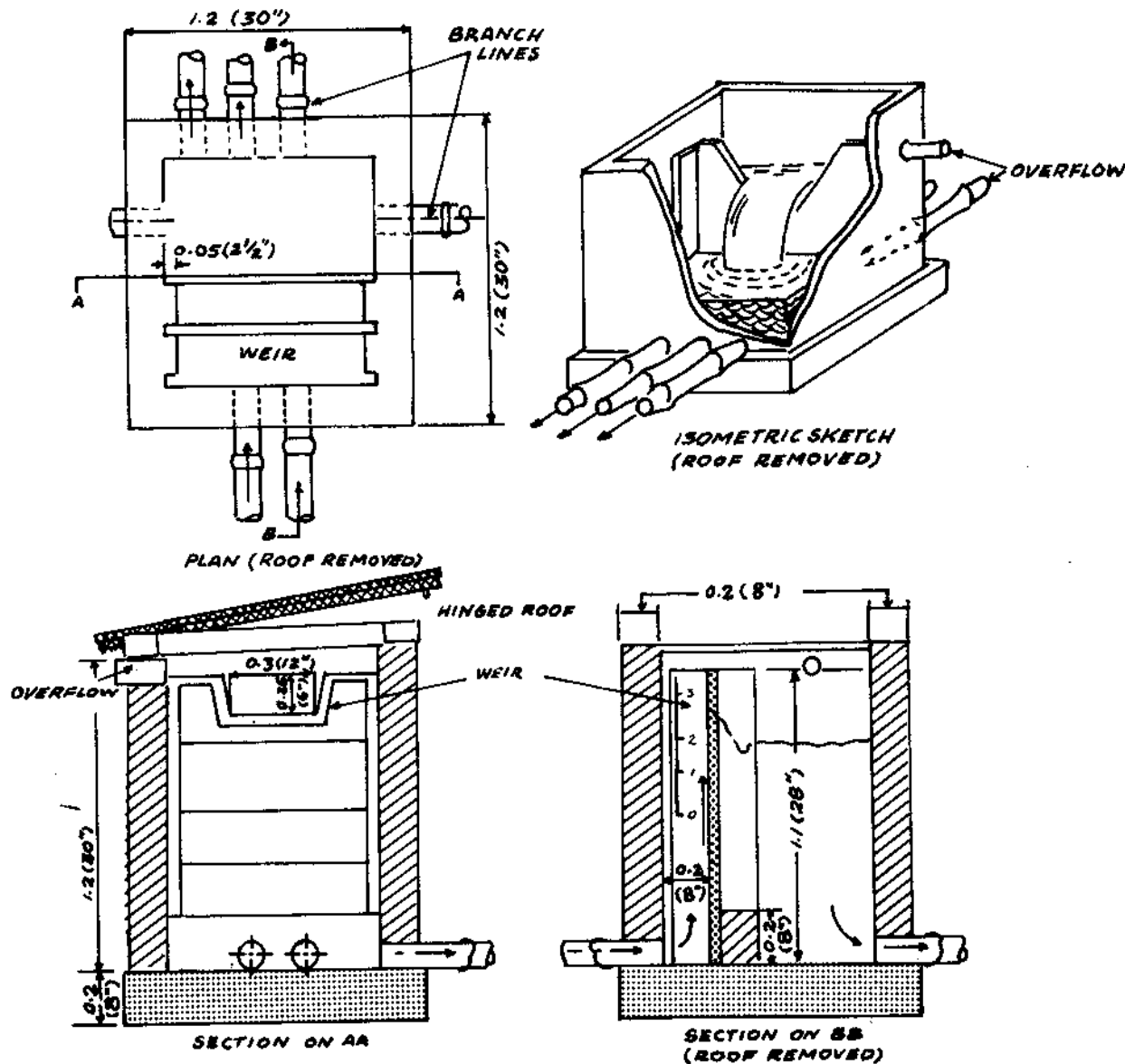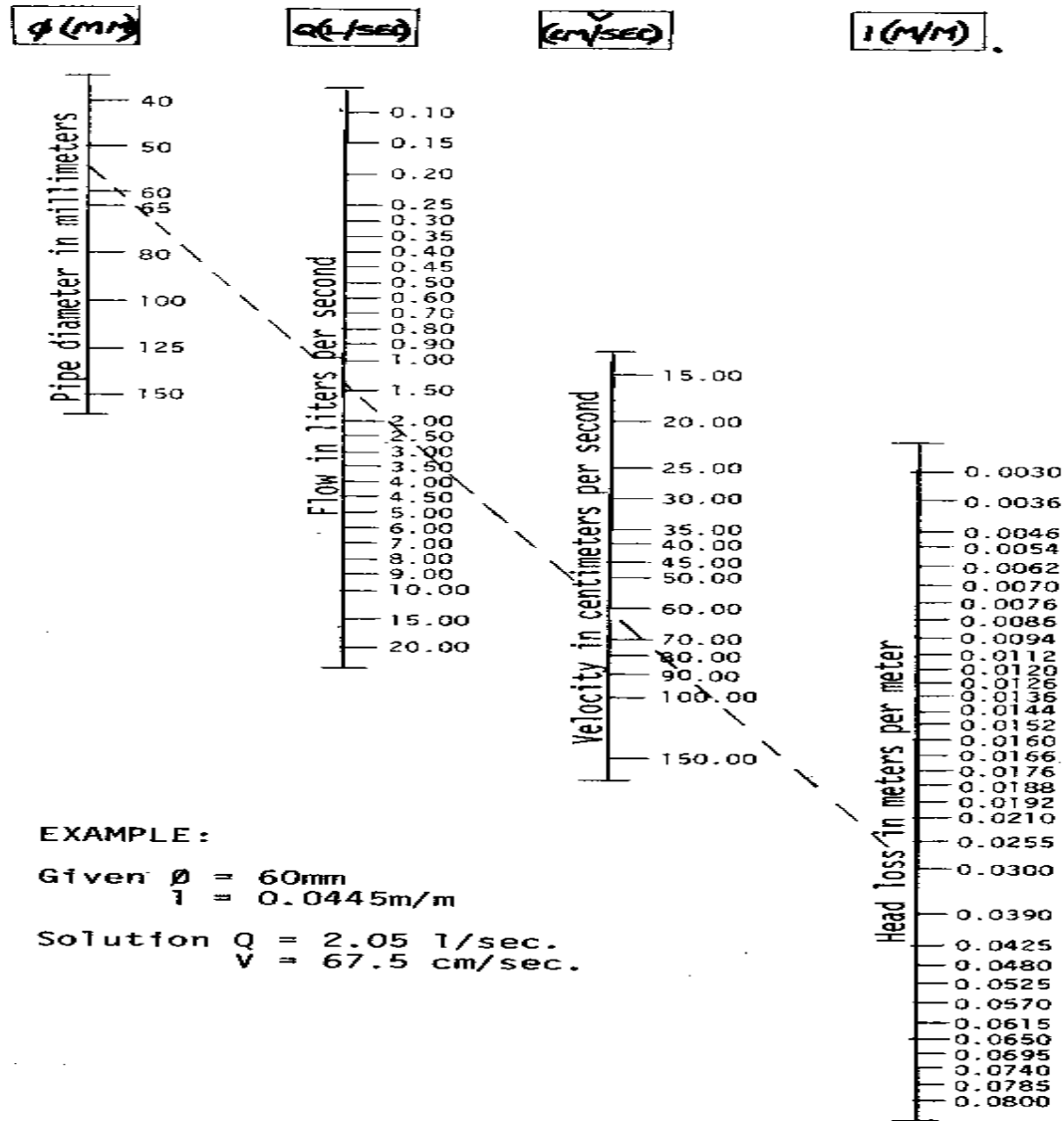
fig5x86.gif (600x600)

FIGURE 5

branch supply lines to villages en route.

Size requirements for bamboo pipe may be determined by using the pipe capacity

alignment chart in Figure 6.

fig6x87.gif (600x600)

FIGURE 6
NOMOGRAPH FOR FLOW IN BAMBOO PIPE

EXAMPLE:

Given Ø = 60mm
      l = 0.0445m/m

Solution Q = 2.05 l/sec.
      V = 67.5 cm/sec.

Source:

Water Supply Using Bamboo Pipe. AID-UNC/IPSED Series Item No. 3, International Program in Sanitary Engineering Design, University of North Carolina, 1966.

WATER LIFTING

Pump Specifications: Choosing or Evaluating a Pump

The form given in Figure 1, the "Pump Application Fact Sheet," is a check list

fig1x89.gif (600x600)

FIGURE 1

PUMP APPLICATION FACT SHEET

NAME *John Doe*   DATE *July 24, 1981*
ADDRESS *P.O. Box 393*
Xanadu
Gondwanaland

1. Liquid to be handled: *Fresh Water*

2. Erosive effect of liquid:
   (a) Weight percent of solids: *1-2 percent*
   (b) Type of solids: *sand*
   (c) Size of solids: *largest particle ~1mm*

3. Maximum temperature of liquid entering pump: *35°C*

4. Special situations (explain):
   (a) Gases in liquid: *no*
   (b) Liquid boiling: *no*

5. Capacity required: _____ liters per minute
        or: *1200* kilograms per hour *— made up of*
        or: *600 kg. per hour from lower outlet*
   and 600 kg per hour from upper outlet

6. Power source available:
   (a) Electrical: *110* volts
       AC: *single* phase   or: DC: _____ volts
          50 cycles per second

   (b) Fuel: _____
   (c) Other: _____

7. Differential head and suction head: *See sketch*

8. Pipe material: Suction: *Galvanized Iron (see sketch for pipe size)*
          Discharge: *Galvanized Iron (see sketch for pipe size)*

9. Pump connections required: *Standard pipe thread*
   Pipe size (inside diameter): Inlet: *5.25 cm** Outlet: *5.25 cm**

10. Sketch of piping (all fittings and valves shown) *attached*

11. Other comments:

Figure 1. Pump Specification Fact Sheet. Make a copy of this form for your own use.

NOTE: For advice on pump selection or application, send the completed form (keeping a copy for your own information)to a local university, a pump manufacturer or to VITA.

* Actually this piping is the same as 2" U.S. Schedule 40.

for collecting the information needed to get help in choosing a pump for a particular situation. If you have a pump on hand, you can also use the form to estimate its capabilities. The form is an adaptation of a standard pump

specification
sheet used by engineers.

Fill out the form and send it off to a manufacturer or a technical assistance
organization like VITA to get help in choosing a pump. If you are doubtful about
how much information to give, it is better to give too much information than to
risk not giving enough. When seeking advice on how to solve a pumping problem
or when asking pump manufacturers to specify the best pump for your service,
give complete information on what its use will be and how it will be installed.
If
the experts are not given all the details, the pump chosen may give you trouble.

The "Pump Application Fact Sheet" is shown filled in for a typical situation.
For
your own use, make a copy of the form. The following comments on each numbered
item on the fact sheet will help you to complete the form adequately.

1. Give the exact composition of the liquid to be pumped: Fresh or salt water,
oil, gasoline, acid, alkali, etc.

2. Weight percent of solids can be found by getting a representative sample in
a pail. Let the solids settle to the bottom and decant the liquid (or filter
the liquid through a cloth so that the liquid coming through is clear). Weigh
the solids and the liquid, and give the weight percent of solids.

If this is not possible, measure the volume of the sample (in liters, U.S.
gallons, etc.) and the volume of solids (in cubic centimeters, teaspoons, etc.)
and send these figures. Describe the solid material completely and send a
small sample if possible. This is important; if the correct pump is not

selected, the solids will erode and/or break moving parts.

Weight percent of solids =

100 x weight of solids in liquid sample
----
weight of liquid sample

3. If you do not have a thermometer to measure temperature, guess at it, making sure you guess on the high side. Pumping troubles are often caused when liquid temperatures at the intake are too high.

4. Gas bubbles or boiling cause special problems, and must always be mentioned.

5. Give the capacity (the rate at which you want to move the liquid) in any convenient units (liters per minute, U.S. gallons per minute) by giving the total of the maximum capacity needed for each outlet.

6. Give complete details on the power source.

A. If you are buying an electric motor for the pump, be sure to give your voltage. If the power is A.C. (Alternating Current) give the frequency (in cycles per second) and the number of phases. Usually this will be single phase for most small motors. Do you want a pressure switch or other special means to start the motor automatically?

B. If you want to buy an engine driven pump, describe the type and cost of fuel, the altitude, maximum air temperature, and say whether the air
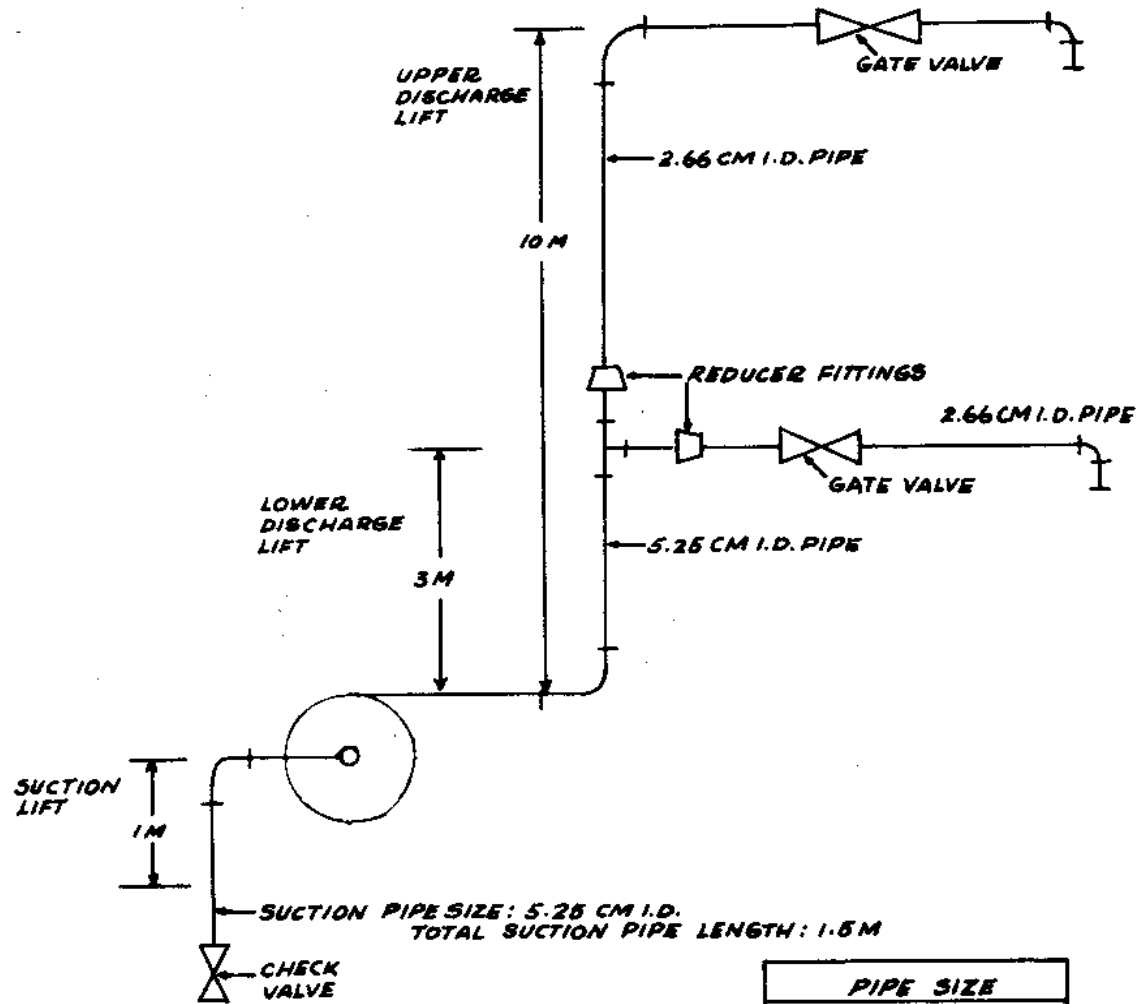
is unusually wet or dusty.

C. If you already have an electric motor or engine, give as much information
about it as you can. Give the speed and sketch the machine, being
especially careful to show the power shaft diameter and where it is
with respect to the mounting. Describe the size and type of pulley if
you intend to use a belt drive. Finally, you must estimate the power.
The best thing is to copy the name plate data completely. If possible
give the number of cylinders in your engine, their size, and the stroke.

7. The "head" or pressure to be overcome by the pump and the capacity (or
required flow of water) determine the pump size and power. The entry
"Determining Pump Capacity and Horsepower Requirements," explains the
calculation of simple head situations. The best approach is to explain the
heads by drawing an accurate piping sketch (see Item 10 in the "Pump
Application Fact Sheet"). Be sure to give the suction lift and piping separately
from the discharge lift and piping. An accurate description of the
piping is essential for calculating the friction head. See Figure 2.

fig2x91.gif (600x600)

FIGURE 2
(NOT DRAWN TO SCALE)

UPPER DISCHARGE LIFT

GATE VALVE

2.66 CM I.D. PIPE

10 M

REDUCER FITTINGS

2.66 CM I.D. PIPE

LOWER DISCHARGE LIFT

GATE VALVE

3 M

5.25 CM I.D. PIPE

SUCTION LIFT

1 M

SUCTION PIPE SIZE: 5.25 CM I.D.
TOTAL SUCTION PIPE LENGTH: 1.5 M

CHECK VALVE

PIPE SIZE	
DIAMETER IN CM	
INSIDE	OUTSIDE
2.66	3.34
5.25	6.04

8. The piping material, inside diameter, and thickness are necessary for making the head calculations and to check whether pipes are strong enough to

withstand the pressure. See "Water Lifting and Transport-Overview" for comments on specifying pipe diameter.

9. Connections to commercial pumps are normally flanged or threaded with standard pipe thread.

10. In the sketch be sure to show the following:

(a) Pipe sizes; show where sizes are changed by indicating reducing fittings.

(b) All pipe fittings-elbows, tees, valves (show valve type), etc.

(c) Length of each pipe run in a given direction. Length of each size pipe and vertical lift are the most important dimensions.

11. Give information on how the pipe will be used. Comment on such points as:

o Indoor or outdoor installation?
o Continuous or intermittent service?
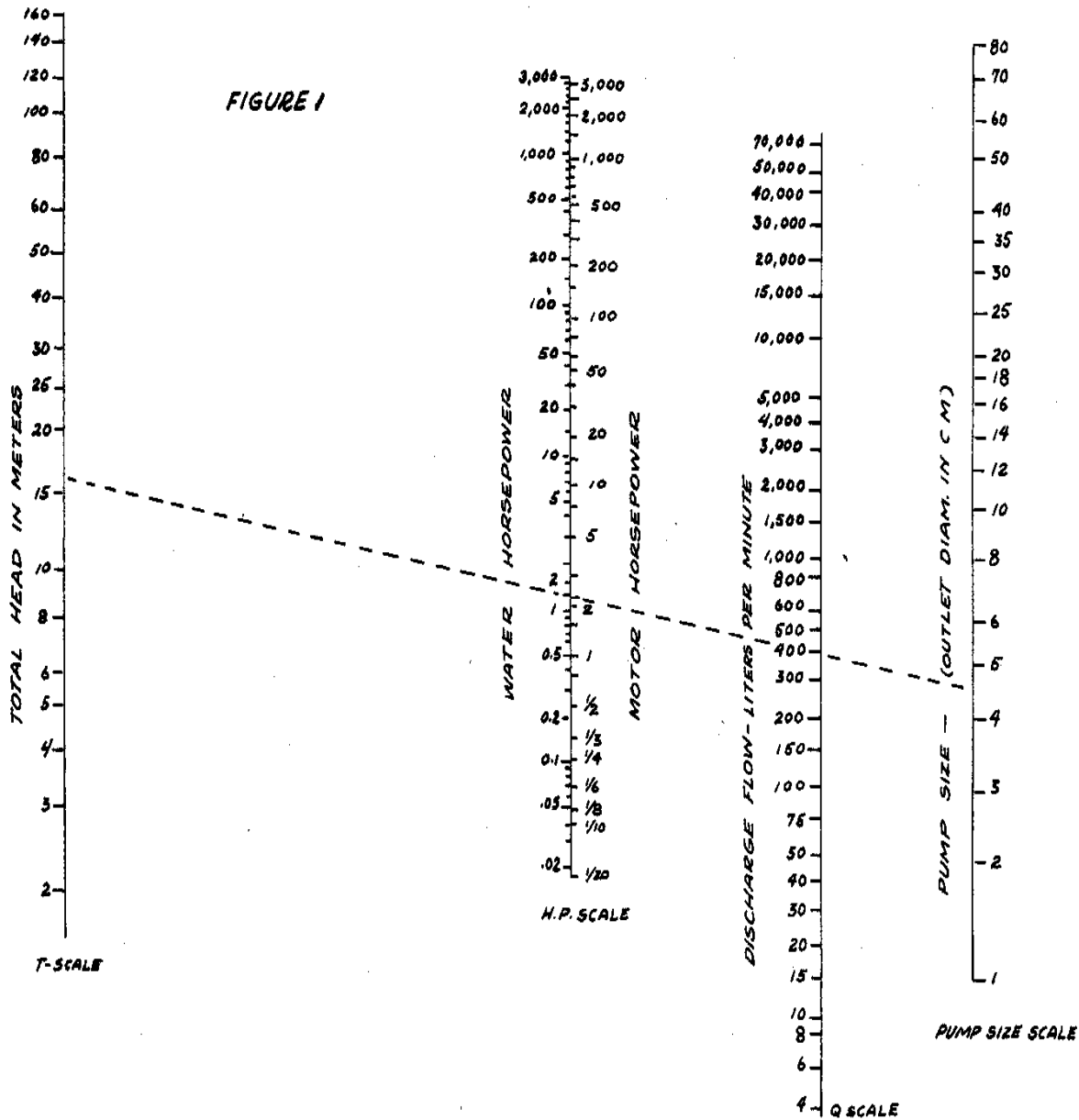o Space or weight limitations?

Source:

Benjamin P. Coe, VITA Volunteer, Schenectady, New York.

Determining Pump Capacity and Horsepower Requirements

With the alignment chart in Figure 1, you can determine the necessary pump size

<b> Village

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fig1x93.gif (600x600)
```

FIGURE 1

(diameter or discharge outlet) and the amount of horsepower needed to power the pump. The power can be supplied by people or by motors.

An average healthy person can generate about 0.1 horsepower (HP) for a reasonably
long period and 0.4HP for short bursts. Motors are designed for varying amounts of horsepower.

To get the approximate pump size needed for lifting liquid to a known height through simple piping, follow these steps:

1. Determine the quantity of flow desired in liters per minute.

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

3. Using the entry "Determining Pipe Size or Velocity of Water in Pipes," page 74, choose a pipe size that will give a water velocity of about 1.8 meters per second (6' per second). This velocity is chosen because it will generally give the most economical combination of pump and piping; Step 5 explains how to convert for higher or lower water velocities.

4. Estimate the pipe friction-loss head (a 3-meter head represents the pressure at the bottom of a 2-meter-high column of water) for the total equivalent pipe length, including suction and discharge piping and equivalent pipe lengths for valves and fittings, using the following equation:

$$\text{Friction-loss head} = \frac{F \times \text{total equivalent pipe length}}{100}$$

where F equals approximate friction head (in meters) per 100 meters of pipe.

To get the value of F, see the table below. For an explanation of total equivalent pipe length, see preceding sections.

5. To find F (approximate friction head in meters per 100m of pipe) when water velocity is higher or lower than 1.8 meters per second, use the following equation:

F [V.sup.2]
at 1.8/[sec.sup.x]
F= ------------------------------
1.8/[sec.sup.2]

where V = higher or lower velocity

Example:

If the water velocity is 3.6m per second and F at 1.8m/sec is 16, then:

F = 16 x [3.6.sup.2]   16 x 13
    ---------------- = ------- = 64
    [1.8.sup.2]   3.24

6. Obtain "Total Head" as follows:

Total Head = Height of Lift + Friction-loss Head

Average friction loss in meters for fresh water flowing through steel pipe velocity is 1.8 meters (6 feet) per second

Pipe inside diameter: cm 2.5 5.1 7.6 10.2 15.2 20.4 30.6 61.2
inches(*) 1" 2" 3" 4" 6" 8" 12" 24"

F (approximate friction 16 7 5 3 2 1.5 1 0.5
loss in meters per 100
meters of pipe)

(*) For the degree of accuracy of this method, either actual inside diameter in
inches, or nominal pipe size, U.S. Schedule 40, can be used.

7. Using a straightedge, connect the proper point on the T-scale with the
proper point on the Q-scale; read motor horsepower and pump size on the
other two scales.

Example:

Desired flow: 400 liters per minute
Height of lift: 16 meters, No fittings
Pipe size: 5cm
Friction-loss head: about 1 meter
Total head: 17 meters

Solution:

Pump size: 5cm
Motor horsepower: 3HP

Note that water horsepower is less than motor horsepower (see HP-scale, Figure
1).

This is because of friction losses in the pump and motor. The alignment chart should be used for rough estimate only. For an exact determination, give all information on flow and piping to a pump manufacturer or an independent expert. He has the exact data on pumps for various applications. Pump specifications can be tricky especially if suction piping is long and the suction lift is great.

For conversion to metric horsepower given the limits of accuracy of this method, metric horsepower can be considered roughly equal to the horsepower indicated by the alignment chart (Figure 1). Actual metric horsepower can be obtained by multiplying horsepower by 1.014.

Source:

Kulman, CA. Nomographic Charts. New York: McGraw-Hill Book Co., 1951.

Determining Lift Pump Capability

The height that a lift pump can raise water depends on altitude and, to a lesser extent, on water temperature. The graph in Figure 1 will help you to find out

fig1x96.gif (600x600)

Example:

Suppose your elevation
is 2000 meters and the
water temperature
is 25C. The graph
shows that the normal
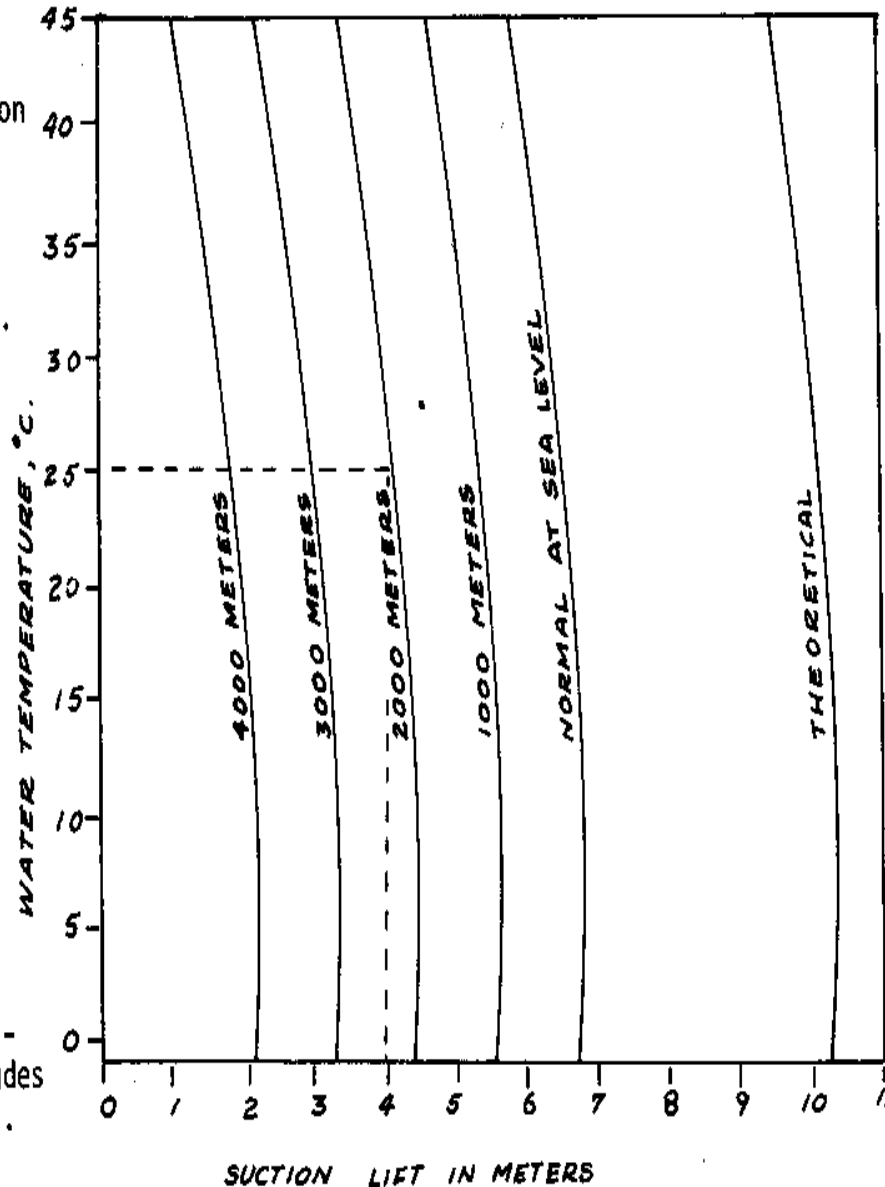lift would be 4 meters.

Figure 1. Graph show-
ing lift pump capabili-
ties at various altitudes
and water temperatures.
Broken lines indicate
example given in text.

FIGURE I

what a lift pump can do at various altitudes and water temperatures. To use it,
you will need a measuring tape and a thermometer.

If you know your altitude and the temperature of your water, Figure 1 will tell you the maximum allowable distance between the pump cylinder and the lowest water level expected. If the graph shows that lift pumps are marginal or will not
work, then a force pump should be used. This involves putting the cylinder down in the well, close enough to the lowest expected water level to be certain of proper functioning.

The graph shows normal lifts. Maximum possible lifts under favorable conditions would be about 1.2 meters higher, but this would require slower pumping and would probably give much difficulty in "losing the prime."

Check predictions from the graph by measuring lifts in nearby wells or by experimentation.

Example:

Suppose your elevation is 2,000 meters and the water temperature is 25[degrees]C. The graph shows that the normal lift would be four meters.

Source:

Baumeister, Theodore. Mechanical Engineer's Handbook, 6th edition. New York: McGraw-Hill Book Co., 1958.

SIMPLE PUMPS

Chain Pump for Irrigation

The chain pump, which can be powered by hand or animal, is primarily a shallow-well
pump to lift water for irrigation (see Figure 1). It works best when the lift
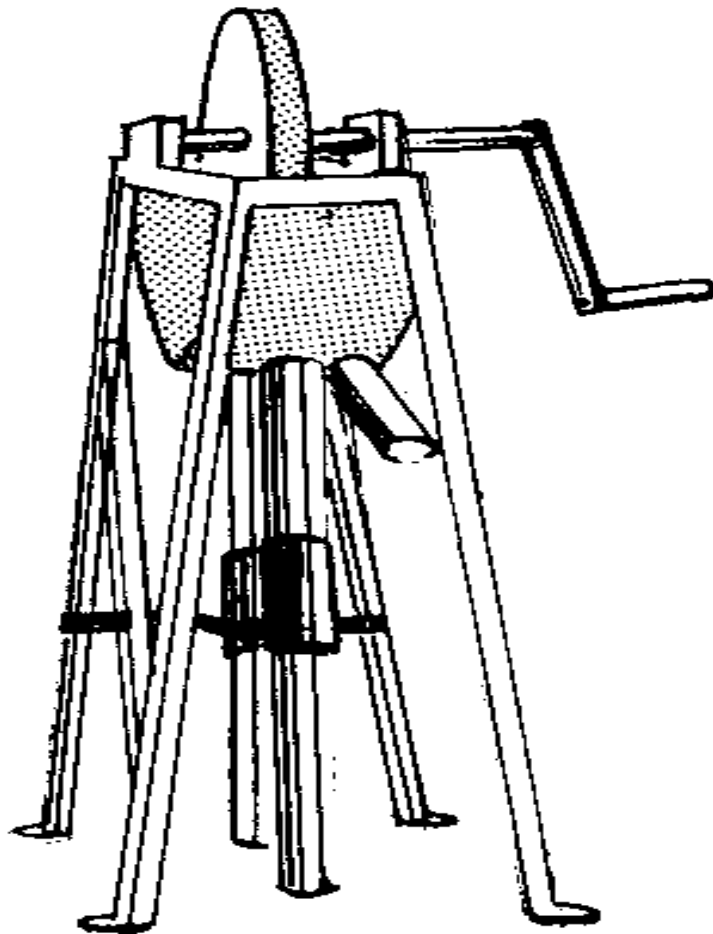
fig1ax96.gif (486x486)

FIGURE 1

is less than 6 meters (20'). The
water source must have a depth of

about 5 chain links.

Both the pump capacity and the
power requirement for any lift are
proportional to the square of the
diameter of the tube. Figure 2

fig2x97.gif (437x437)

FIGURE 2

LIFT	QUANTITY
6 METERS (18 FEET)	11 CUBIC METERS/HOUR (2906 GALLONS/HOUR)
3 METERS (9 FEET)	20 CUBIC METERS/HOUR (5284 GALLONS/HOUR)
1.5 TO 2 METERS (4.5 TO 6 FEET)	25-30 CUBIC METERS/HOUR (6605 TO 7926 GALLONS/HOUR)

shows what can be expected from a

10cm (4") diameter tube operated
by four people working in two
shifts.

The pump is intended for use as an
irrigation pump because it is
difficult to seal for use as a
sanitary pump.

Tools and Materials

Welding or brazing equipment
Metal-cutting equipment
Woodworking tools
Pipe: 10cm (4") outside diameter, length as needed
5cm (2") outside diameter, length as needed
Chain with links about 8mm (5/16") in diameter, length as needed
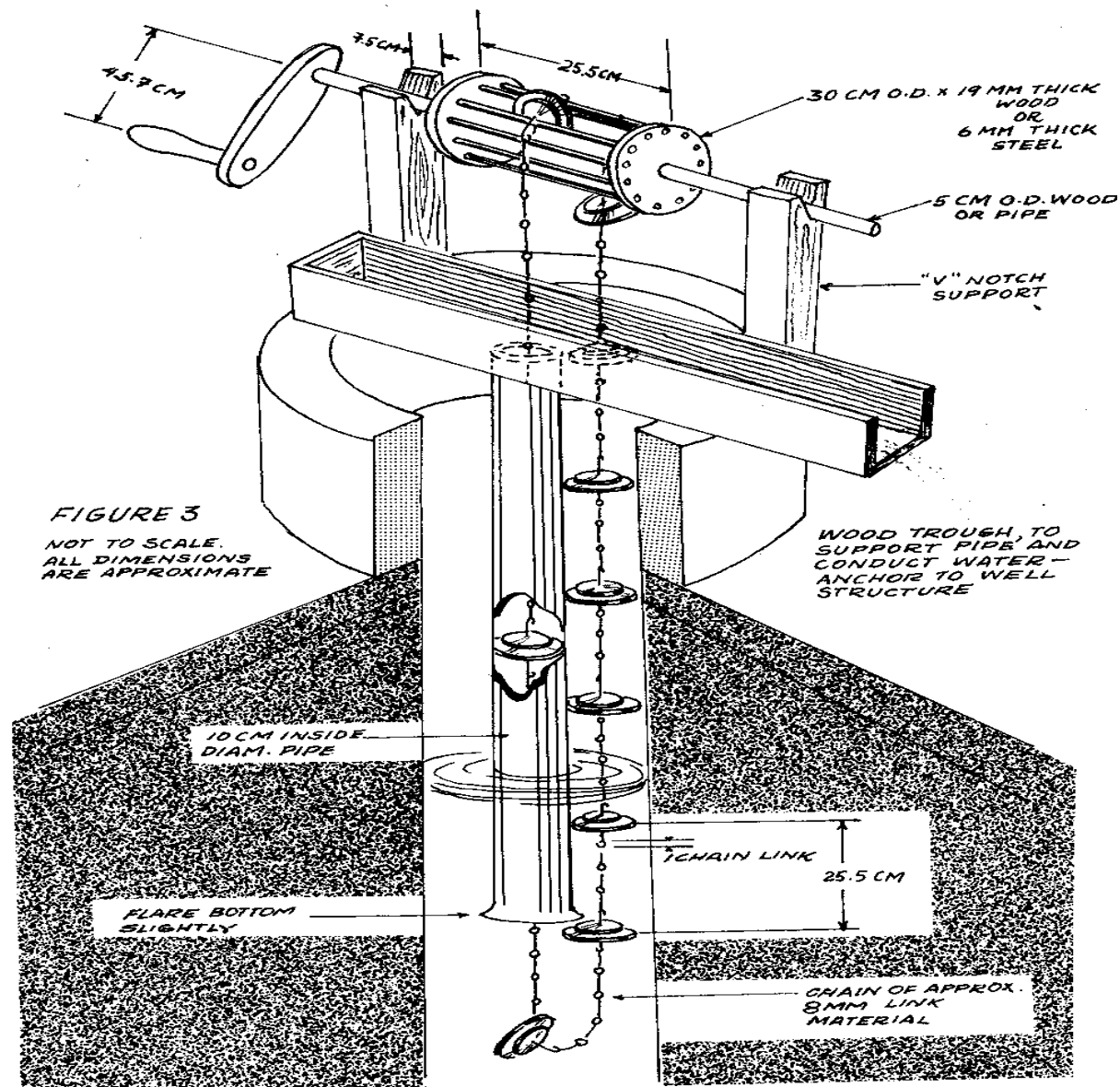Sheet steel, 3mm (1/8") thick
Sheet steel, 6mm (1/4") thick
Steel rod, 8mm (5/16") in diameter
Steel rod, 12.7mm (1/2") in diameter
Leather or rubber for washers

The entire chain pump is shown in Figure 3. Details of this pump can be changed
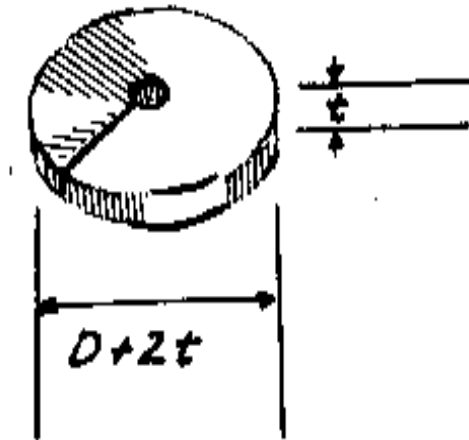
fig3x98.gif (600x600)

FIGURE 3

NOT TO SCALE.
ALL DIMENSIONS
ARE APPROXIMATE

to fit materials available and structure of the well.

The piston links (see Figures 4, 5, 6 and 7) are made from three parts:

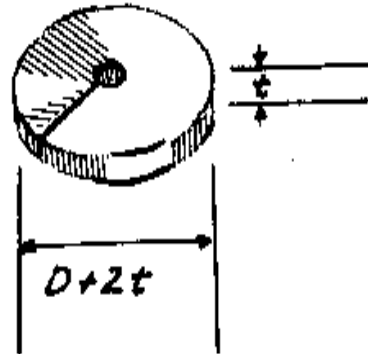**fig4x990.gif (393x393)**

FIGURE 4
LEATHER WASHER

D+2t

PIPE DIAMETER PLUS TWICE t

1. a leather or rubber washer (see Figure 4) with an outside diameter about

fig4x99.gif (317x317)

FIGURE 4
LEATHER WASHER

D+2t

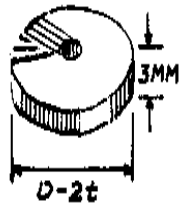PIPE DIAMETER <u>PLUS</u> TWICE t

two thicknesses of a washer larger than the inside diameter of the pipe.

2. a piston disk (see Figure 5).
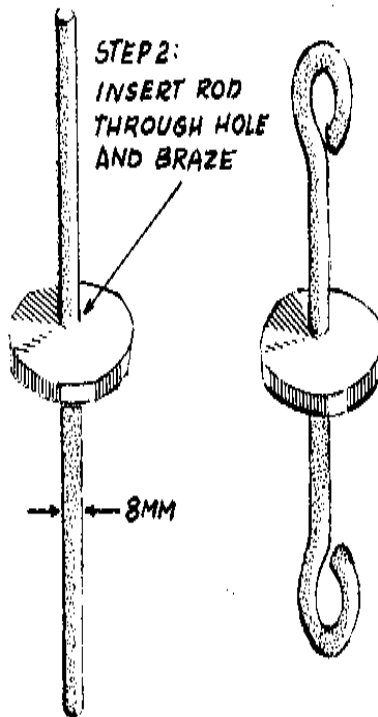
fig5x99.gif (437x437)

FIGURE 5

STEP 1:
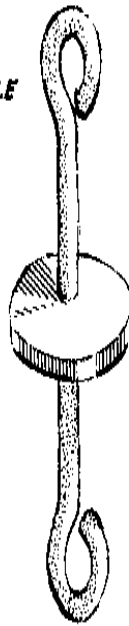CUT CIRCULAR DISK
AND DRILL HOLE
IN CENTER

STEP 2:
INSERT ROD
THROUGH HOLE
AND BRAZE

STEP 3:
BEND ROD
ENDS TO
LINK WITH
CHAIN

3MM

D-2t

PIPE DIAMETER
LESS TWICE THE
THICKNESS OF
LEATHER WASHER

8MM

3. a retaining plate (see Figure 6).

fig6x100.gif (317x317)

FIGURE 6
RETAINING PLATE

3MM

D-2t
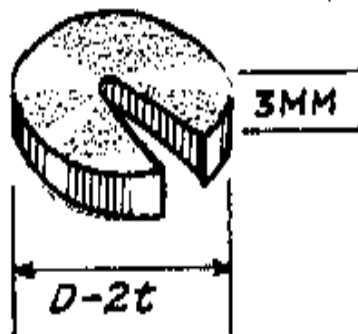
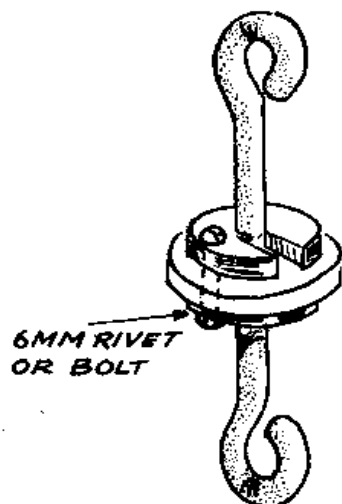**The piston link is made as shown in Figure 7. Center all three parts and clamp**

fig7x100.gif (317x317)

FIGURE 7
PISTON LINK
ASSEMBLED

6MM RIVET
OR BOLT

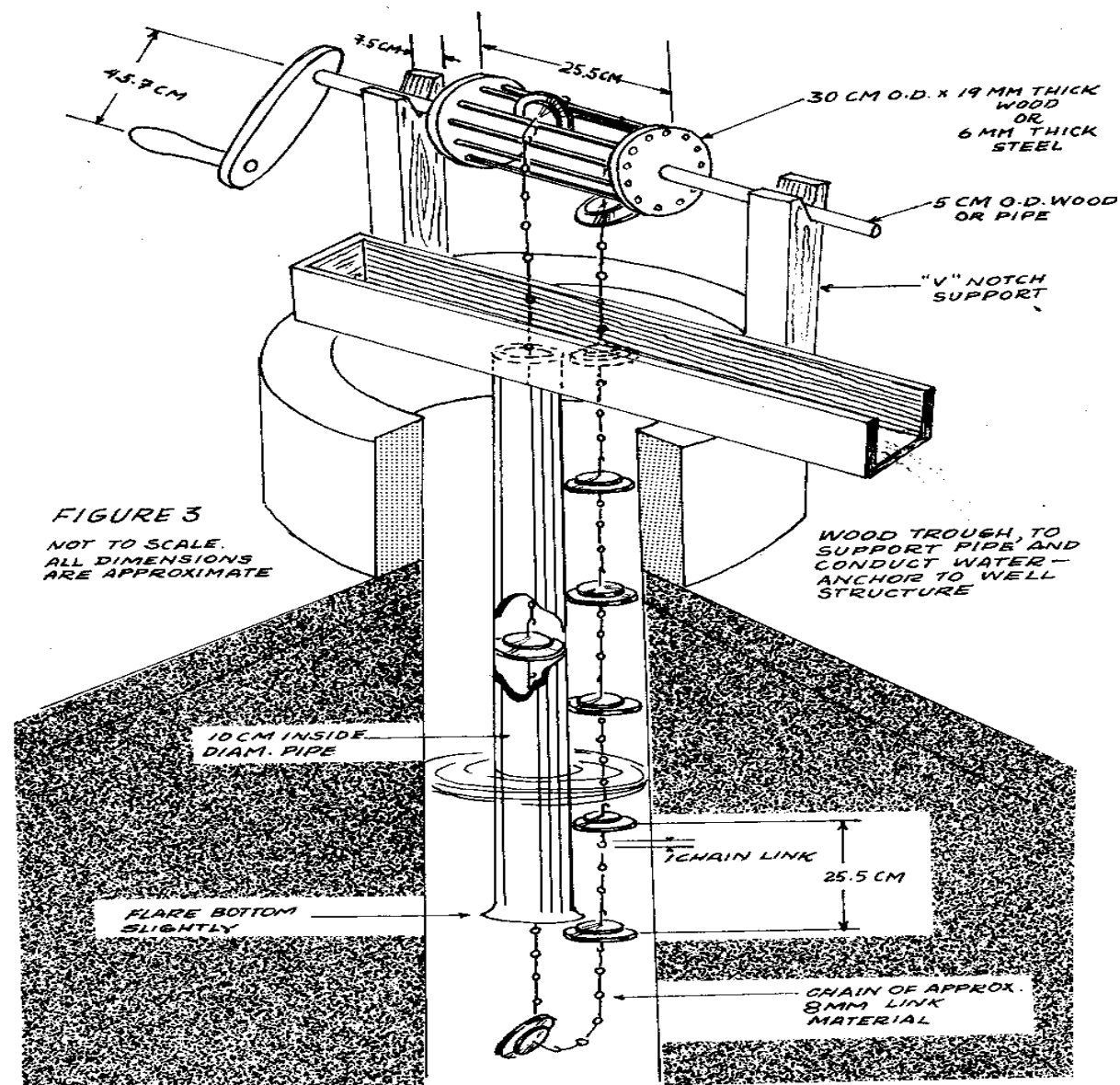them together temporarily. Drill a hole about 6mm (1/4") in diameter through all three parts and fasten them together with a bolt or rivet.

The winch is built as shown in Figure 3. Two steel disks 6mm (1/4") thick are

fig3x98.gif (600x600)

FIGURE 3

NOT TO SCALE.
ALL DIMENSIONS
ARE APPROXIMATE

welded to the pipe shaft.

Twelve steel rods, 12.7mm (1/2") thick, are spaced at equal distances, at or

near

the outside diameter, and are welded in place. The rods may be laid on the outside of the disks, if desired.

A crank and handle of wood or metal is then welded or bolted to the winch shaft.

The supports for the winch shaft (see Figure 3) can be V-notched to hold the shaft, which will gradually wear its own groove. A strap or block can be added across the top, if necessary, to hold the shaft in place.

The pipe can be supported by threading or welding a flange to its upper end (see Figure 8).

fig8x100.gif (540x540)

FIGURE 8 PIPE SUPPORT

FLANGE

TROUGH

10 CM PIPE
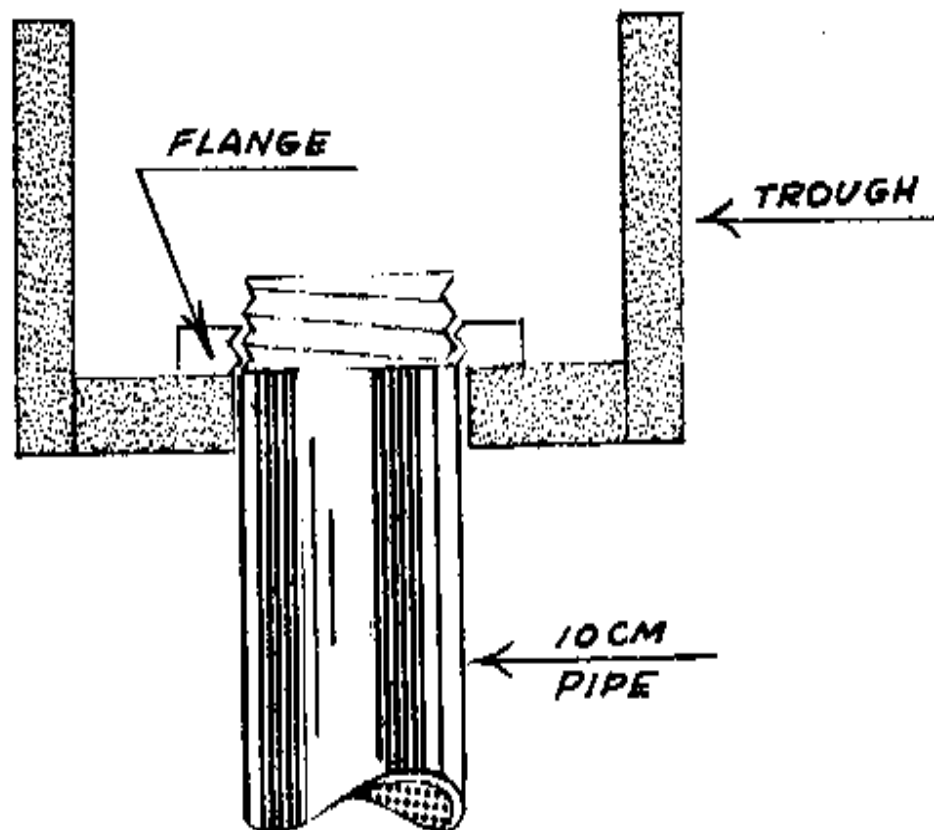
The flange should be 8mm to 10mm (5/16" to 3/8") thick. The pipe passes through a hole in the bottom of the trough and hangs from the trough into the well.

Sources:

Robert G. Young, VITA Volunteer, New Holland, Pennsylvania

Molenaar, Aldert. Water Lifting Devices for Irrigation. Rome: Food and Agriculture
Organization, 1956.

Inertia Hand Pump

The inertia hand pump described
here (Figure 1) is a

fig1x101.gif (600x600)

STEP I   DOWNWARD MOTION

TOP OF PIPE MUST BE
AIR TIGHT

TRAPPED AIR ESCAPES
THROUGH VALVE

WATER ALLOWED IN

STEP 2   UPWARD MOTION

SUCTION MAKES THE
VALVE AIR TIGHT

WATER LEVEL IN PIPE

STEP 3   REPEATED DOWNWARD MOTION
                        FORCES WATER OUT

COMBINED WATER
FROM BOTH STROKES
FORCED OUT

FIGURE 1
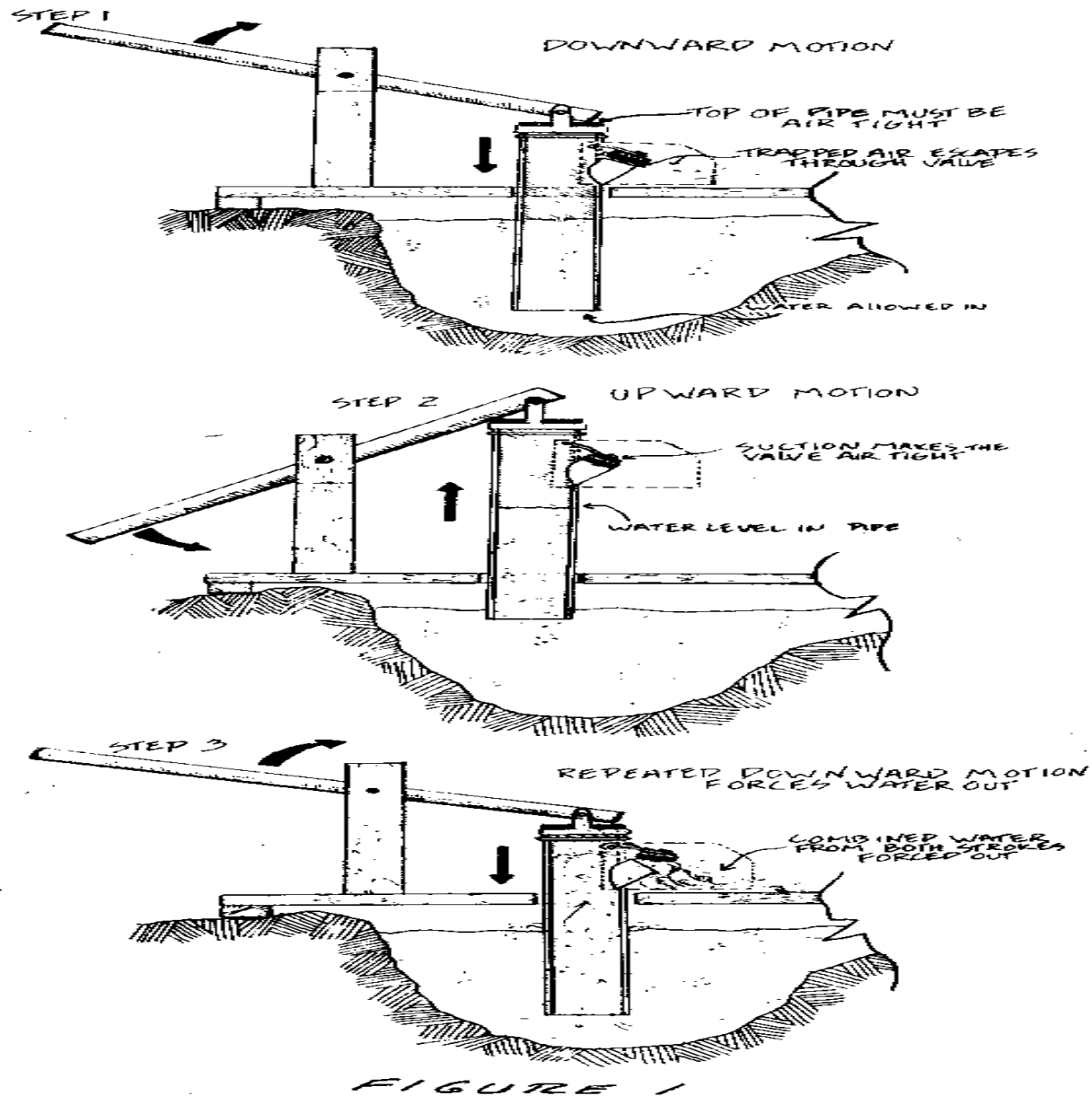
**very efficient pump for lifting
water short distances. It lifts
water 4 meters (13') at the**

rate of 75 to 114 liters (20 to
30 U.S. gallons) per minute. It
lifts water 1 meter (3.3') at
the rate of 227 to 284 liters
(60 to 75 gallons) per minute.
Delivery depends on the number
of persons pumping and
their strength.

The pump is easily built by a
tinsmith. Its three moving
parts require almost no maintenance.
The pump has been
built in three different sizes
for different water levels.

The pump is made from galvanized
sheet metal of the
heaviest weight obtainable
that can be easily worked by
a tinsmith (24- to 28-gauge
sheets have been used successfully).
The pipe is formed
and made air tight by soldering
all joints and seams.
The valve is made from the
metal of discarded barrels and
a piece of truck inner tube
rubber. The bracket for

**attaching the handle is also
made from barrel metal.**

**Figure 1 shows the pump in
operation. Figure 2 gives the**

fig2x103.gif (600x600)

FIGURE 2

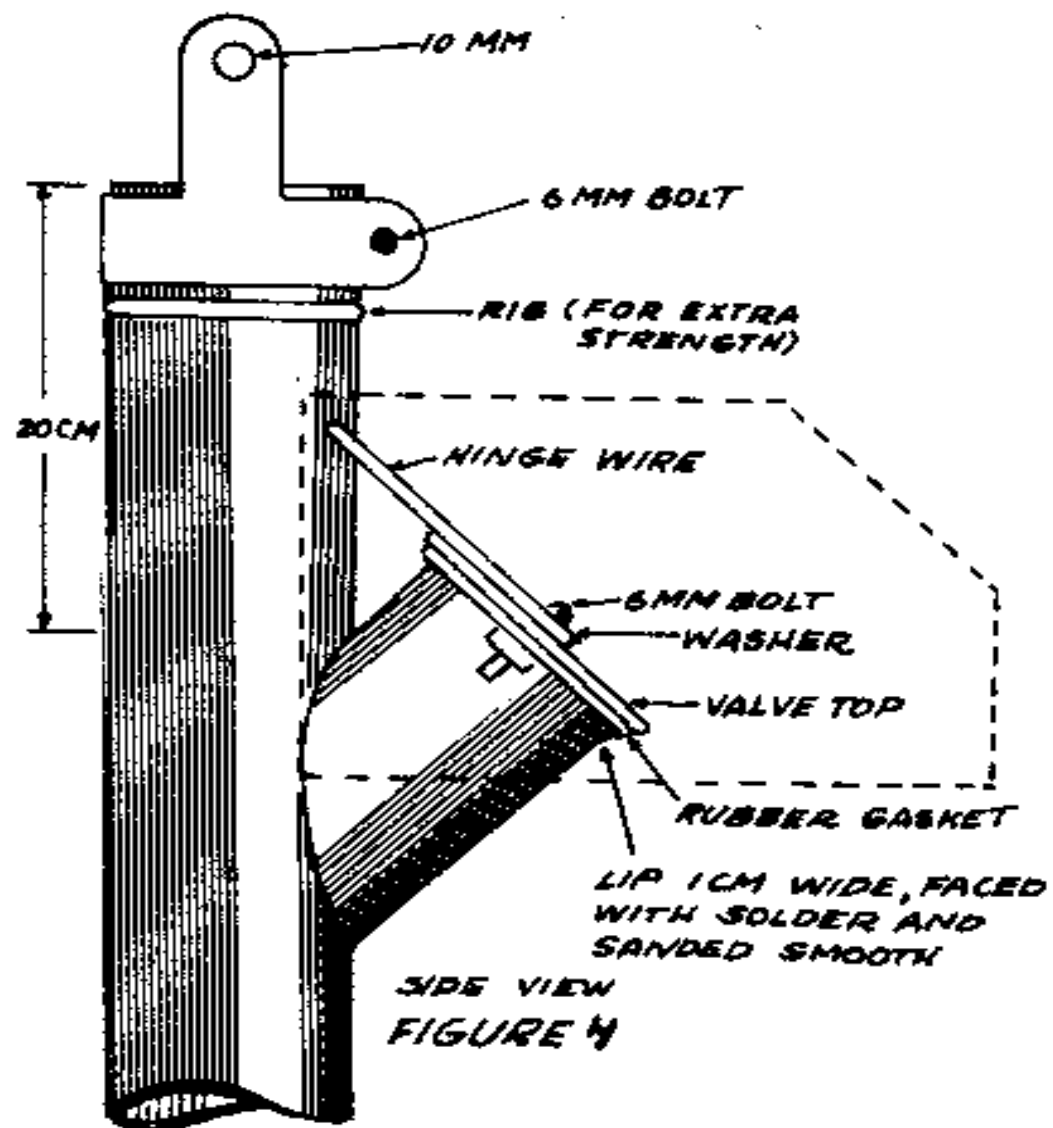| PART	MATERIAL	8 CM PIPE	10 CM PIPE	15 CM PIPE
HANDLE BRACKET	BARREL METAL			
A		34 CM	40 CM	54 CM
B		24	30	44
C		5½	5	8½
D		7	10	17
SHIELD	GALVANIZED TIN			
E		43	49	61
F		14	16	20
G		14	16	20
H		3	3	2½
I		8	10	15
J		4	4	4
K		30	30	32
SHIELD COVER	GALVANIZED TIN			
L		15	17	21
M		20	20	22
N	BARREL METAL	6	8	12
O	INNER TUBE RUBBER	11	13	18
P	BARREL METAL	11	13	18
Q	WIRE (4 MM)	16	18	22
HANDLE	WOOD POLE			
POST	WOOD POST			

dimensions of parts for pumps
in three sizes and Figure 3

fig3x103.gif (393x393)

FIGURE 3

DIAMETER OF PIPE	LENGTH OF PIPE	HEIGHT OF LIFT	LITERS PER MINUTE AT 1830 METERS ELEVATION
8 CM	450 CM	2 TO 4 METERS	75 TO 114
10 CM	270 CM	1 TO 2 METERS	114 TO 152
15 CM	140 CM	1 METER	227 TO 284

shows the capacity of each size. Figures 4, 5, and 6 are

fig41030.gif (600x600)

10 MM

6 MM BOLT

RIB (FOR EXTRA STRENGTH)

20 CM

HINGE WIRE

6 MM BOLT

WASHER

VALVE TOP

RUBBER GASKET

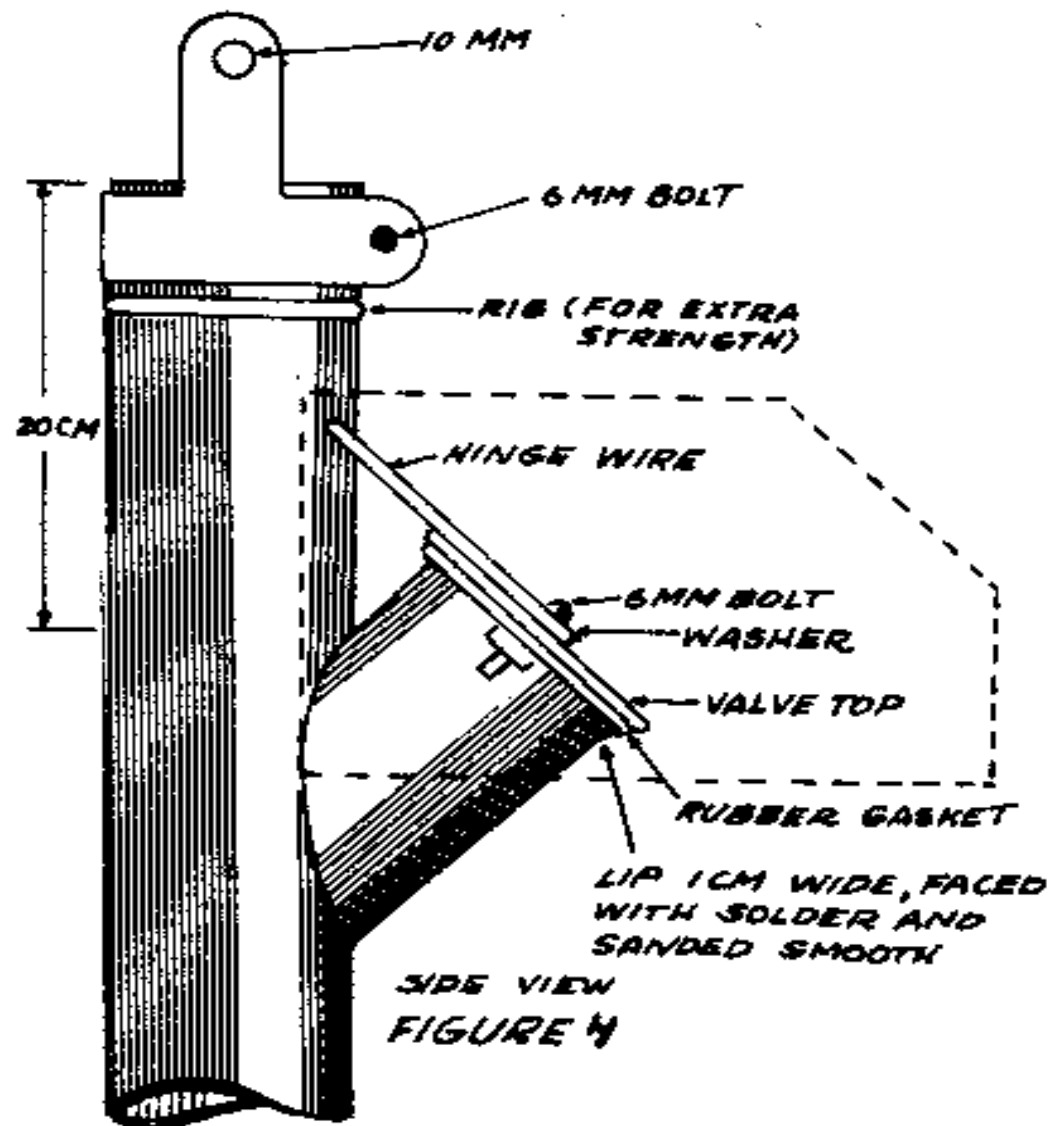LIP 1 CM WIDE, FACED WITH SOLDER AND SANDED SMOOTH

SIDE VIEW
FIGURE 4

**Tools and Materials
(for 1-meter (3.3') pump)**

```
Soldering equipment
Drill and bits or punch
Hammer, saws, tinsnips
Anvil (railroad rail or iron pipe)
Galvanized iron (24 to 28 gauge):
Shield: 61cm x 32cm, 1 piece (24" x 12 5/8")
Shield cover: 21cm x 22cm, 1 piece (8 1/4" x 8 5/8")
Pipe: 140cm x 49cm, 1 piece (55 1/8" x 19 1/4")
Top of pipe: 15cm x 15cm, 1 piece (6" x 6")
"Y" pipe: 49cm x 30cm, 1 piece (19 1/4" x 12")
Barrel metal:
Bracket: 15cm x 45cm, 1 piece (6" x 21 1/4")
Valve-bottom: 12cm (4 3/4") in diameter, 1 piece
Valve-top: 18cm (7 1/8") in diameter, 1 piece
Wire:
Hinge: 4mm (5/32") in diameter, 32cm (12 5/8") long
```

This pump can also be made from plastic pipe or bamboo.

There are two points to be remembered concerning this pump. One is that the distance from the top of the pipe to the top of the hole where the short section of pipe is connected must be 20cm (8"). See Figure 4. The air that stays in the

fig4x103.gif (600x600)

10 MM

6 MM BOLT

RIB (FOR EXTRA STRENGTH)

20CM

HINGE WIRE

6 MM BOLT
WASHER
VALVE TOP

RUBBER GASKET

LIP 1CM WIDE, FACED WITH SOLDER AND SANDED SMOOTH

SIDE VIEW
FIGURE 4

pipe above this junction serves as a cushion (to prevent "hammering") and regulates the number of strokes pumped per minute. The second point is to remember to operate the pump with short strokes, 15 to 20cm (6" to 8"), and at a

rate of about 80 strokes per minute. There is a definite speed at which the pump
works best and the operators will soon get the "feel" of their own pumps.

In building the two larger size pumps it is sometimes necessary to strengthen
the
pipe to keep it from collapsing if it hits the side of the well. It can be
strengthened
by forming "ribs" about every 30cm (12") below the valve or banding with
bands made from barrel metal and attached with 6mm (1/4") bolts.

The handle is attached to the pump and post with a bolt 10mm (3/8") in diameter,
or a large nail or rod of similar size.

Source:
Dale Fritz, VITA Volunteer, Schenectady, New York.

Handle Mechanism for Hand Pumps

The wearing parts of this durable handpump handle mechanism are wooden (see
Figure 1).

fig1x105.gif (600x600)
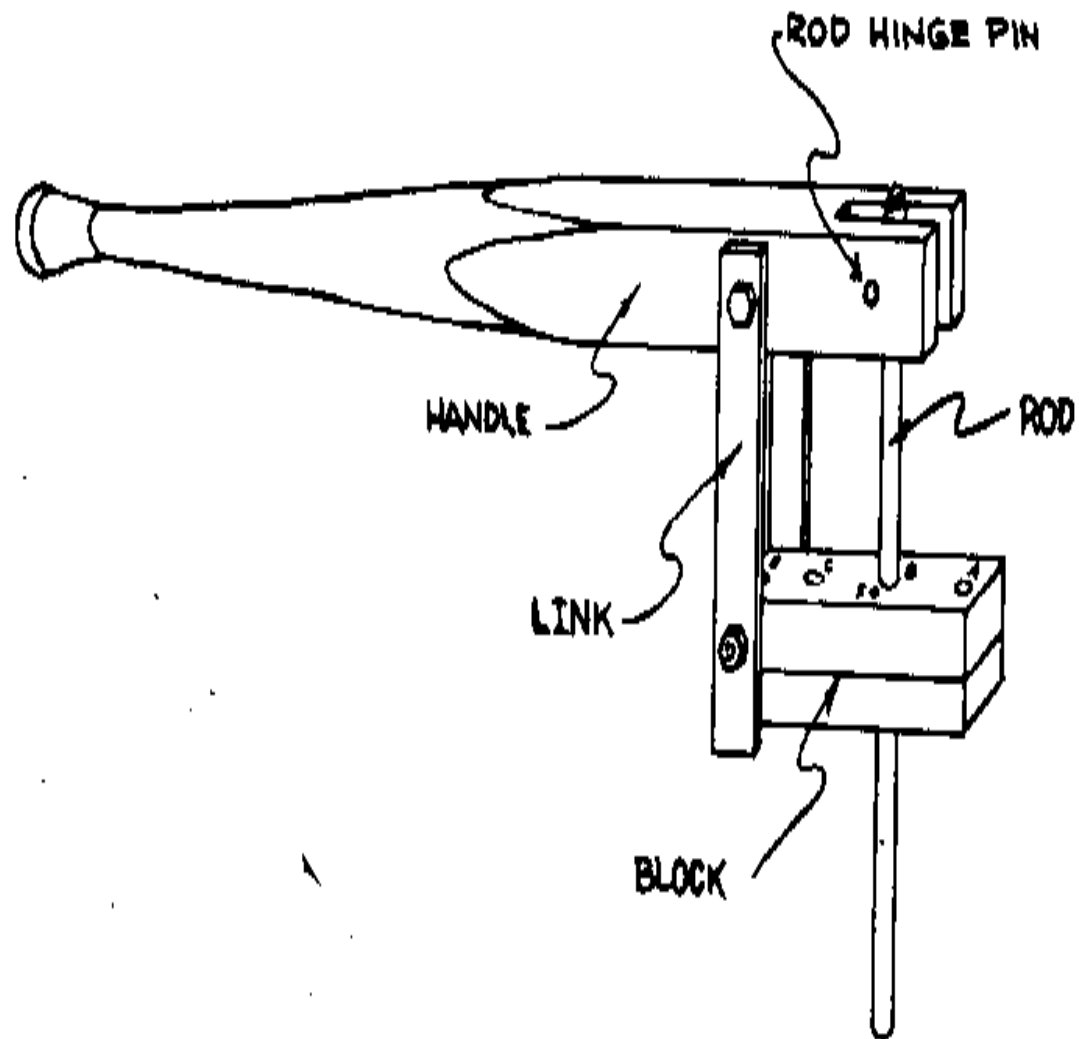
ROD HINGE PIN

HANDLE

ROD

LINK

BLOCK

FIG 1

They can be easily replaced by a village carpenter. This handle has
been designed to replace pump handle mechanisms which are difficult to maintain.
Some have been in use for several years in India with only simple, infrequent

repairs.

The mechanism shown in Figure 1 is bolted to the top flange of your pump. The mounting holes A and C in the block should be spaced to fit your pump (see Figure 6).
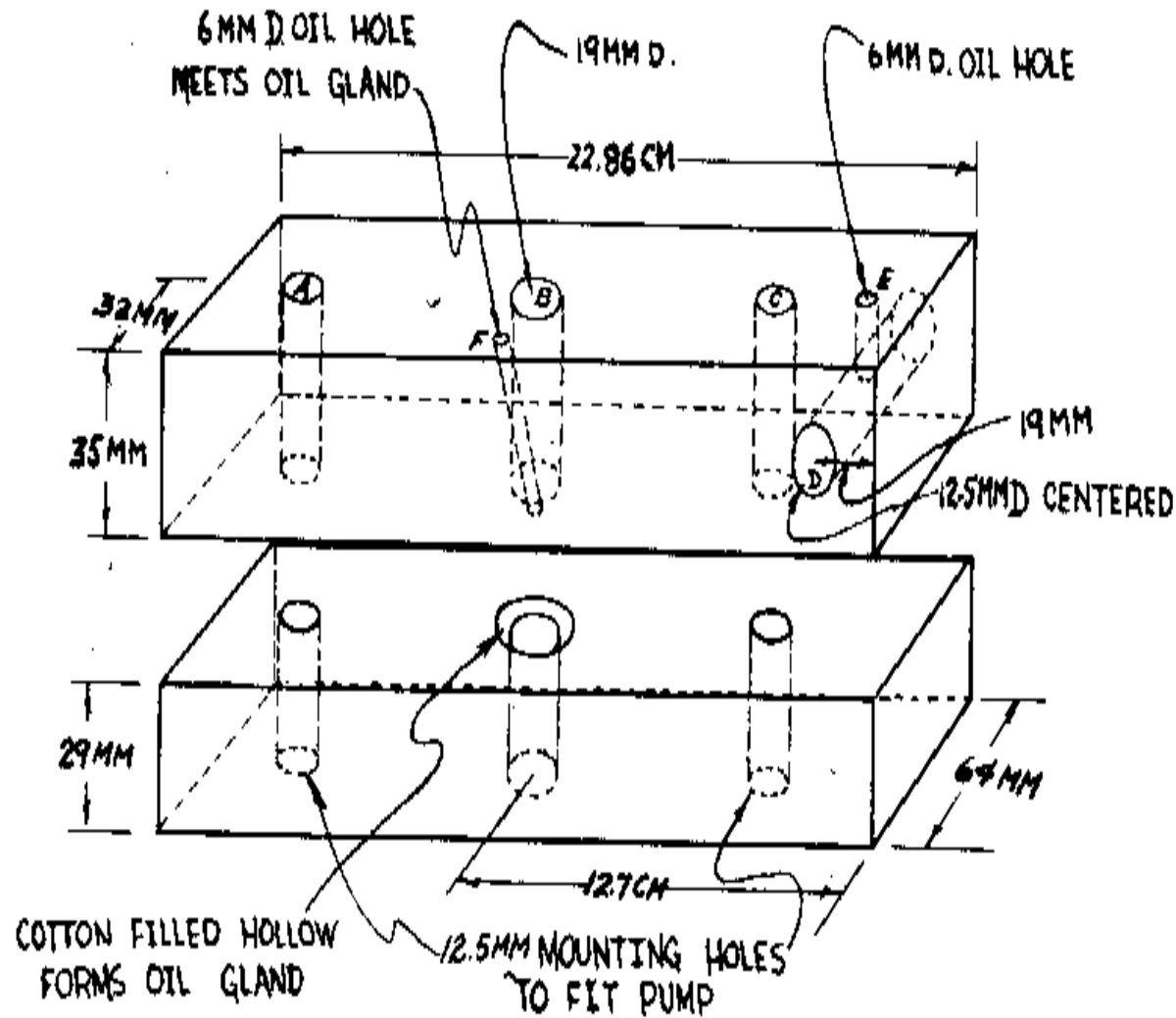
fig6x107.gif (600x600)

FIG 6
BLOCK

Figure 2 shows a pump with this handle mechanism that is manufactured

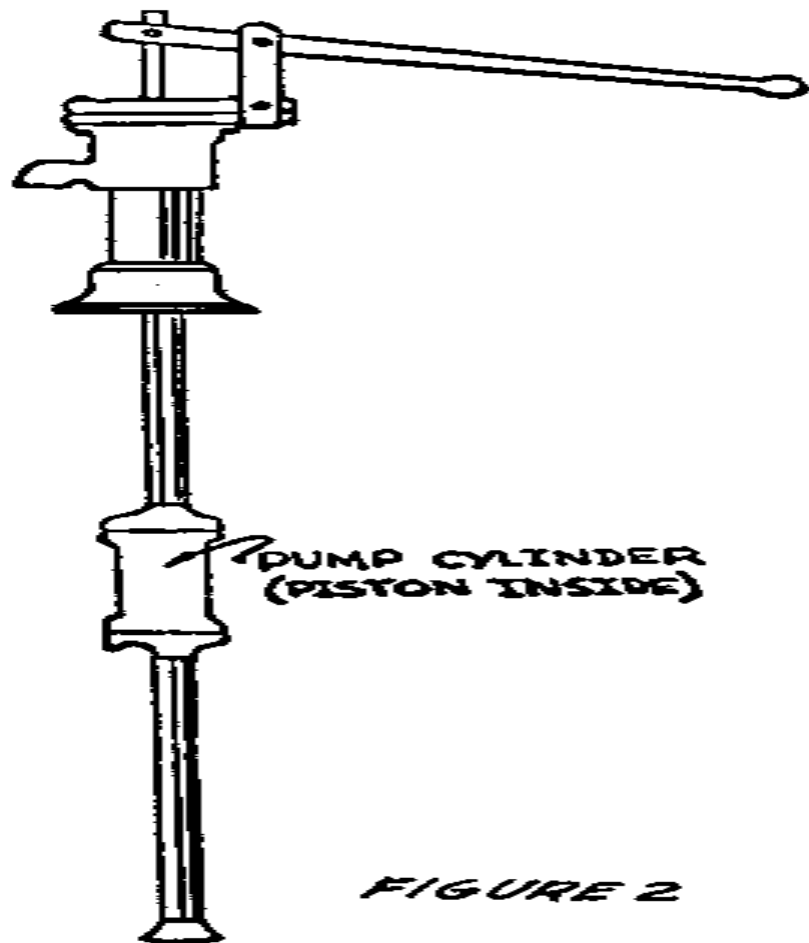**fig2x106.gif (486x486)**

DUMP CYLINDER
(PISTON INSIDE)

FIGURE 2

by F. Humane and Bros., 28 Strand Road, Calcutta, India.

Tools and Materials

Saw
Drill
Bits

Tap: 12.5mm (1/2")
Tap: 10mm (3/8")
Chisel
Drawknife, spokeshave or lathe
Hardwoods 86.4cm x 6.4cm x 6.4cm
(34" x 2 1/2" x 2 1/2")
Mild steel rod: 10mm (3/4") in diameter
and 46.5cm (16") long
Strap iron, 2 pieces: 26.7cm x 38mm x 6mm
(10 1/2" x 1 1/2" x 1/4")

BOLT HARDWARE

| Number of bolts needed	Dia. mm	Length mm	Number of nuts needed	Number of lock-washers	Number of plain washers	Purpose-fastens:
1	10	38	0	0	0	76mm bolt to rod
1	10	76	0	0	2	Rod to handle
2	12.5	89	2	4	4	Link to handle
						Link to block
2	12.5	?	2	2	2	Block to pump
1	12.5	?	1	1	0	Rod to piston

Handle

Make the handle of tough hardwood,
shaped on a lathe or by hand
shaving. The slot should be cut

**wide enough to accommodate the
rod with two plain washers on
either side. See Figure 3.**

fig3x106.gif (486x486)

FIG 3

HANDLE
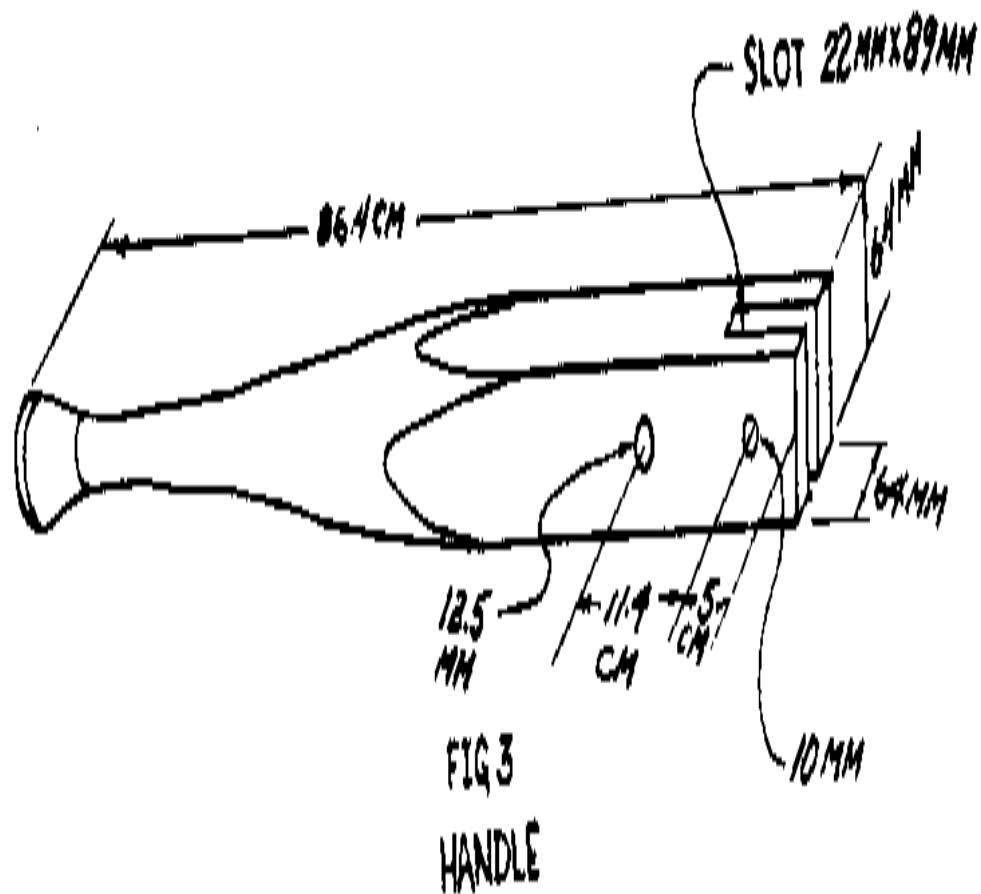
Rod

The rod is made of mild steel as shown in Figure 4. A 10mm (3/8")

fig4x107.gif (486x486)

DRILL + TAP
FOR 10MM BOLT

25 MM

10 MM HOLE
FOR ROD HINGE PIN

46.5
CM

19MM DIA. ROD

DRILL + TAP.
FOR 12.5MM THREAD
38MM DEEP

FIG 4
ROD
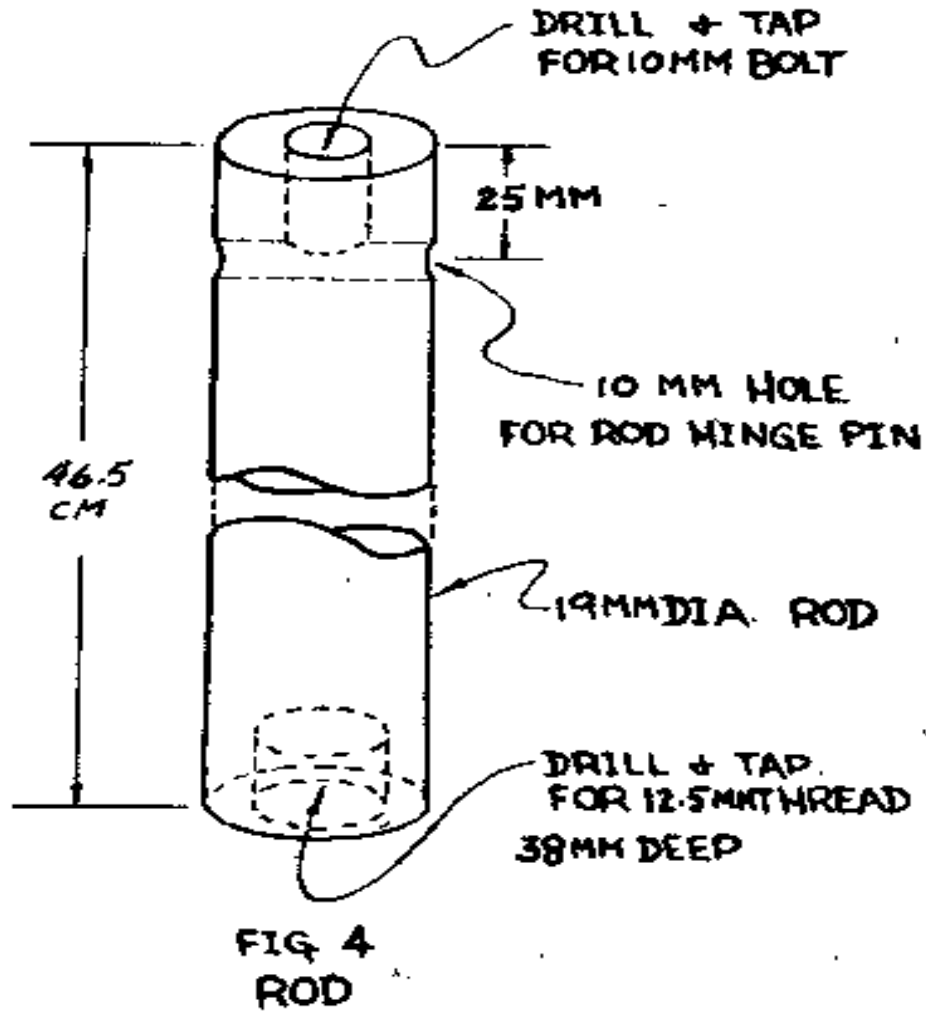
diameter machine bolt 38mm (1 1/2") long screws into the end of

the rod to lock the rod hinge pin
in place. The rod hinge pin is a
10mm (3/8") diameter machine bolt
that connects the rod to the handle
(see Figure 1). The end of the rod

fig1x105.gif (486x486)

ROD HINGE PIN

HANDLE

ROD

LINK

BLOCK

FIG I
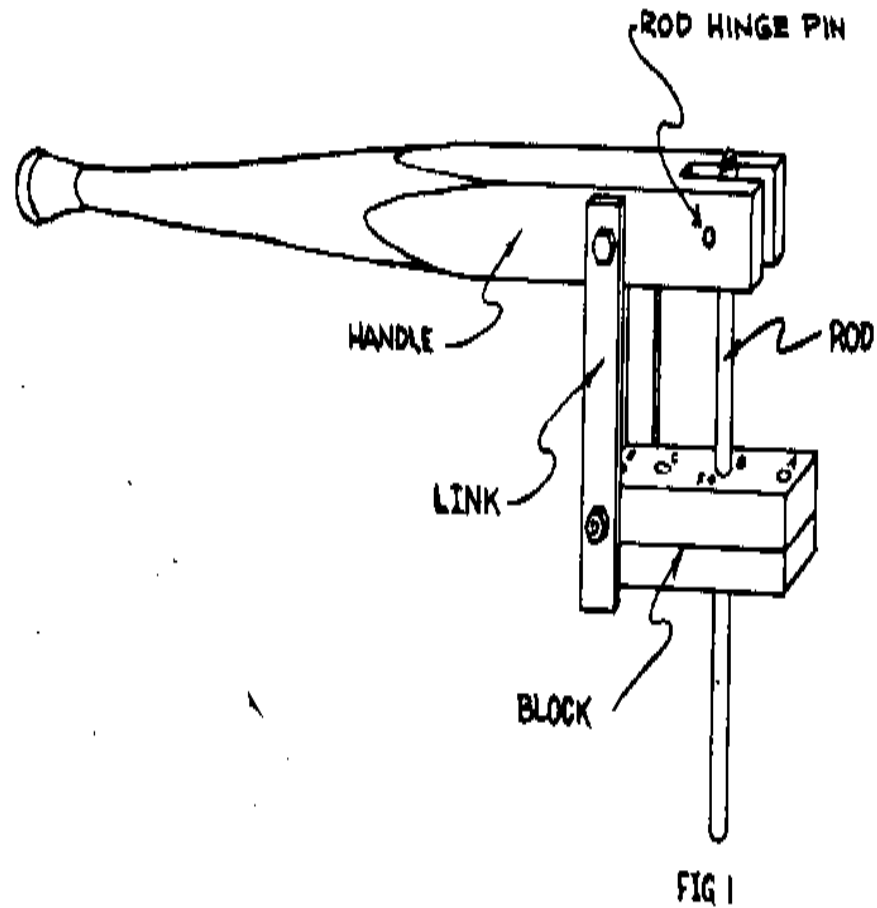
can be bolted directly to the pump
piston with a 12.5mm bolt. If the
pump cylinder is too far down for
this, a threaded 12.5mm (1/2") rod
should be used instead.

Links

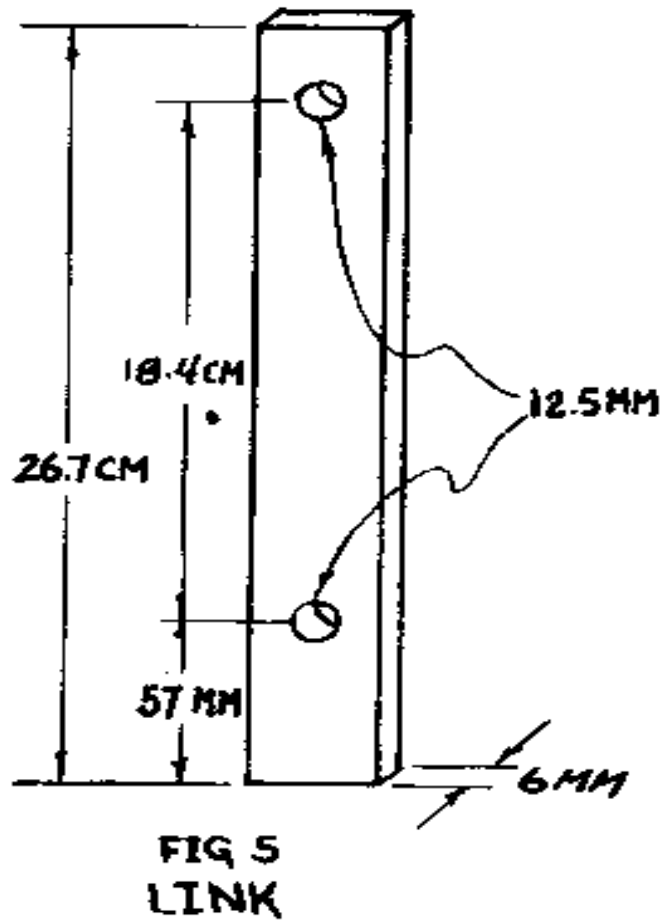**The links are two pieces of flat steel strap iron. Clamp them together for drilling**
to make the hole spacing equal. See Figure 5.

fig5x107.gif (486x486)

FIG 5
LINK

Block

The block forms the base of the lever mechanism, serves as a lubricated guide
hole for the rod, and provides a means for fastening the mechanism to the pump
barrel. If the block is accurately made of seasoned tough hardwood without
knots,
the mechanism will function well for many years. Carefully square the block to
22.9cm x 6.4cm x 6.4cm (9" x 1 1/2" x 1 1/2"). Next holes, A, B, C, and D are
drilled perpendicular to the block as shown in Figure 6. The spacing of the

fig6x107.gif (540x540)

6MM D OIL HOLE
MEETS OIL GLAND

19MM D.

6MM D. OIL HOLE

22.86 CM

A

B

C

E

F

32MM

35MM

19MM

12.5MM D CENTERED

D

29MM

64MM

12.7CM

COTTON FILLED HOLLOW
FORMS OIL GLAND
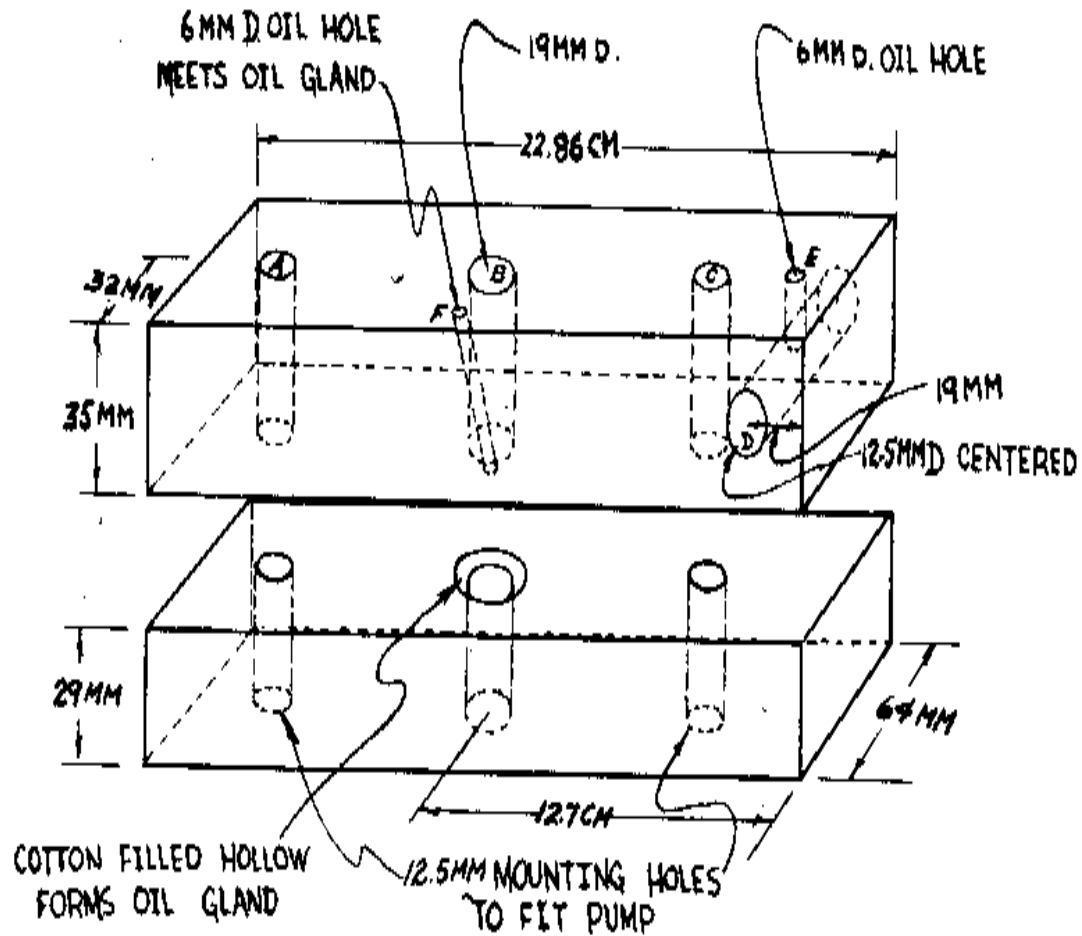
12.5MM MOUNTING HOLES
TO FIT PUMP

FIG 6

BLOCK

mounting holes A and C from hole B is determined by the spacing of the bolt
holes in the barrel flange of your pump. Next saw the block in half in a plane
3.5cm (13/8") down from the top side. Enlarge hole B at the top of the lower
section with a chisel to form an oil well around the rod. This well is filled
with

cotton. A 6mm (1/4") hole, F, is drilled at an angle from the oil well to the surface of the block. A second oil duct hole E is drilled in the upper section of
the block to meet hole D. Use lockwashers under the head and nut of the link bolts to lock the bolts and links together. Use plain washers between the links and the wooden parts.

Source:

Abbott, Dr. Edwin. A Pump Designed for Village Use. Philadelphia: American Friends Service Committee, 1955.

Hydraulic Ram

A hydraulic ram is a self-powered pump that uses the energy of falling water to lift some of the water to a level above the original source. This entry explains the use of commercial hydraulic rams, which are available in some countries. Plans
for building your own hydraulic ram are also available from VITA and elsewhere.

Use of the Hydraulic Ram

A hydraulic ram can be used wherever a spring or stream of water flows with at least a 91.5cm (3') fall in altitude. The source must be a flow of at least 11.4 liters (3 gallons) a minute. Water can be lifted about 7.6 meters (25') for each 30.5cm (12") of fall in altitude. It can be lifted as high as 152 meters (500'), but
a more common lift is 45 meters (150').

The pumping cycle (see Figure 1) is:

fig1x108.gif (600x600)

A. AIR CHAMBER
B. CHECK VALVE
C. ADJUSTMENT WEIGHT
D. DRIVE PIPE
E. GATE VALVE
F. OUTSIDE VALVE
G. CAST IRON BASE
H. AIR FEEDER VALVE
I. DELIVERY PIPE
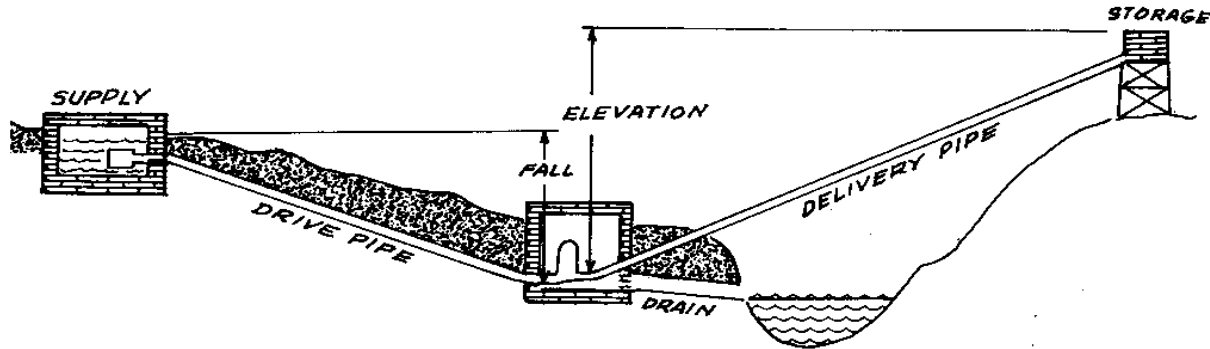
FIGURE 1
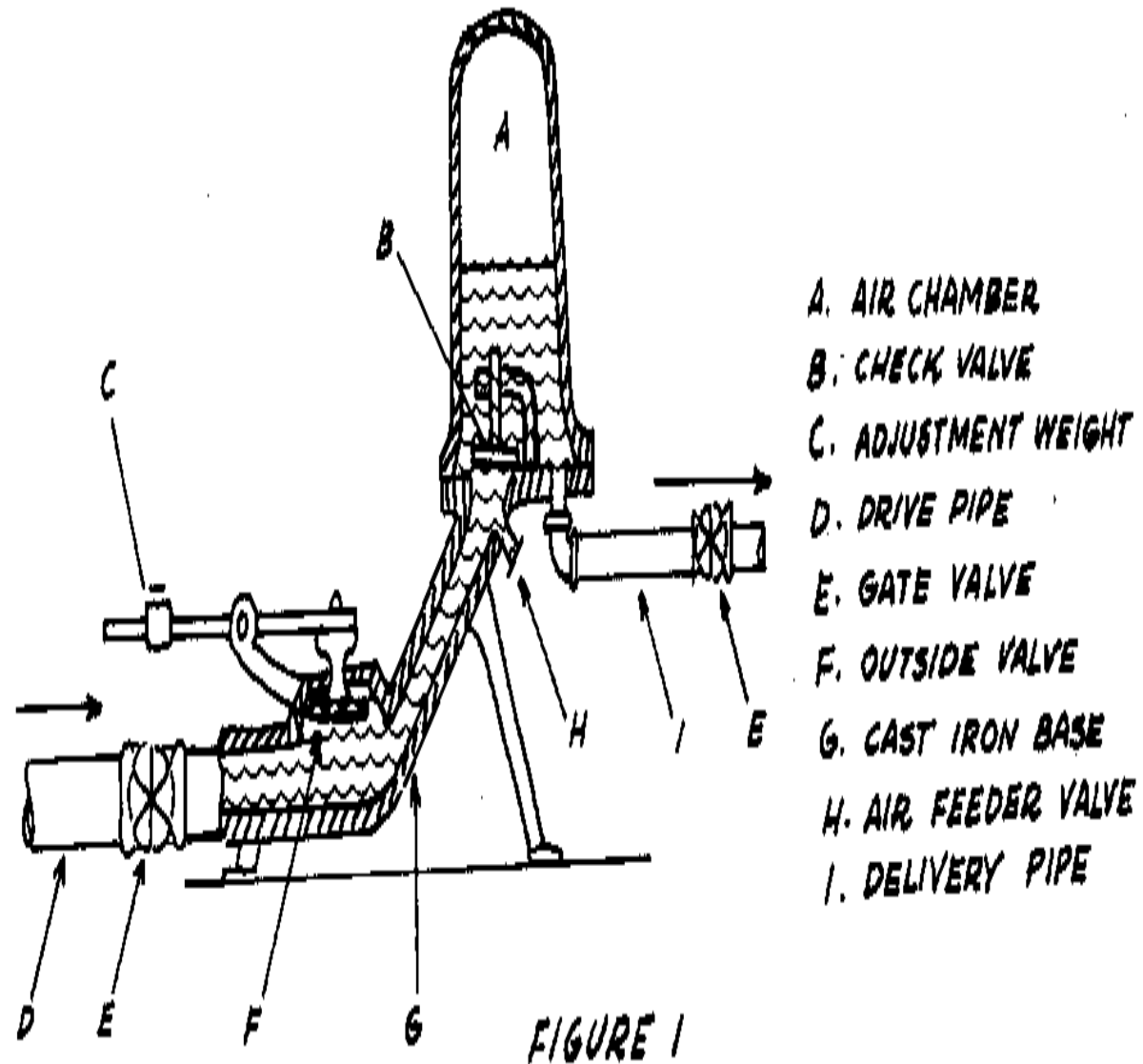
o **Water flows through the drive pipe (D) and out the outside valve (F).**

o **The drag of the moving water closes the valve (F).**

o **The momentum of water in the drive pipe (D) drives some water into the air chamber (A) and out the delivery pipe (I).**

o **The flow stops.**

o **The check valve (B) closes**

o **The outside valve (F) opens to start the next cycle.**

This cycle is repeated 25 to 100 times a minute; the frequency is regulated by moving the adjustment weight (C).

The length of the drive pipe must be between five and ten times the length of the fall (see Figure 2). If the distance from the source to the ram is greater than

fig2x109.gif (600x600)

A. COMMON ARRANGEMENT OF DRIVE PIPE, RAM AND STORAGE
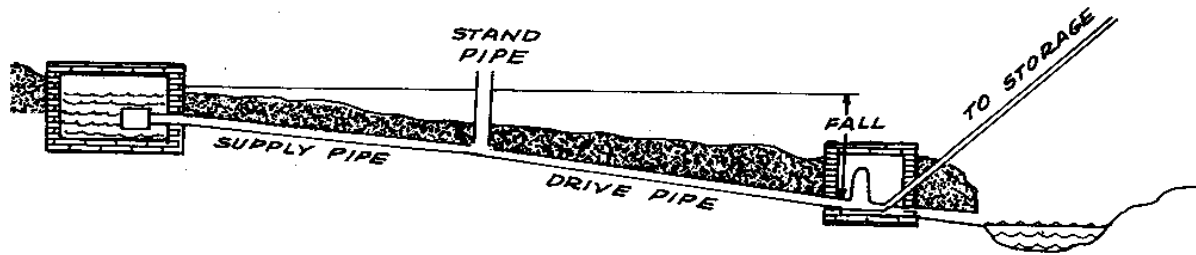
B. ARRANGEMENT OF DRIVE PIPE FOR A DISTANT WATER SUPPLY

C. ARTESIAN WELL OPERATING A RAM

FIGURE 2

ten times the length of the fall, the length of the drive pipe can be adjusted by
installing a stand pipe between the source and the ram (see B in Figure 2).

Once the ram is installed there is little need for maintenance and no need for skilled labor. The cost of a hydraulic ram system must include the cost of the pipe and installation as well as 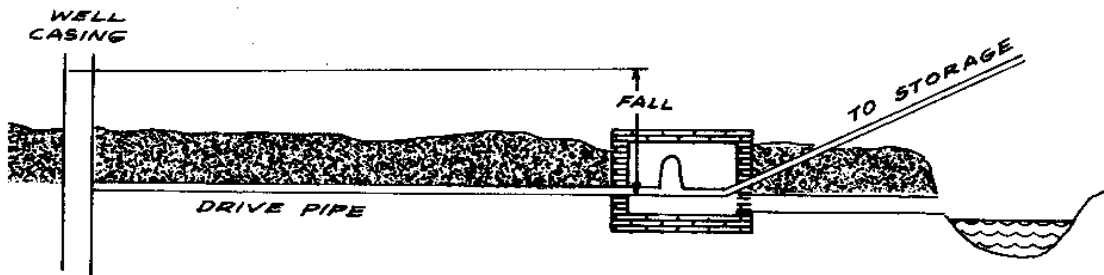the ram. Although the cost may seem high, it must be remembered that there is no further power cost and a ram will last for 30 years or more. A ram used in freezing climates must be insulated.

A double-acting ram will use an impure water supply to pump two-thirds of the pure water from a spring or similar source. A third of the pure water mixes with the impure water. A supplier should be consulted for this special application.

To calculate the approximate pumping rate, use the following equation:

Capacity (gallons per hour) = V x F x 40

E

V = gallons per minute from source
F = fall in feet
E = height the water is to be raised in feet

Data Needed for Ordering a Hydraulic Ram

1. Quantity of water available at the source of supply in liters (or gallons) per
minute

2. Vertical fall in meters (or feet) from supply to ram

3. Height to which the water must be raised above the ram

4. Quantity of water required per day

5. Distance from the source of supply to the ram

6. Distance from the ram to the storage tank

Sources:

Loren G. Sadler, New Holland, Pennsylvania

Rife Hydraulic Engine Manufacturing Company, Millburn, New Jersey

Sheldon, W.H. The Hydraulic Ram. Extension Bulletin 171, July 1943, Michigan State College of Agriculture and Applied Science.

"Country Workshop." Australian Country. September 1961, pages 32-33.

"Hydraulic Ram Forces Water to Pump Itself." Popular Science, October 1948, pages 231-233.

"Hydraulic Ram." The Home Craftsman, March-April 1963, pages 20-22.

RECIPROCATING WIRE POWER TRANSMISSION
FOR WATER PUMP

A reciprocating wire can transmit power from a water wheel to a point up to 0.8km (1/2 mile) away where it is usually used to pump well water. These devices

have been used for many years by the Amish people of Pennsylvania. If they are properly installed, they give long, trouble-free service.

The Amish people use this method to transmit <see figure 1> mechanical power from small water

fig1x111.gif (486x486)
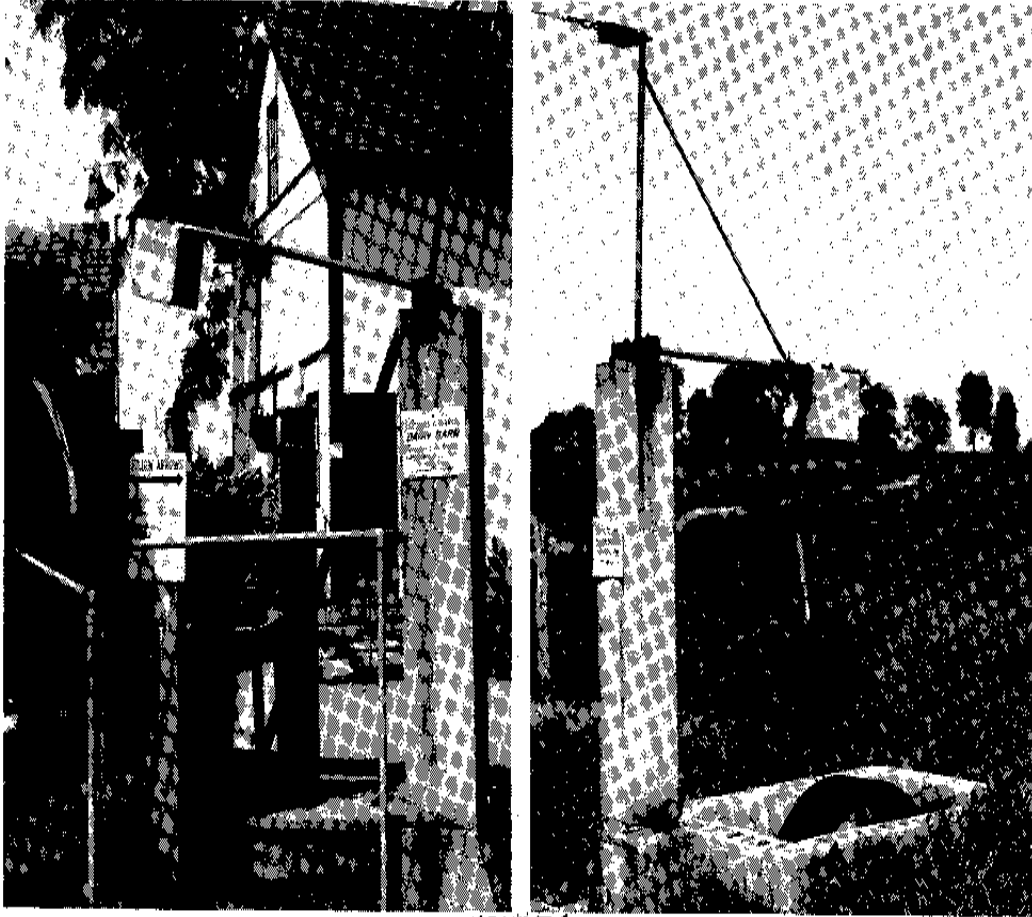
FIGURE 1.

wheels to the barnyard, where the reciprocating motion is used to pump well water for home and farm use. The water wheel is typically a small undershot wheel (with the water flowing under the wheel) one or two feet in diameter. The wheel shaft is fitted with a crank, which is attached to a triangular frame that pivots on a pole (see Figure 2). A wire is used to connect this frame to another

fig2x112.gif (600x600)

POWER WIRE MAY BE
0.8KM LONG

POLES WITH CHAINS SUPPORT
WIRE AT INTERVALS

2m

COUNTER
WEIGHT

RIGID
TRIANGULAR
FRAME
PIVOTS
HERE

2m

COUNTER
WEIGHT
(50-70KG)

1.5m

CRANK
ARM

ABOUT 25m

FIGURE2

PUMP
CYLINDER

UNDERSHOT
WATER WHEEL
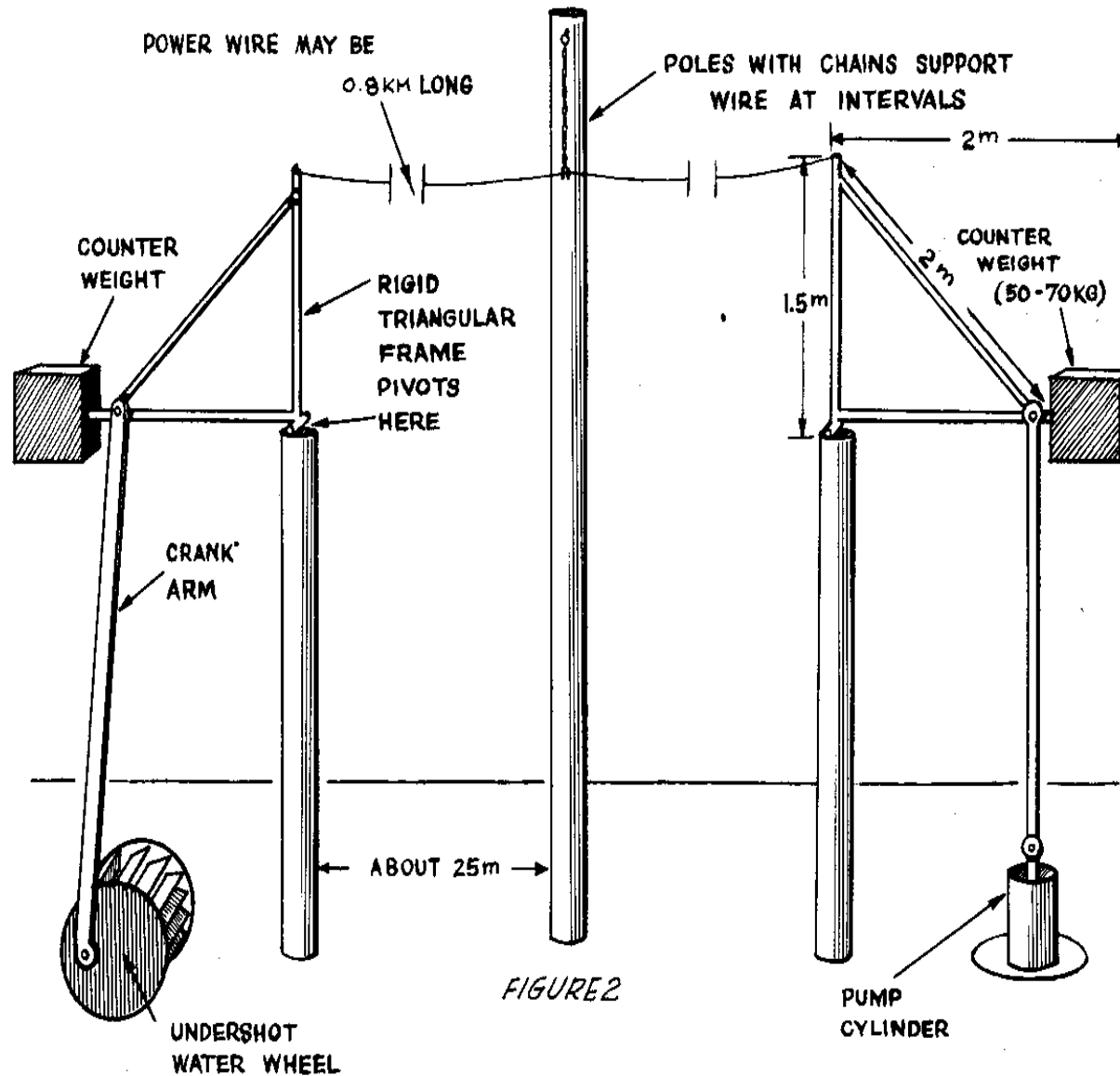
identical unit located over the well. Counterweights keep the wire tight.

Tools and Materials

Wire: galvanized smooth fence wire
Water wheel with eccentric crank to give a motion slightly less than largest
stroke of farmyard pump
Galvanized pipe for triangle frames: 2cm (3/4") by 10 meters long (32.8')
Welding or brazing equipment to make frames
Concrete for counterweight
2 Poles: 12 to 25cm (6" to 10") in diameter.

As the water wheel turns, the
crank tips the triangular frame
back and forth. This action pulls
the wire back and forth. One
typical complete back and forth
cycle takes 3 to 4 seconds.
Sometimes power for several
transmission wires comes from one
larger water wheel.

The wire is mounted up on poles to
keep it overhead and out of the
way. If the distance from stream to
courtyard is far, extra poles will be
needed to help support the wire.
Amish folks use a loop of wire
covered with a small piece of
garden hose attached to the top of
the pole. The reciprocating wire
slides back and forth through this

loop. If this is not possible, try making the pole 1-2 meters higher than the power wire. Drive a heavy nail near the pole top and attach a chain or wire from it to the power wire as shown in Figure 3.

fig3x113.gif (486x486)

POLE

HEAVY
NAIL

1 OR 2 M

POWER WIRE
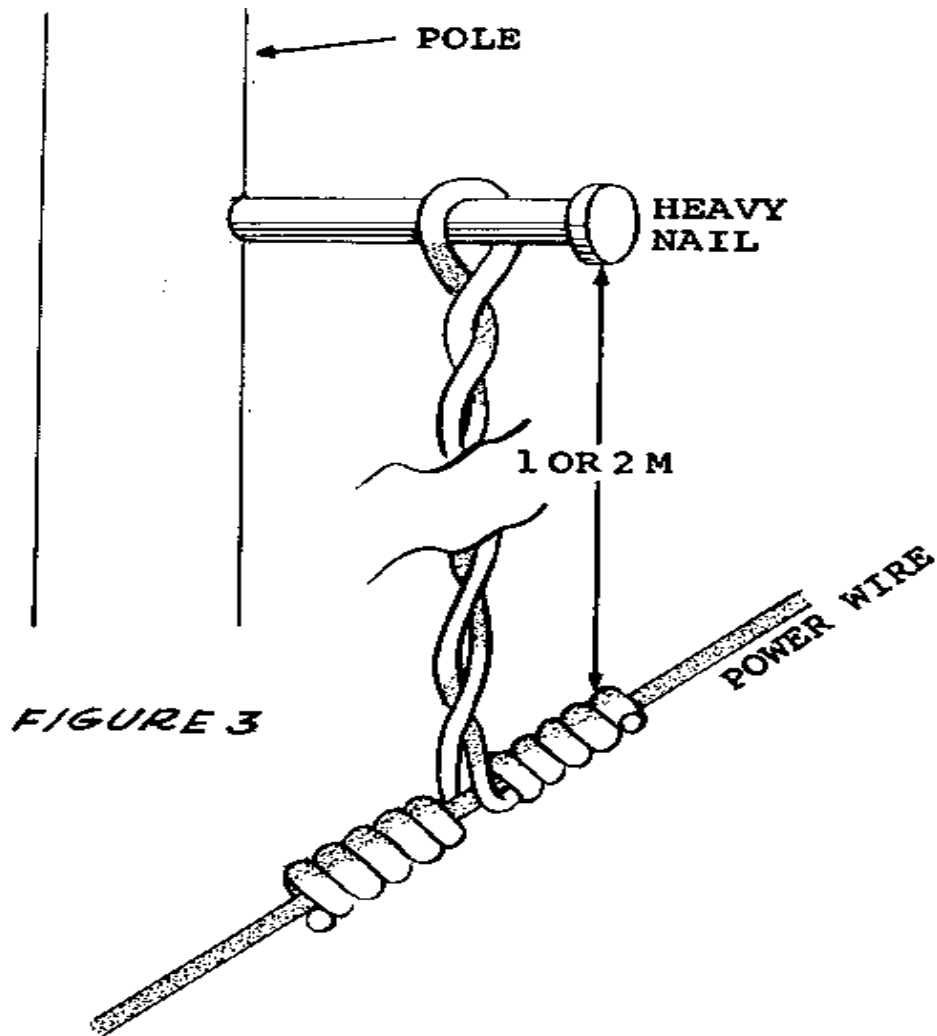
FIGURE 3

Turns can be made in order to
follow hedgerows by mounting a
small triangular frame horizontally
at the top of a pole as shown in
Figure 4.

fig4x113.gif (486x486)

POWER WIRE

STEEL ROD OR PIPE
SUNK INTO POLE

PIPE FRAME WELDED
OR BRAZED

POWER WIRE

POLE
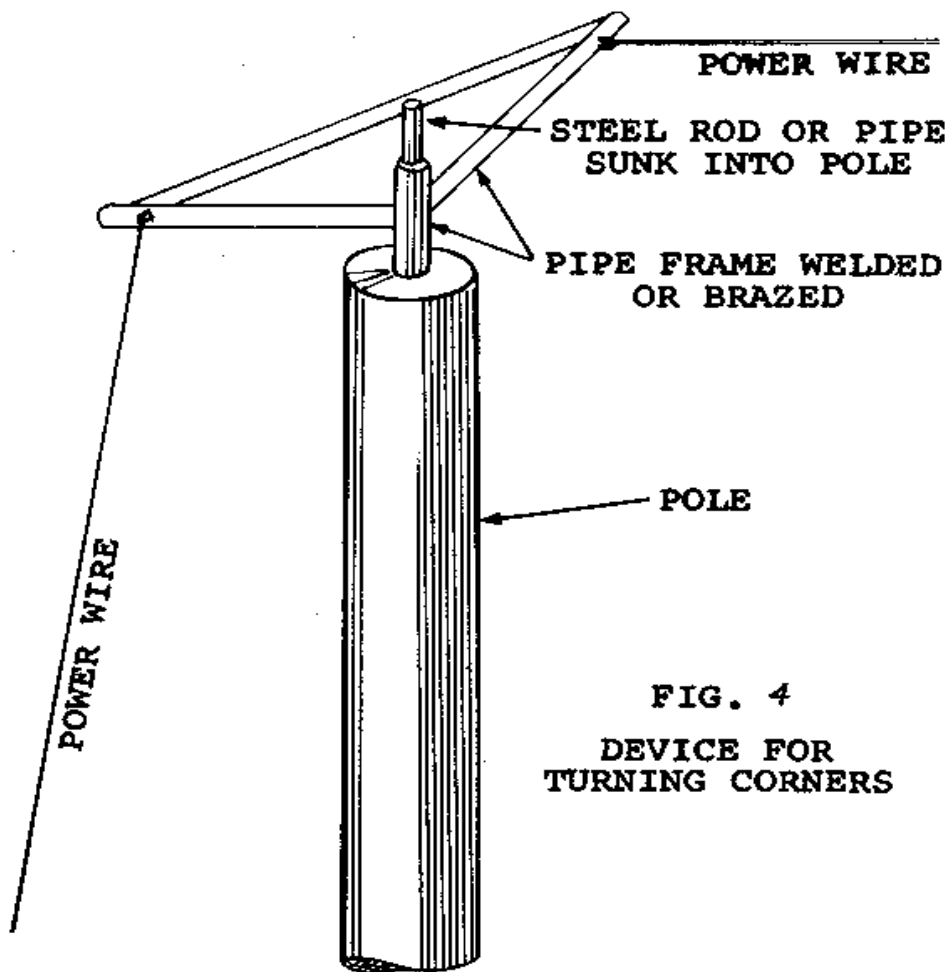
FIG. 4

DEVICE FOR
TURNING CORNERS

Figures 5, 6, and 7 show how to

fig51140.gif (600x600)

DRIVE PLATE
PINNED TO
SHAFT

THIN SLABS APPROX.
5 CM. THICK SLICED
FROM LOGS AND
NOTCHED FOR
BAMBOO CUPS

WHEEL SHOULD BE
AT LEAST 90 CM
IN DIAMETER

SHAFT OR PIPE

BAMBOO CUPS
BOUND TO DISCS
WITH WIRE THROUGH
HOLES ON EACH END

DRIVE PLATE
WELDED ON
LOCKED SHAFT

FIGURE 5

9 CM FOR 90 CM WHEEL
10 CM FOR 100 CM WHEEL
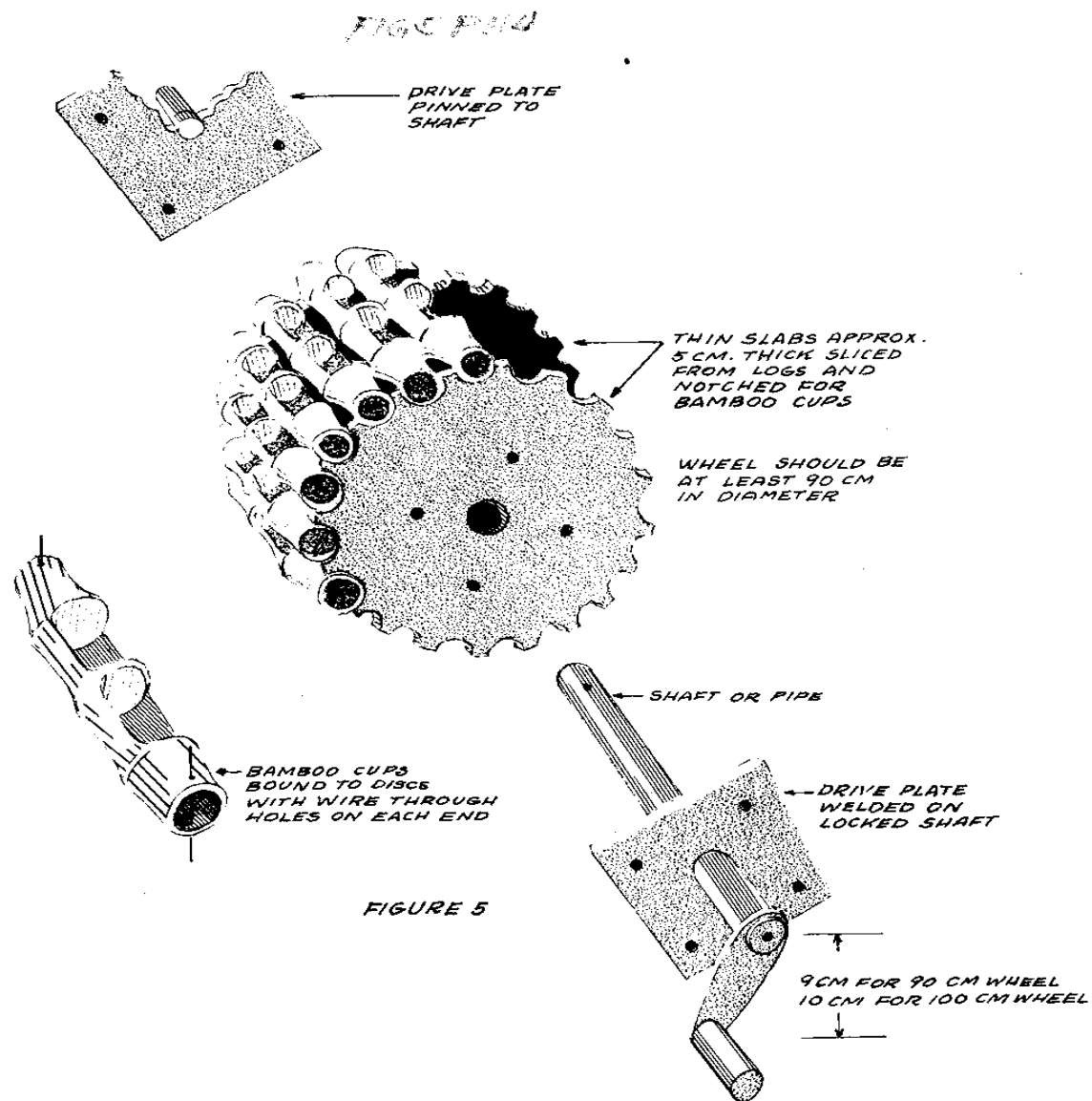
wheel made from wood and bamboo.

Source

New Holland, Pennsylvania VITA Chapter.

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Conversion Tables

CONVERSION TABLES

MULTIPLY BY TO OBTAIN

acres 43,560 square feet
acres 4,047 square meters
acres 1.562 X [10.sup.-3] square miles
acres 0.004047 square kilometers
acres 4840 square yards
atmospheres 76.0 cms of mercury
atmospheres 29.92 inches of mercury
atmospheres 10,333 kgs/square meter
atmospheres 14.70 pounds/square inch
British thermal units 0.2530 kilogram-calories
B.t.u. 777.5 foot-pounds
B.t.u. 3.927 X [10.sup.-4] horsepower-hours
B.t.u. 1,054 joules
B.t.u. 107.5 kilogram-meters
B.t.u. 2.928 X [10.sup.-4] kilowatt-hours
B.t.u./min. 0.02356 horsepower
B.t.u./min. 0.01757 kilowatts
B.t.u./min. 17.57 watts
calories 0.003968 B.t.u.
calories 3.08596 foot-pounds
calories 1.1622 X [10.sup.-6] kilowatt-hours
centimeters 0.3937 inches
centimeters 0.01 meters
centimeters of mercury 0.1934 pounds/square inch

```
centimeters/second 1.969 feet/minute
centimeters/second 0.036 kilometer/hour
centimeters/second 0.6 meters/minute
centimeters/second 0.02237 miles/hour
cubic centimeters [10.sup.-6] cubic meters
cubic centimeters 6.102 X [10.sup.-2] cubic inches
cubic centimeters 3.531 x [10.sup.-5] cubic feet
cubic centimeters 1.308 X [10.sup.-6] cubic yards
cubic feet 1,728 cubic inches
cubic feet 0.02832 cubic meters
cubic feet 2.832 X [10.sup.4] cubic centimeters
cubic feet 7.481 gallons
cubic feet 28.32 liters
cubic feet/minute 472.0 cubic cms/second
cubic feet/minute 0.1247 gallons/second
cubic feet/minute 0.4720 liters/second
cubic feet/minute 62.4 pounds water/min
cubic inches 5.787 X [10.sup.-4] cubic feet
cubic inches 1.639 X [10.sup.-5] cubic meters
cubic inches 2.143 X [10.sup.-5] cubic yards
cubic meters 35.31 cubic feet
cubic meters 264.2 gallons
cubic meters [10.sup.3] liters
cubic yards 7.646 X [10.sup.5] cubic centimeters
cubic yards 27.0 cubic feet
cubic yards 46,656 cubic inches
cubic yards 0.7646 cubic meters
cubic yards 202.0 gallons
cubic yards 764.6 liters
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cubic yards/min. 0.45 cubic feet/second


MULTIPLY BY TO OBTAIN
cubic yards/min. 3.367 gallons/second
cubic yards/min. 12.74 liters/second
degrees (angle) 60 minutes
degrees (angle) 0.01745 radians
degrees (angle) 3,600 seconds
dynes 1.020 X [10.sup.-3] grams
dynes 2.248 X [10.sup.-6] pounds
ergs 9.486 X [10.sup.-11] B.t.u.
ergs 1 dyne-centimeters
ergs 7.376 X [10.sup.-8] foot-pounds
ergs [10.sup.-7] joules
ergs 2.390 X [10.sup.-11] kilogram-calories
ergs 1.020 X [10.sup.-8] kilogram-meters
ergs/second 1.341 X [10.sup.-10] horsepower
ergs/second [10.sup.-10] kilowatts
feet 30.48 centimeters
feet 0.3048 meters
feet/second 18.29 meters/minute
foot-pounds 1.286 X [10.sup.-3] B.t.u.
foot-pounds 1.356 X [10.sup.7] ergs
foot-pounds 5.050 X [10.sup.-7] horsepower-hours
foot-pounds 3.241 X [10.sup.-4] kilogram-calories
foot-pounds 0.1383 kilogram-meters
foot-pounds 3.766 X [10.sup.-7] kilowatt-hours
foot-pounds/minute 1.286 X [10.sup.-3] B.t.u./minute
foot-pounds/minute 0.01667 foot-pounds/second
```

Foot-pounds/minute 3.241 X [10.sup.-4] kg-calories/min
foot-pounds/minute 2.260 X [10.sup.-5] kilowatts
foot-pounds/second 7.172 X [10.sup.-2] B.t.u./minute
foot-pounds/second 1.818 X [10.sup.-3] horsepower
foot-pounds/second 1.945 X [10.sup.-2] kg-calories/min
foot-pounds/second 1.356 X [10.sup.-3] kilowatts
gallons 0.1337 cubic feet
gallons 231 cubic inches
gallons 3.785 X [10.sup.-3] cubic meters
gallons 3.785 liters
gallons/minute 2.228 X [10.sup.-3] cubic feet/second
gallons/minute 0.06308 liters/second
grams [10.sup.-3] kilograms
grams [10.sup.3] miligrams
grams 0.03527 ounces
grams 0.03215 troy ounces
grams/cubic centimeter 62.43 pounds/cubic feet
grams centimeters 9.297 X [10.sup.-8] B.t.u.
horsepower 42.44 B.t.u./minute
horsepower 33,000 foot-pounds/minute
horsepower 550 foot-pounds/second
horsepower 10.70 kg-calories/min
horsepower 0.7457 kilowatts
horsepower 745.7 watts
horsepower 1.014 horsepower(metric)
horsepower-hours 2547 B.t.u.
horsepower-hours 1.98 X [10.sup.6] foot-pounds
horsepower-hours 641.7 kilogram-calories
horsepower-hours 2.737 X [10.sup.5] kilogram-meters

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horsepower-hours 0.7457 kilowatt-hours
horsepower-hours 2.684 X [10.sup.6] joules
inches 2.540 centimeters
inches 254.0 millimeters


MULTIPLY BY TO OBTAIN
inches of mercury 0.03342 atmospheres
inches of mercury 1.133 feet of water
inches of mercury 345.3 kgs/sq meter
inches of mercury 70.73 pounds/sq foot
inches of mercury 0.4912 pounds/sq inch
inches of water 0.002458 atmospheres
inches of water 0.07355 inches of mercury
inches of water 25.40 kgs/square meter
inches of water 0.5781 ounces/square inch
inches of water 5.204 pounds/square foot
inches of water 0.03613 pounds/square inch
joules 0.0009458 B.t.u.
joules 0.73756 foot-pounds
joules 0.0002778 watt-hours
joules 1.0 watt-seconds
kilograms 980,665 dynes
kilograms [10.sup.3] grams
kilograms 2.2046 pounds
kilograms 1.102 X [10.sup.-3] short tons
kilogram-calories 3.968 B.t.u.
kilogram-calories 3,086 foot-pounds
kilogram-calories 1.558 X [10.sup.-3] horsepower-hours
kilogram-calories 4,183 joules
```

kilogram-calories 426.6 kilogram-meters

kilogram-calories/min. 51.43 foot-pounds/second

kilogram-calories/min. 0.09351 horsepower

kilogram-calories/min. 0.06972 kilowatts

kilograms/hectare .893 pounds/acre

kilometers [10.sup.5] centimeters

kilometers 0.6214 miles

kilometers 3,281 feet

kilometers 1,000 meters

kilometers 1093.6 yards

kilometers/hour 27.78 centimeters/sec

kilometers/hour 54.68 feet/minute

kilometers/hour 0.9113 feet/second

kilometers/hour 0.5396 knots/hour

kilometers/hour 16.67 meters/hour

kilometers/hour 0.6214 miles/hour

kilowatts 56.92 B.t.u./minute

kilowatts 4.425 X [10.sup.4] foot-pounds/minute

kilowatts 737.6 foot-pounds/second

kilowatts 1.341 horsepower

kilowatts 14.34 kg-calories/min

kilowatts [10.sup.3] watts

kilowatts-hours 3,412 B.t.u.

kilowatts-hours 2.655 X [10.sup.6] foot-pounds

kilowatts-hours 1.341 horsepower-hours

kilowatts-hours 3.6 X [10.sup.6] joules

kilowatts-hours 860.5 kilogram-calories

kilowatts-hours 3.671 X [10.sup.5] kilogram-meters

meters 100 centimeters

```
meters 3.2808 feet
meters 39.37 inches
meters [10.sup.-3] kilometers
meters [10.sup.3] millimeters
meters 1.0936 yards
meter-kilograms 9.807 X [10.sup.7] centimeter-dynes


MULTIPLY BY TO OBTAIN
meter-kilograms [10.sup.5] centimeter-grams
meter-kilograms 7.233 pound-feet
meters/minute 1.667 centimeters/second
meters/minute 3.281 feet/minute
meters/minute 0.05468 feet/second
meters/minute 0.06 kilometers/hour
meters/minute 0.03728 miles/hour
meters/second 196.8 feet/minute
meters/second 3.281 feet/second
meters/second 3.6 kilometers/hour
meters/second 0.06 kilometers/minute
meters/second 2.237 miles/hour
meters/second 0.03728 miles/minute
miles 1.609 X [10.sup.5] centimeters
miles 5,280 feet
miles 1.6093 kilometers
miles 1,760 yards
miles/min 88.0 feet/second
miles/min 1.6093 kilometers/minute
miles/min 0.8684 knots/minute
ounces 8.0 drams
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ounces 437.5 grains
ounces 28.35 grams
ounces 0.625 pounds
ounces/square inch 0.0625 pounds/square inch
pints (dry) 33.60 cubic inches
pints (liquid) 28.87 cubic inches
pounds 444,823 dynes
pounds 7,000 grains
pounds 453.6 grams
pounds 0.45 kilograms
pounds of water 0.01602 cubic feet
pounds of water 27.68 cubic inches
pounds of water 0.1198 gallons
pounds of water/min. 2.669 X [10.sup.-4] cubic feet/second
pounds/cubic foot 0.01602 grams/cubic cms.
pounds/cubic foot 16.02 kgs/cubic meter
pounds/cubic foot 5.787 X [10.sup.-4] pounds/cubic inch
pounds/square foot 4.882 kgs/sq meter
pounds/square foot 6.944 X [10.sup.-3] pounds/square inch
pounds/square inch 0.06304 atmospheres
pounds/square inch 703.1 kgs/square meter
pounds/square inch 144.0 pounds/square foot
quarts (dry) 67.20 cubic inches
quarts (liquid) 57.75 cubic inches
quadrants (angle) 90 degrees
quadrants (angle) 5,400 minutes
quadrants (angle) 1.571 radians
radians 57.30 degrees
radians 3,438 minutes
```

```
radians/second 57.30 degrees/second
raidans/second 0.1592 revolutions/second
revolutions 360.0 degrees
revolutions 4.0 quadrants
revolutions 6.283 radians
revolutions/minute 6.0 degrees/second
square centimeters 1.076 X [10.sup.-3] square feet
square centimeters 0.1550 square inches
square centimeters [10.sup.-6] square meters


MULTIPLY BY TO OBTAIN
square centimeters 100 square millimeters
square feet 2.296 X [10.sup.-5] acres
square feet 929.0 square centimeters
square feet 144.0 square inches
square feet 0.09290 square meters
square feet 3.587 X [10.sup.-8] square miles
square feet 0.1111 square yards
square inches 6.452 square centimeters
square inches 645.2 square millimeters
square meters 2.471 X [10.sup.-4] acres
square meters 10.764 square feet
square meters 3.861 X [10.sup.-7] square miles
square meters 1.196 square yards
square miles 640.0 acres
square miles 2.7878 X [10.sup.7] square feet
square miles 2.590 square kilometers
square miles 3.098 X [10.sup.6] square yards
square yards 2.066 X [10.sup.-4] acres
```

square yards 9.0 square feet
square yards 0.8361 square meters
square yards 3.228 X [10.sup.-7] square miles
temp (degs C) + 237 1.0 abs temp (degs K)
temp (degs C) + 17.8 1.8 temp (degs F)
temp (degs F) - 32 5/9 temp (degs C)
tons (long) 1,016 kilograms
tons (long) 2,240 pounds
tons (metric) [10.sup.3] kilograms
tons (metric) 2,205 pounds
tons (short) 907.2 kilograms
tons (short) 2,000 pounds
tons (short)/sq. foot 9,765 kgs/square meter
tons (short)/sq. foot 13.89 pounds/square inch
tons (short)/sq. inch 1.406 X [10.sup.6] kgs/square meter
tons (short)/sq. inch 2,000 pounds/square inch
yards 0.9144 meters

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 (Degrees Celsius) +32

Example:

This example may help to clarify the use of the equations; 72F equals how may 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.

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