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Village Technology Handbook

SECTION 1: WATER RESOURCES

Part 2: Water Lifting and Transport

FOREWORD

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

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

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

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

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

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

A NOTE ON USING THE HANDBOOK

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

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

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

Information on cooperatives is available from:

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

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

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

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

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

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

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

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

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

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

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

4. Explain any pertinent social or cultural conditions.

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

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

WHAT IS VITA?

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

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

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

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

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

SYMBOLS AND ABBREVIATIONS
USED IN THIS BOOK

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

QUESTIONNAIRE

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

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

Date ____________

Name ______________________________ Agency ____________________

Address ____________________________

____

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

2. Have results been good or otherwise?

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

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

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

6. Other comments and suggestions:

TABLE OF CONTENTS

Water Lifting and Transport

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

1. What is the rate of flow of water needed 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.

Water Transport

The first three entries are equations and alignment charts (also called nomographs) which 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.

Pipe Size

You will note that in these and other alignment charts, 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.

Water Lifting

The next four entries follow the steps required to design a water-pumping system with piping.

The first entry in this group, "Pump Selection" presents all factors that must be considered in selecting a pump. One should fill out the form included in the entry and make a piping sketch whether he plans to send it to a consultant for help or do the design and selection himself.

The next three entries enable the reader to design his own piping system and specify his own pump.

Selecting a Pump

The first information needed for selecting pump type and size is: (1) the flow rate of water needed and (2) the "head" or pressure to be overcome by the pump. This "head" is composed of two parts, (a) the height the liquid must be raised and (b) 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 Size and Horsepower Requirement," page 82 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 Size and Horsepower Requirement."

These four 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 Selection" 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.

Pumps

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 which will serve better than others. We will discuss here only two broad classes of pumps: lift pumps and force pumps.

Lift 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 on "Lift Pump Capability" explains how to find out the height a lift pump will raise water at different altitudes with different water temperatures.

Force Pumps

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

Construction details are given on two irrigation pumps which can be made at the village level. An easy-to-maintain pump handle mechanism is described. Suggestions are also given on using bamboo for piping.

Further details on pumps are given in:

Water Lifting Devices for Irrigation, by Aldert Molenaar, Food and Agriculture Organization of the United Nations, Rome, 1956.

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

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

Wells, TM 5-297/Armed Forces Manual 85-23, Government Printing Office, Washington, D.C., 1957.

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)

Stick for measuring depth

The following equation will help you to measure flow quickly: Q = K x A x V, 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 stages use K = 900 to 950.

FIGURE 1

To Find A (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.

1. Take a measuring stick and place it upright in the water about 50cm from the bank.

2. Note the depth of water.

3. Move the stick 1 meter from the bank in a line directly across the stream.

4. Note the depth.

5. Move the stick 1.5 meters from the bank, note the depth, and continue moving it at 50cm 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 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.

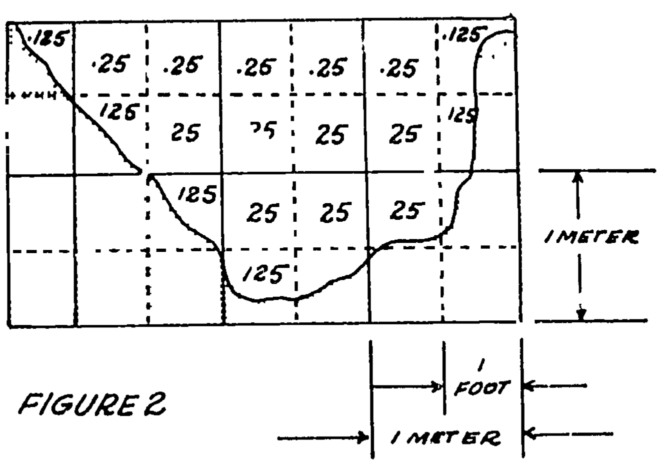


FIGURE 2

To Find V (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 should be as constant as possible and free of rapids, where the velocity is being measured.

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, will not change course so easily and makes a better 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

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

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 to be used would be similar to the one in Figure 3; a commonly used scale is 1" to 12".

Example:

Cross-section is 15 square fe t

Velocity of float = 20 feet traveled in 1/2 minute

Stream flow is normal

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

Q = 3800 gallons per minute

Source:

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

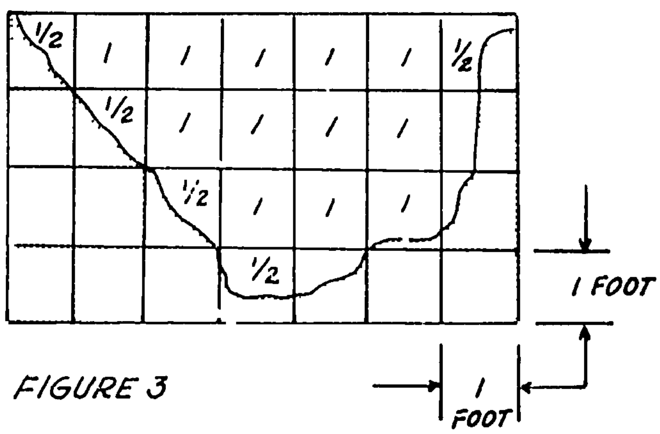


FIGURE 3

MEASURING THE FLOW OF WATER IN PARTIALLY FILLED PIPES

The flow of water in partially-filled horizontal pipes or circular 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.

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 bob 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 of 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 $K = \frac{h}{d}$ (see Figure 1).

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 a flow of 18 liters per minute.

Source:

Greve Bulletin, Purdue University (12, No. 5, 1928, Bulletin 32).

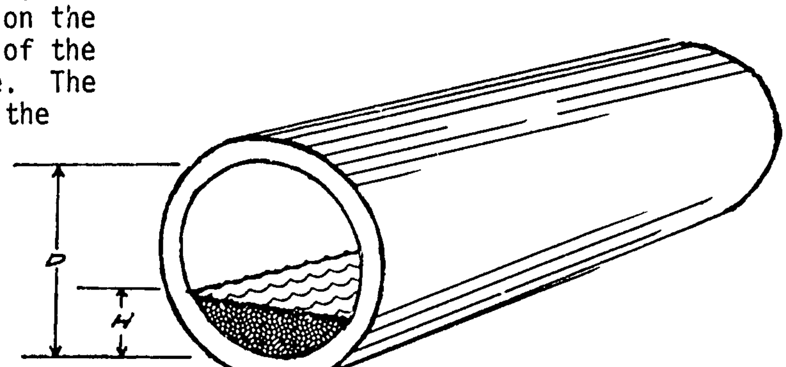
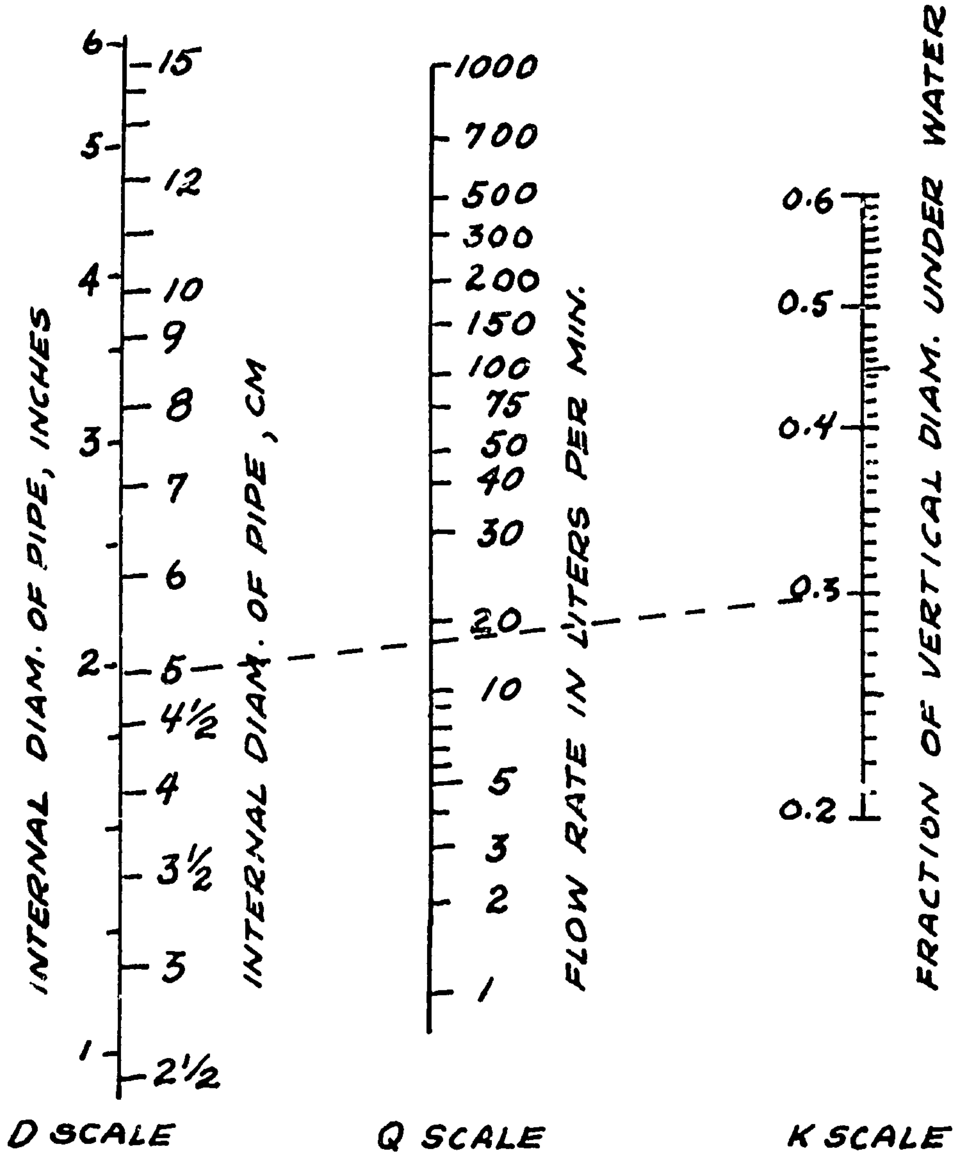


FIGURE 1

FIGURE 2


INTERNAL DIAM. OF PIPE, INCHES
INTERNAL DIAM. OF PIPE, CM
FLOW RATE IN LITERS PER MIN.
FRACTION OF VERTICAL DIAM. UNDER WATER
6
5
4
3
2
1
15
12
10
9
8
7
6
5
4½
4
3½
3
2½
1000
700
500
300
200
150
100
75
50
40
30
20
10
5
3
2
1
0.6
0.5
0.4
0.3
0.2
D SCALE
Q SCALE
K SCALE

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.

Materials

Straight edge, 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 which 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 handbook entry "Flow Resistance of Pipe Fittings," p. 80. 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 = 3000cm.

Calculate $L/D = \frac{3000\text{cm}}{3\text{cm}} = 1000$

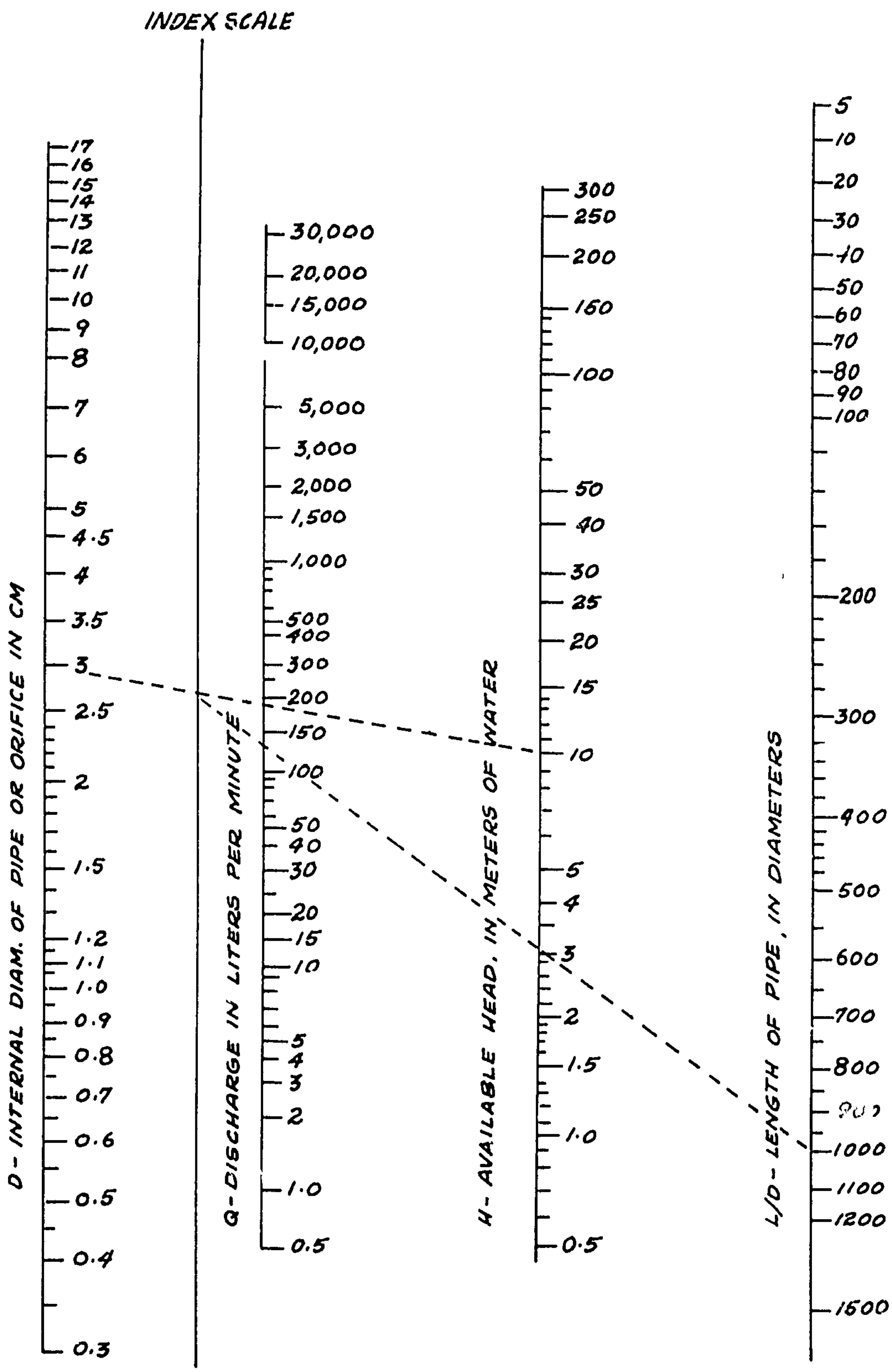
The alignment chart solution is in two steps:

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 (1000), and read flow rate (Q) of approximately 140 liters per minute.

Source:

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

FIGURE 1



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

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

Materials

Straightedge and pencil, to use alignment chart

Tape measure

Level

Plumb bob

The water flowing from the pipe must completely fill the pipe openin~ (see 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:

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

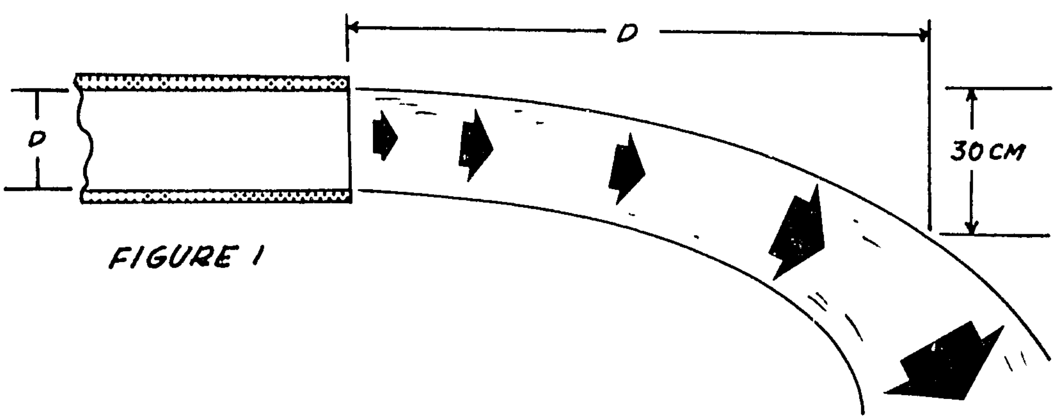


FIGURE 1

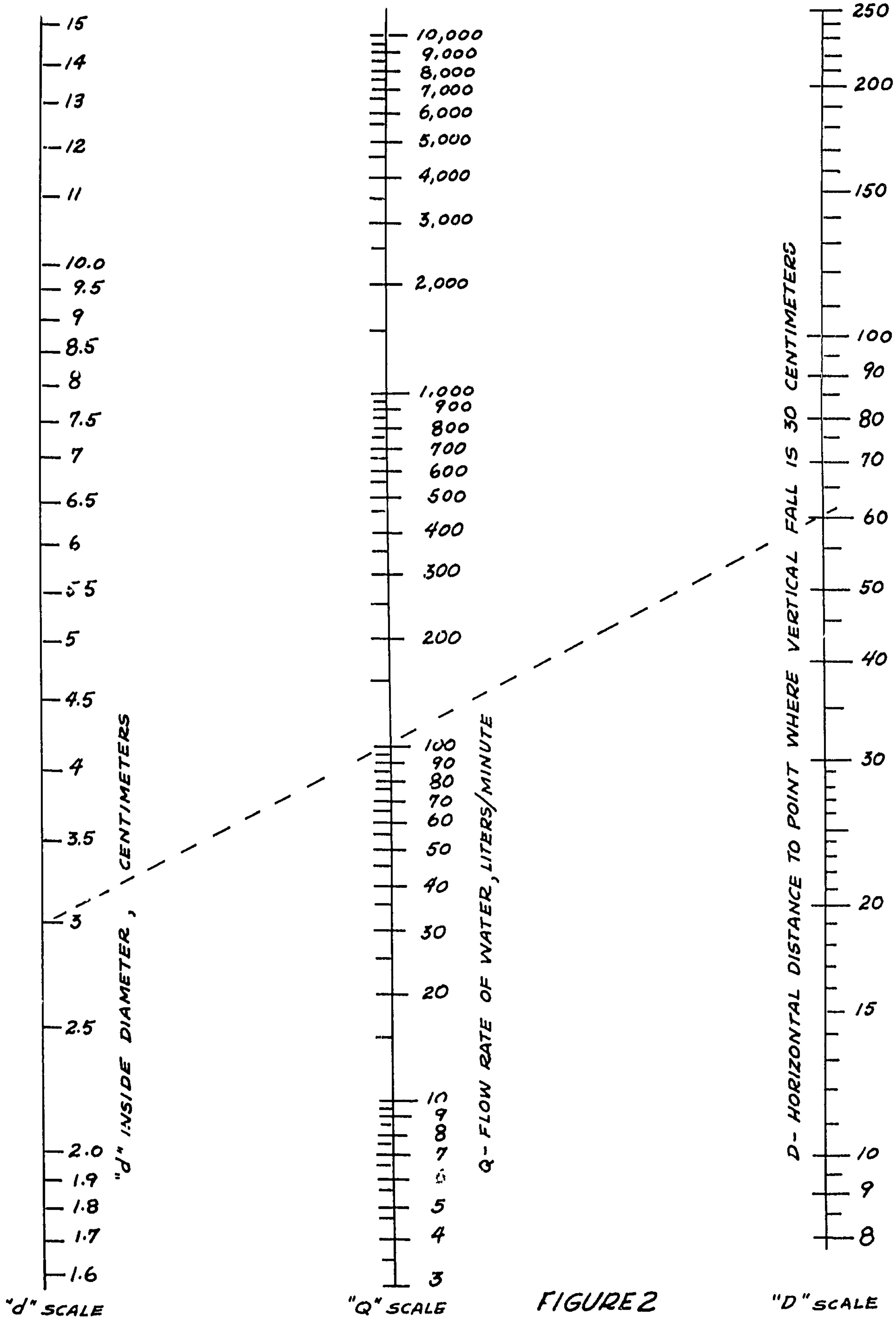

"d" INSIDE DIAMETER, CENTIMETERS
Q - FLOW RATE OF WATER, LITERS/MINUTE
D - HORIZONTAL DISTANCE TO POINT WHERE VERTICAL FALL IS 30 CENTIMETERS
"d" SCALE
"Q" SCALE
"D" SCALE

FIGURE 2

PUMP SPECIFICATION: Choosing a Pump for a Specific Job or Evaluating an Available Pump

The form given in Figure 1, the "Pump Application Fact Sheet," is a check list 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 what its capabilities are. The form is an adaptation of a standard pump specification sheet used by engineers.

If you are doubtful about how much information to give, it is better to give too much information rather than 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.

To give a better idea of how to use the "Pump Application Fact Sheet," it 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 off 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 since, if the correct pump is not selected, the solids will erode and break moving parts.

   Weight percent of solids =

   $$\frac{100 \times \text{weight of solids in liquid sample}}{\text{weight of liquid sample}}$$

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

PUMP APPLICATION FACT SHEET

NAME John Doe
ADDRESS P.O. Box 393
Xanadu
Gondwanaland

DATE July 14, 1969

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 - 1 mm

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, College Campus, Schenectady, New York, 12308, U.S.A.

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

motor or engine, give as much information about it as you can. Give the speed, 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 nameplate data completely. If the following data is available for your engine, give the number of cylinders, their size, and the stroke if possible.

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 "Pump Size and Horsepower Requirement", page 82, 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.

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" for comments on specifying pipe diameter.

9. Connections to commercial pumps are normally flanged or 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. (Read "Introduction" for comments on pipe diameter.)

    (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 information as:

    Indoor or outdoor installation?

    Continuous or intermittent service?

    Space or weight limitations?

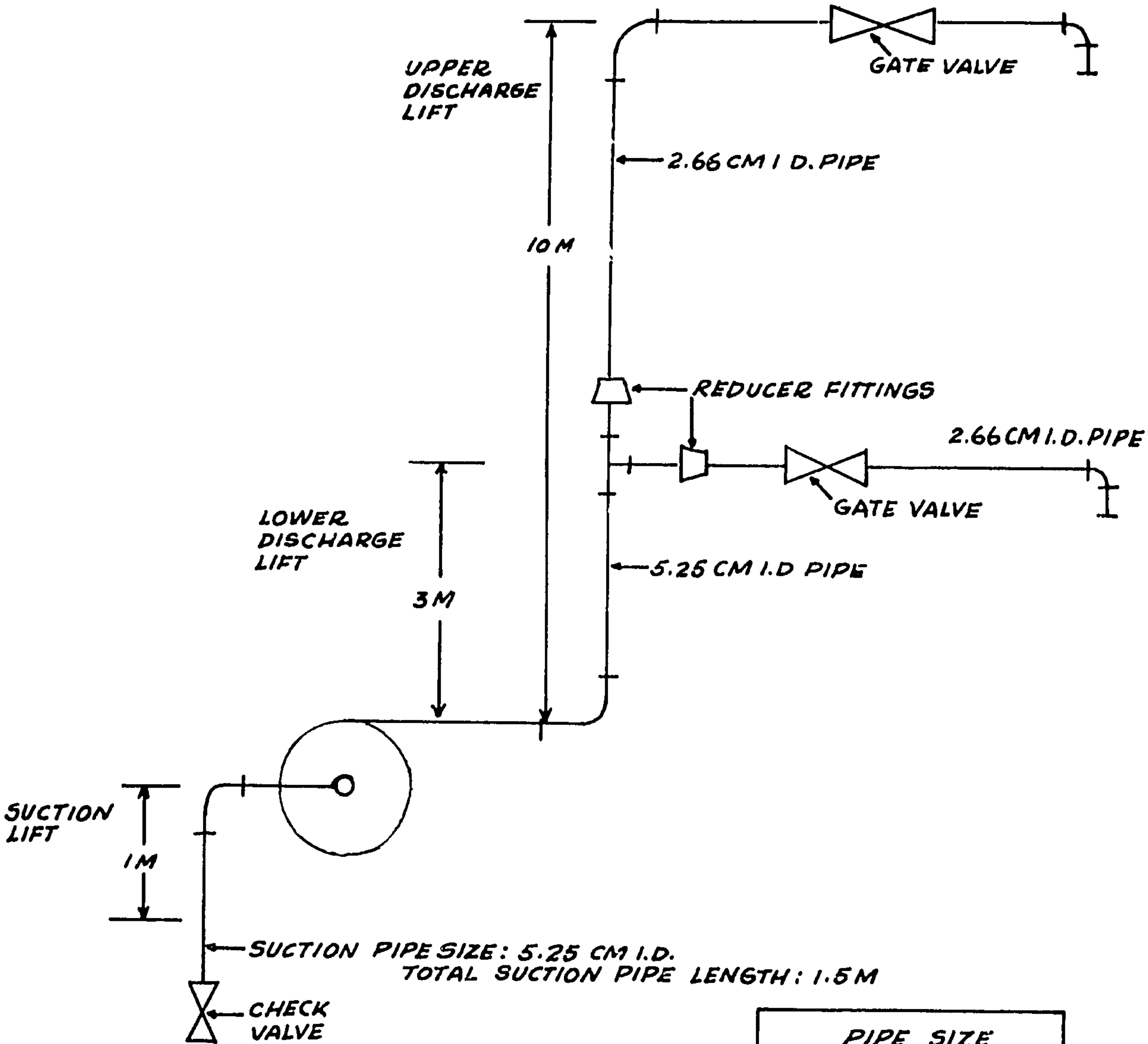
NOTE: For advice on pump selection or application, send a completed "Pump Application Fact Sheet" to a local university, a pump manufacturer or to VITA, College Campus, Schenectady, New York 12308, U.S.A.

Source:

Benjamin P. Coe, P.E./Executive Director, VITA, Schenectady, New York

FIGURE 2

(NOT DRAWN TO SCALE)



PIPE SIZE	
DIAMETER IN CM	
INSIDE	OUTSIDE
2.66	3.34
5.25	6.04

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 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 and pencil

Practical water systems use water velocities from 1.2 to 1.8 meters per second. Very fast velocity requires high pressure pumps which in turn require high pressure pumps which in turn require large motors and use excessive power. Velocities which 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 size. Remember, it is usually wise to choose a little larger pipe if higher flows are expected in the next 5 or 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, though 1.8m/sec velocity on the V-scale to the d-scale. Choose the nearest standard size pipe.

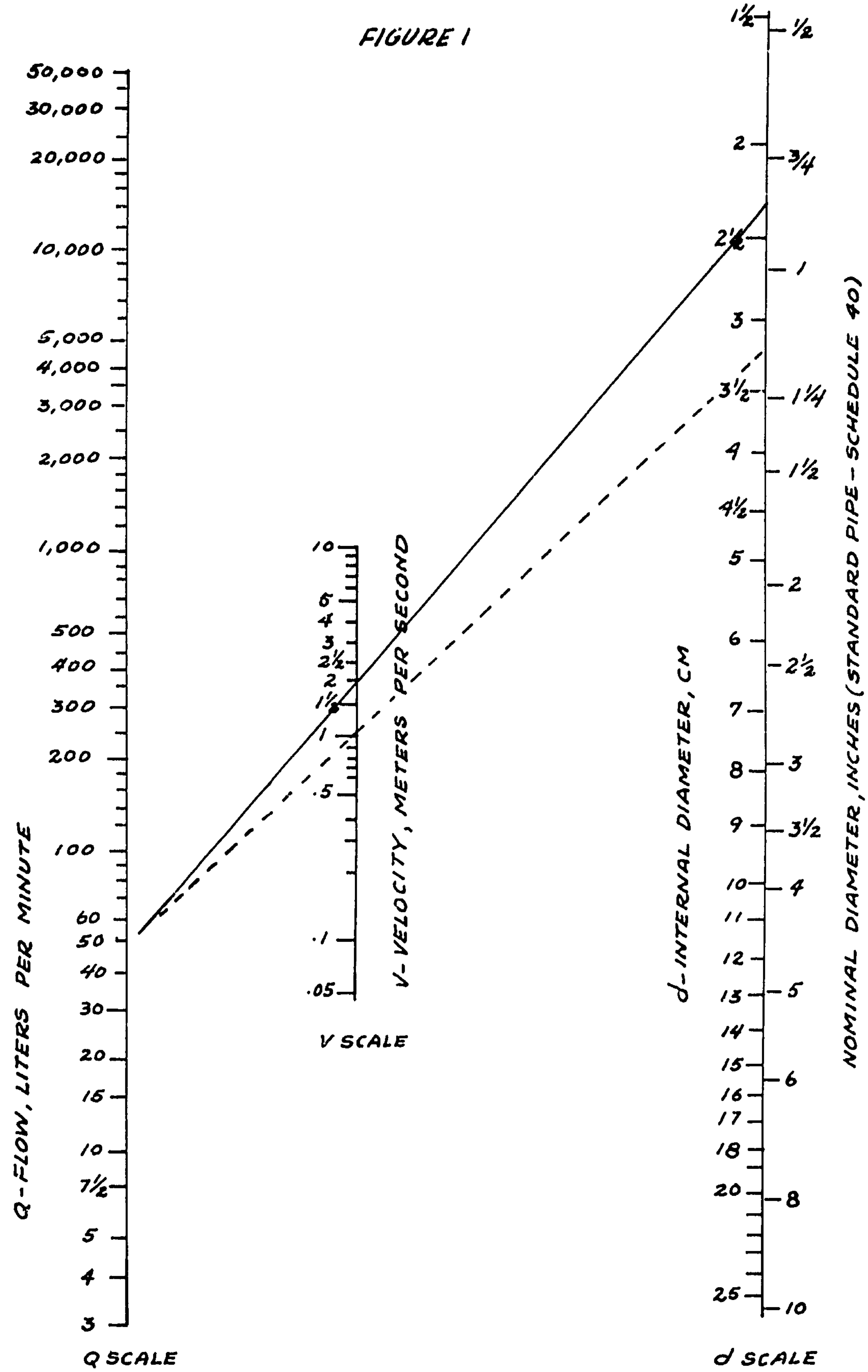
Example:

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 limit velocity to 1.2m/sec and install a slightly larger pipe size.

Source:

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

FIGURE I



Q-FLOW, LITERS PER MINUTE
50,000
30,000
20,000
10,000
5,000
4,000
3,000
2,000
1,000
500
400
300
200
100
60
50
40
30
20
15
10
7½
5
4
3
Q SCALE
V-VELOCITY, METERS PER SECOND
10
6
4
3
2½
2
1½
1
.5
.1
.05
V SCALE
d-INTERNAL DIAMETER, CM
1½
2
2½
3
3½
4
4½
5
6
7
8
9
10
11
12
13
14
15
16
17
18
20
25
d SCALE
NOMINAL DIAMETER, INCHES (STANDARD PIPE - SCHEDULE 40)
½
¾
1
1¼
1½
2
2½
3
3½
4
5
6
8
10

ESTIMATING FLOW RESISTANCE OF PIPE FITTINGS

One of the forces which 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 which 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 following entry, "Determining Pump Capacity and Horsepower Requirement," to determine total friction loss.

Rather than calculate the pressure drop for each valve or fitting separately, this chart will give 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.

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, using a straight edge; read equivalent length of straight pipe in meters, (c) add the fitting equivalent length to the actual length of pipe being used.

Source:

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

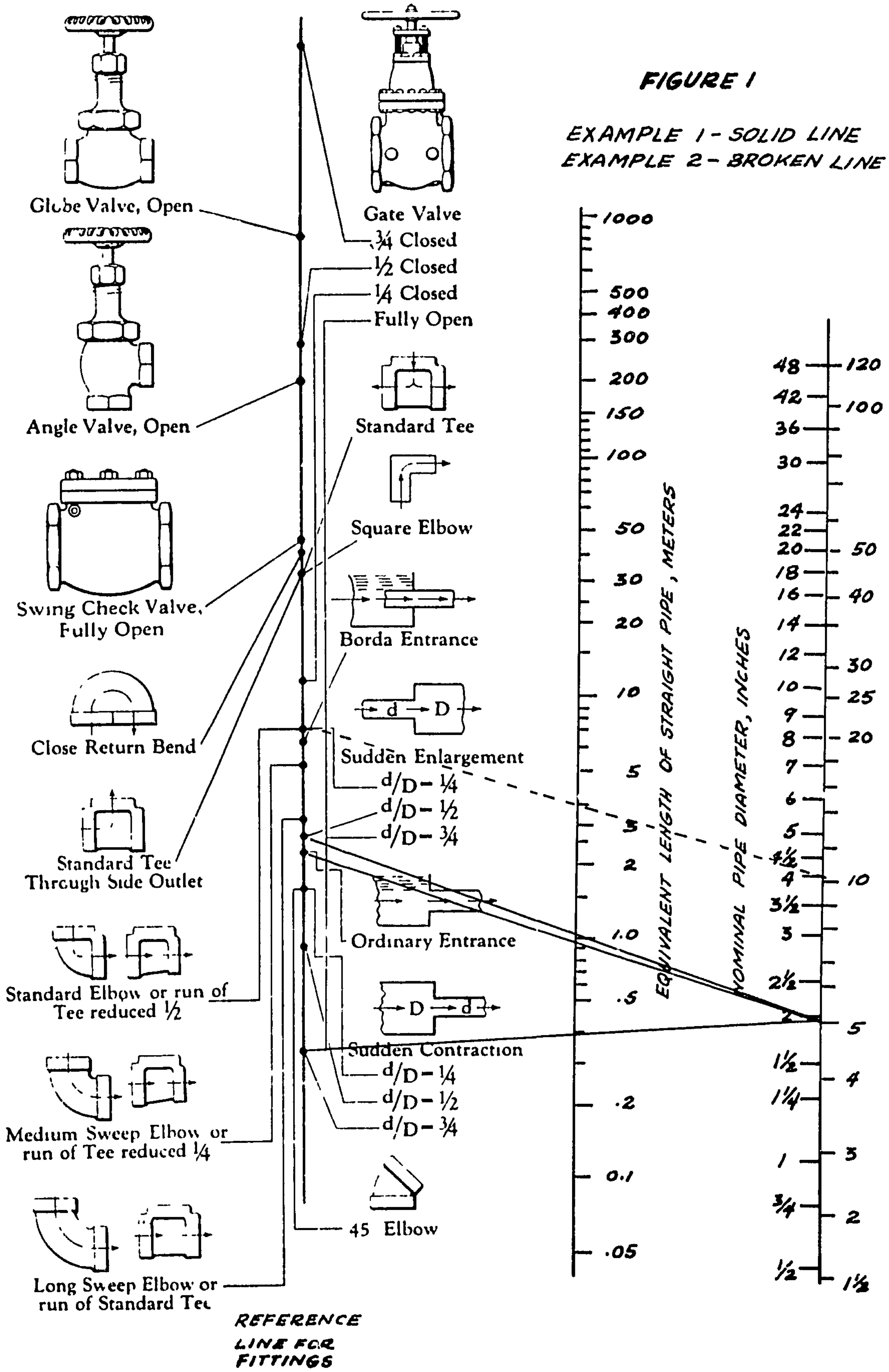
Example 1:

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 ($d/D = 1/2$)	1.0
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

Resistance of Valves and Fittings to Flow of Fluids



DETERMINING PUMP OUTLET SIZE AND HORSEPOWER REQUIREMENT

With the alignment chart in Figure 2, you can determine the necessary pump size (diameter of discharge outlet) and the amount of horsepower needed to power the pump. The power can be supplied by men or by motors.

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

Tools

Straight edge and pencil for alignment chart

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 78, choose a pipe size which 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:

   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 in Figure 1. For an explanation of total equivalent pipe length, see the preceding entry.

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:

   $$F = \frac{F_{at\ 1.8m/sec} \times V^2}{1.8m/sec^2},$$

   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:

   $$F = \frac{16 \times 3.6^2}{1.8^2} = \frac{16 \times 13}{3.24} = 64$$

6. Obtain "Total Head" as follows: Total Head = Height of Lift + Friction-loss Head

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

Figure 1. Average friction loss in meters for fresh water flowing through steel pipe when velocity is 1.8 meters (6 feet) per second.

*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 straight edge, 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 2). 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.

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. Actual metric horsepower can be obtained by multiplying horsepower by 1.014.

Source:

Nomographic Charts, by C. A. Kulman, McGraw-Hill Book Co., New York, 1951, pages 108-109.

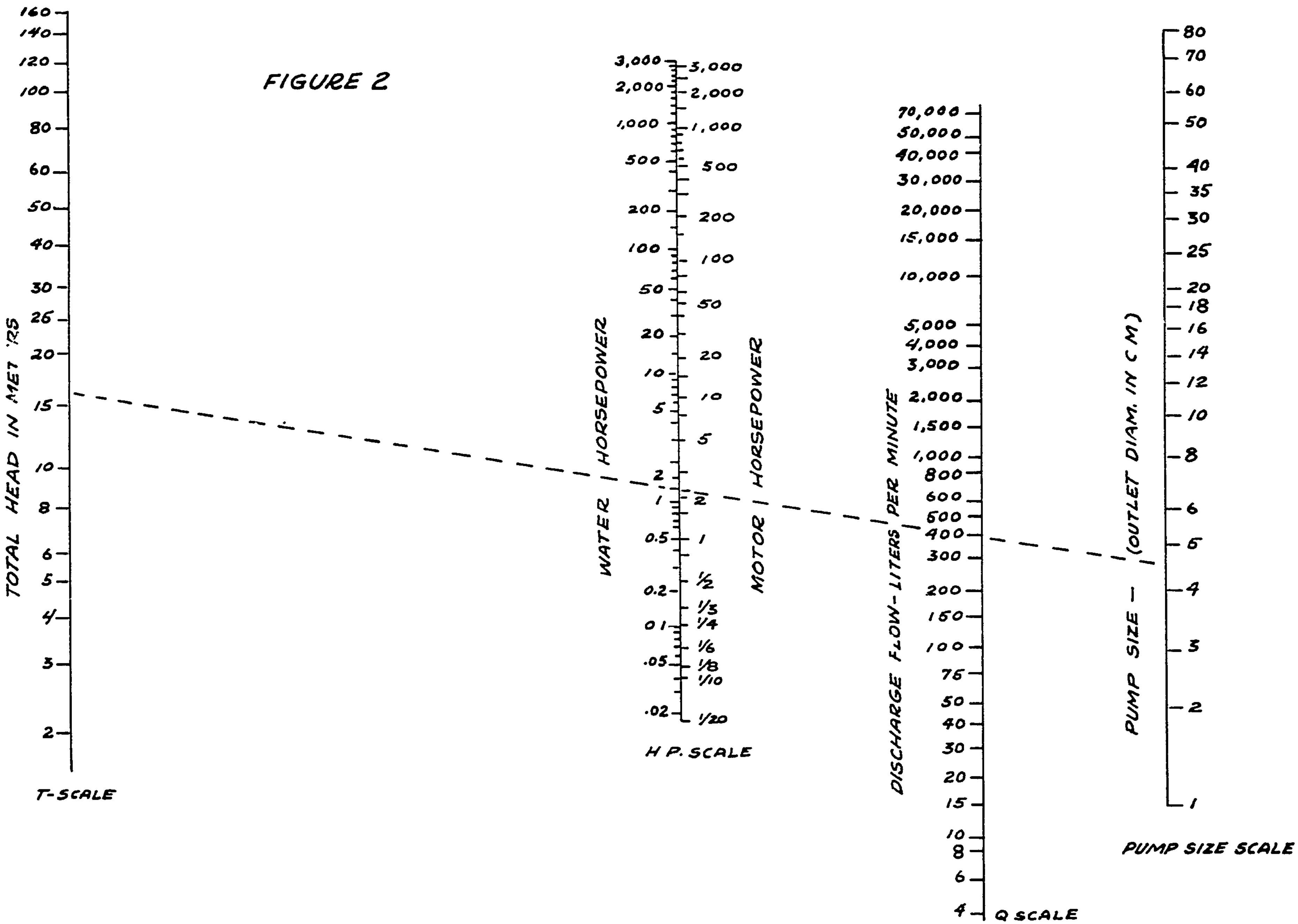


FIGURE 2
TOTAL HEAD IN MET 'RS
T-SCALE
WATER HORSEPOWER
MOTOR HORSEPOWER
H P. SCALE
DISCHARGE FLOW-LITERS PER MINUTE
Q SCALE
PUMP SIZE - (OUTLET DIAM. IN C M)
PUMP SIZE SCALE

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 what a lift pump can do at various altitudes and water temperatures.

Tools

Measuring tape

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.

Source:

Mechanical Engineer's Handbook, by Theodore Baumeister, 6th edition, McGraw-Hill Book Co., New York, copyright 1958. Used by permission. (Adapted.)

Example:

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

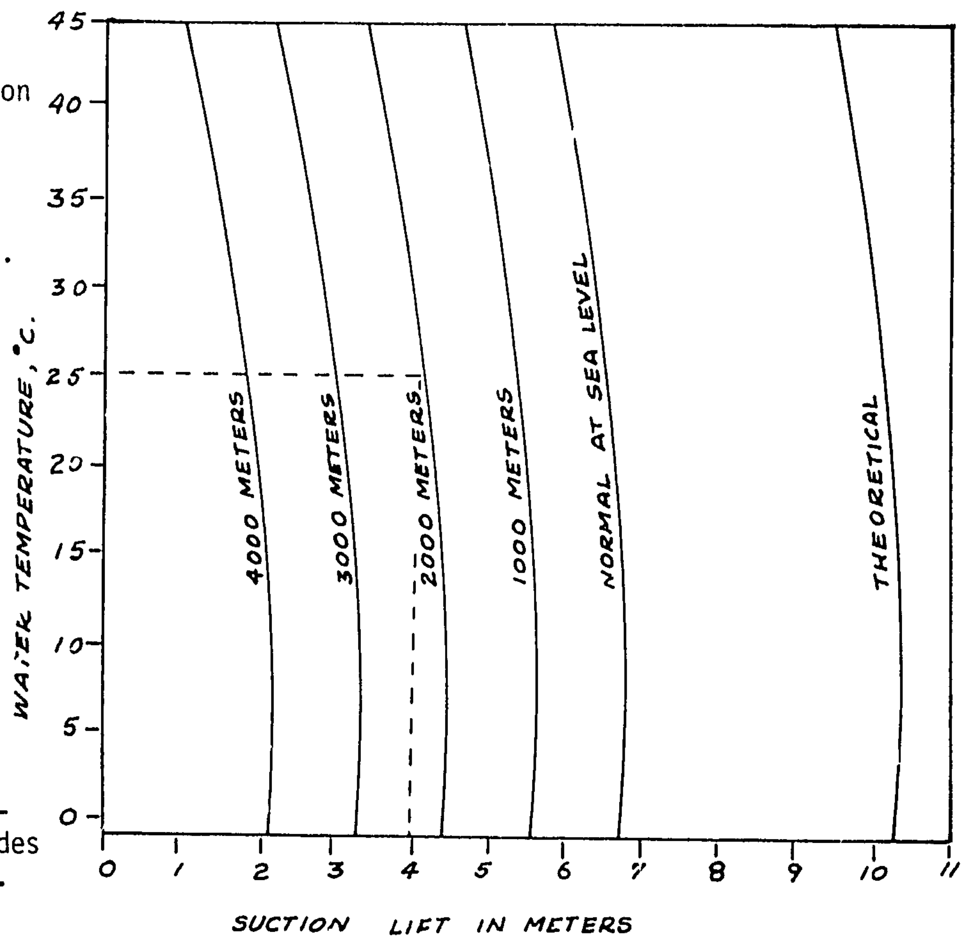


FIGURE 1

Figure 1. Graph showing lift pump capabilities at various altitudes and water temperatures. Broken lines indicate example given in text.

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.

Tools and Materials

Chisels (see text and Figure 2)

Nail, cotter pin or linchpin

Caulking materials

Tar

Rope

Bamboo piping can hold pressure up to two atmospheres (about 2.1kq 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

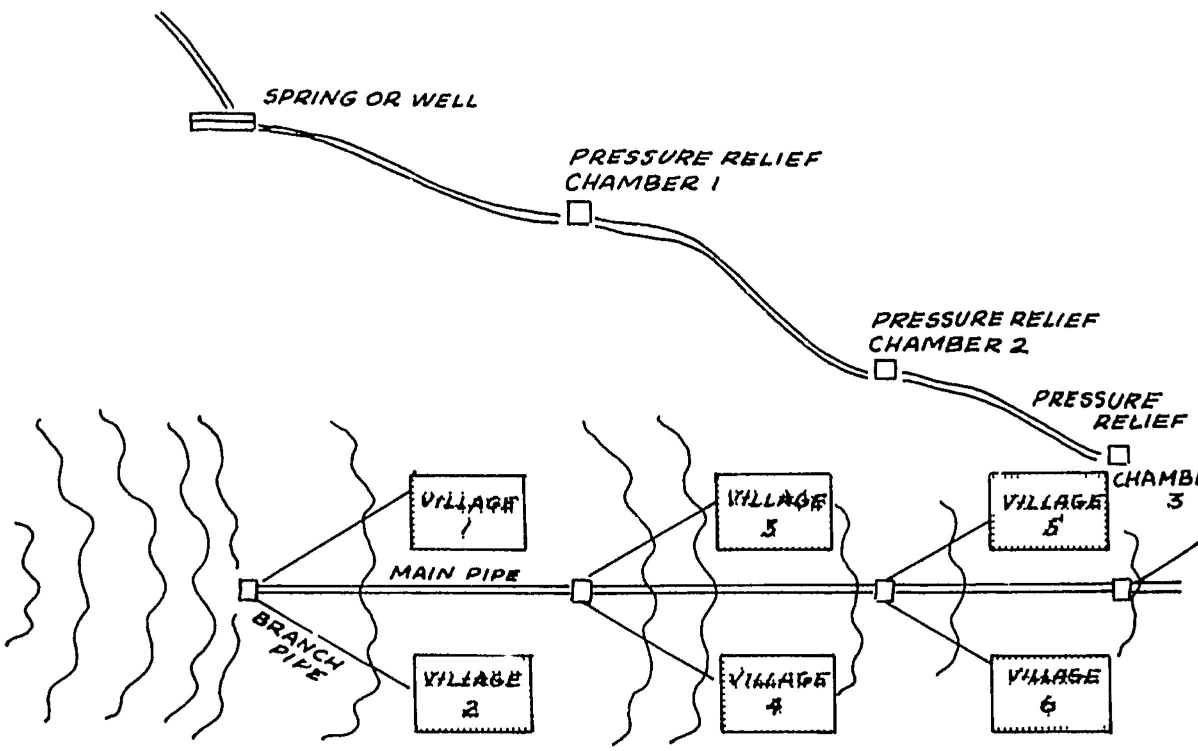


FIGURE 1

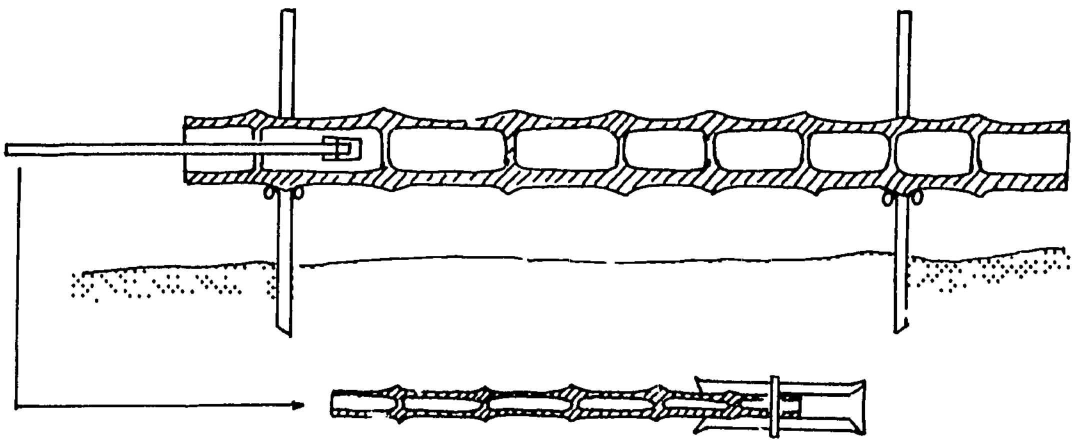


FIGURE 2

supply is higher than the area to be served and the flow is under gravity.

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: borax.

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 internal pressure within the pipe at a higher level than any external water pressure outside the pipe. Any leakage will then be from the pipe, and contaminated water will not enter the pipe.

Design and Construction

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 2. 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. This nail is also known as a cotter pin or linchpin. 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 3. Joints 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.

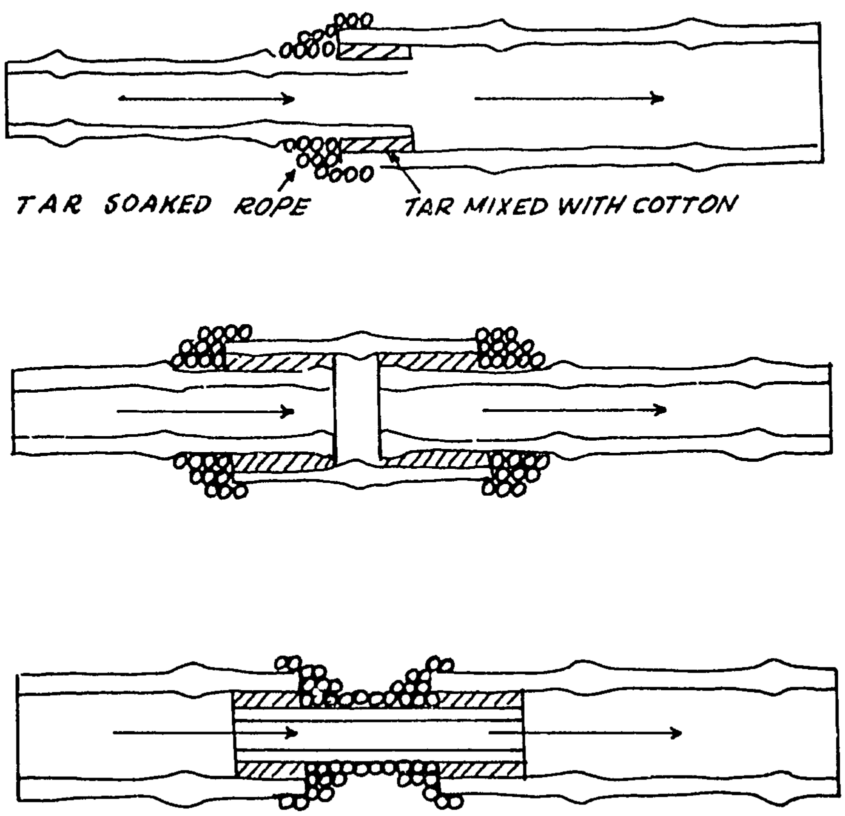
Where the depth of the pipe below the water source is such that the maximum pressure will be exceeded, pressure relief chambers must be installed. A typical chamber is shown in Figure 4. These chambers are also installed as reservoirs for branch supply lines to villages en route.

A diagrammatic sketch of a bamboo pipe water supply system for a number of villages is shown in Figure 1. Size requirements for bamboo pipe may be determined by using the pipe-capacity alignment chart in Figure 5. A design for a public fountain made from bamboo is shown in Figure 6.

Source:

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

FIGURE 3



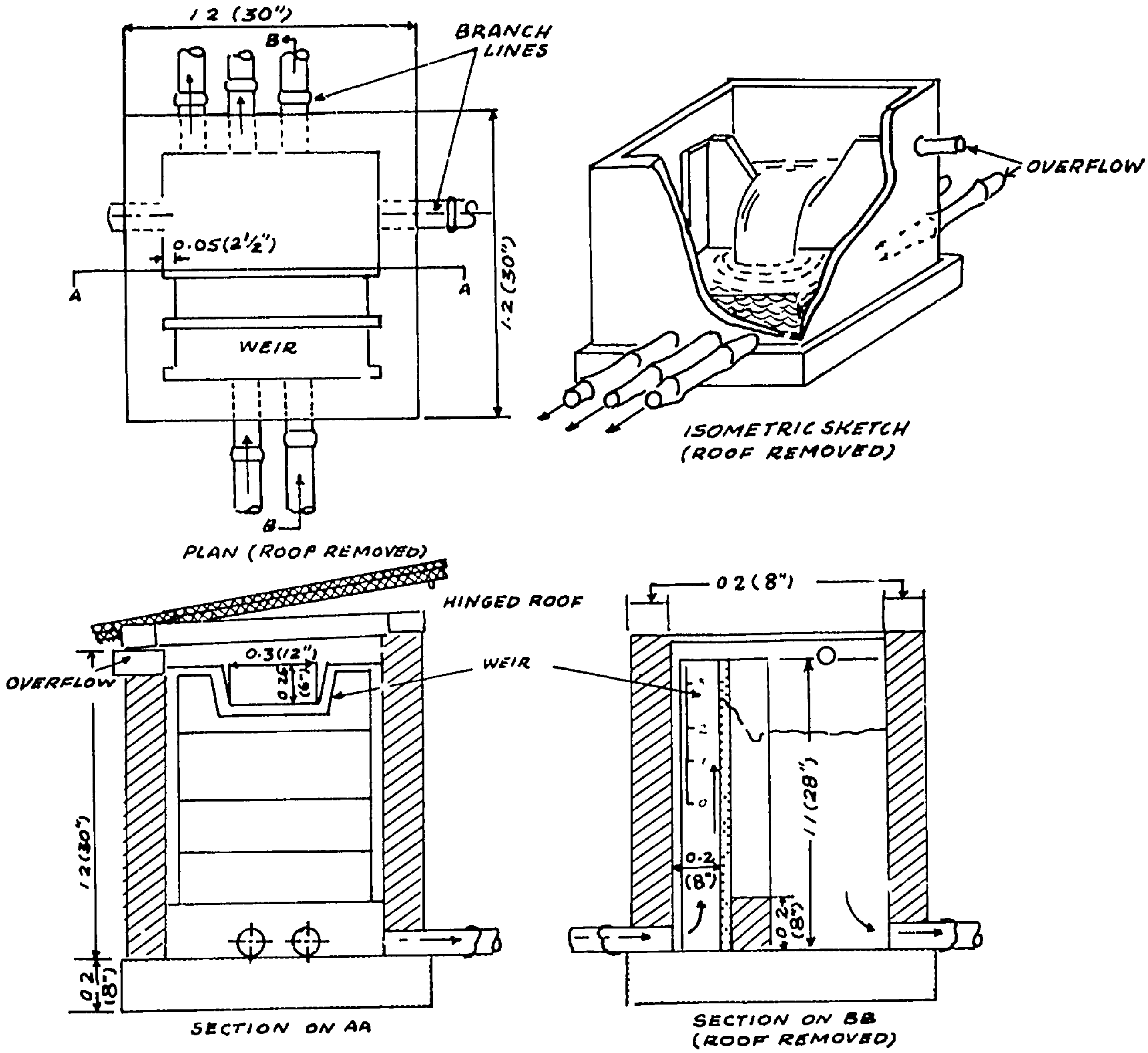
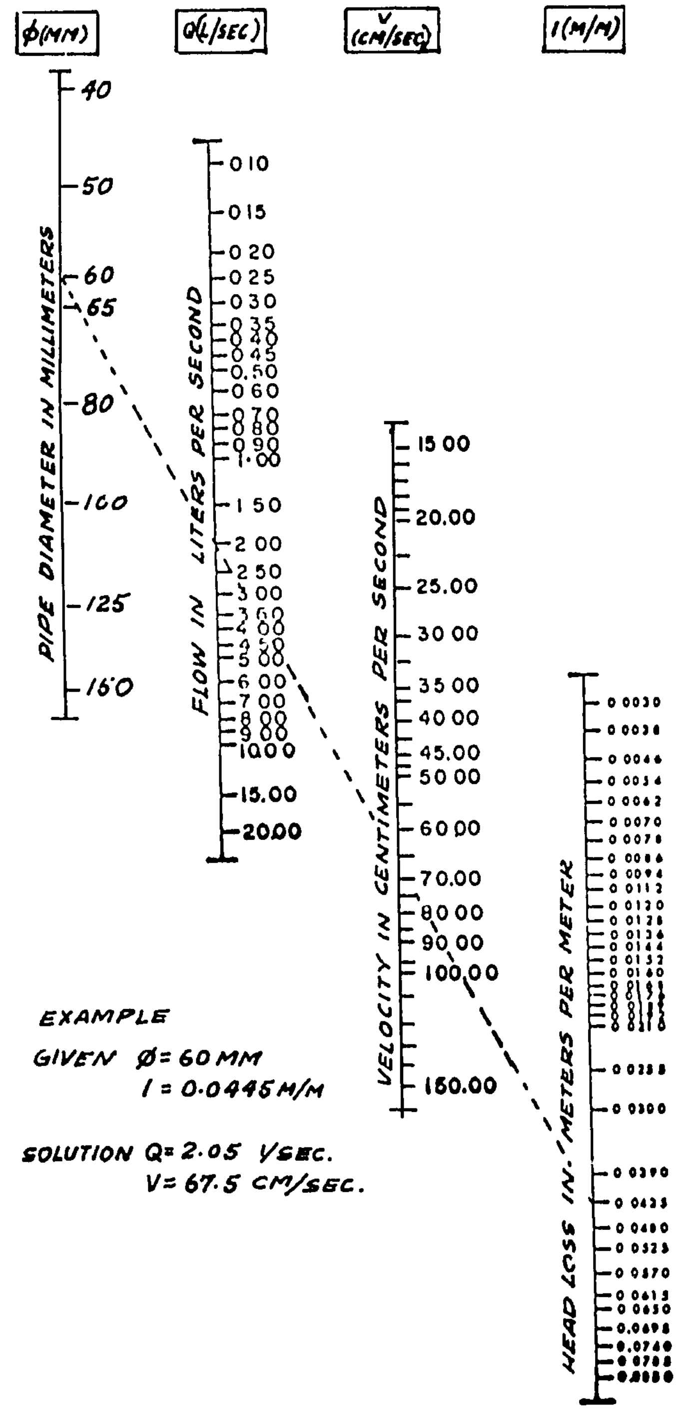

1.2 (30")
BRANCH LINES
B
0.05(2½")
A
A
1.2 (30")
WEIR
B
PLAN (ROOF REMOVED)
OVERFLOW
ISOMETRIC SKETCH (ROOF REMOVED)
HINGED ROOF
OVERFLOW
0.3(12")
0.15 (6")
WEIR
1.2(30")
0.2 (8")
SECTION ON AA
0.2 (8")
1.1(28")
0.2 (8")
0.2 (8")
SECTION ON BB (ROOF REMOVED)

FIGURE 4

FIGURE 5
NOMOGRAPH FOR FLOW IN BAMBOO PIPE



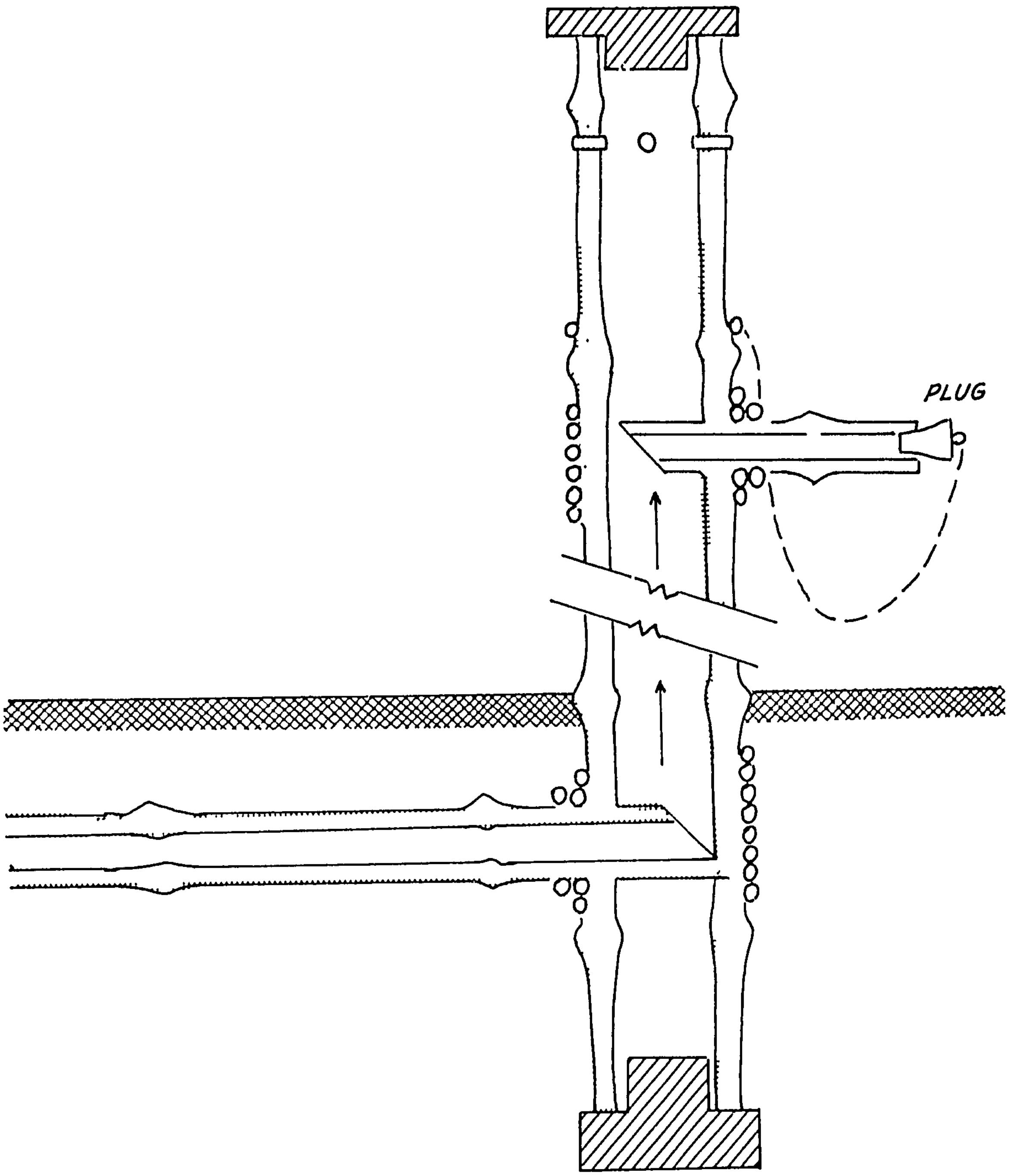


FIGURE 6 PUBLIC FOUNTAIN

CHAIN PUMP FOR IRRIGATION

The chain pump, which can be powered by man or animal, is primarily a shallow-well pump to lift water for irrigation (see Figure 1). It works best when the lift 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 shows what can be expected from a 10cm (4") diameter tube operated by four men 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 to fit materials available and structure of the well.

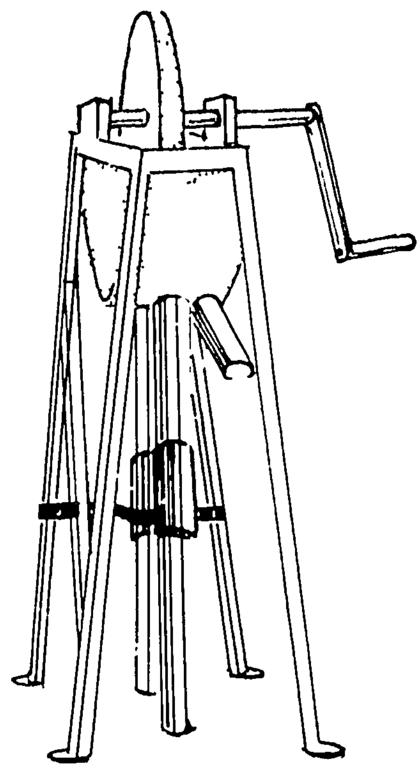


FIGURE 1

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

1. a leather or rubber washer (see Figure 4) with an outside diameter about two thicknesses of a washer larger than the inside diameter of the pipe.

2. a piston disc (see Figure 5).

3. a retaining plate (see Figure 6).

The piston link is made as shown in Figure 7. Center all three parts, clamp 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 discs 6mm (1/4") thick are welded to the pipe shaft.

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

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 discs, 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). 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, Chapter

Water Lifting Devices for Irrigation, by Aldert Molenaar, Rome: Food and Agriculture Organization of the United Nations, 1956.

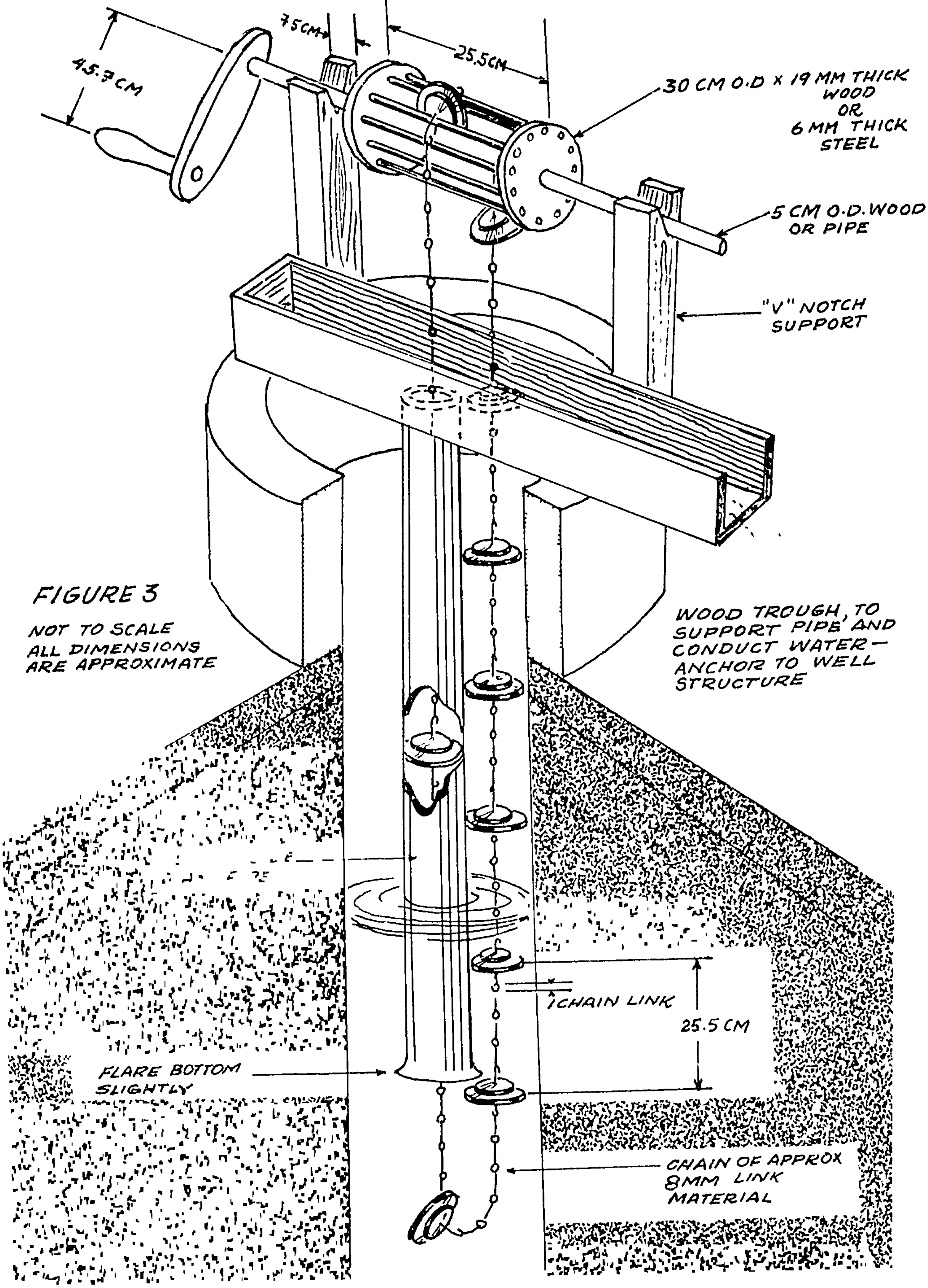


FIGURE 3

NOT TO SCALE
ALL DIMENSIONS ARE APPROXIMATE

FIGURE 4
LEATHER WASHER

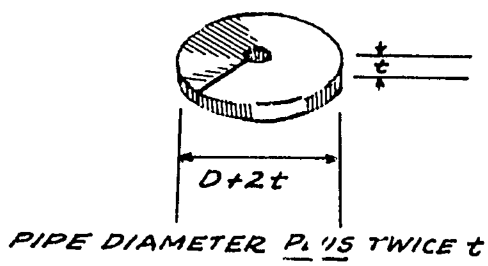


FIGURE 5

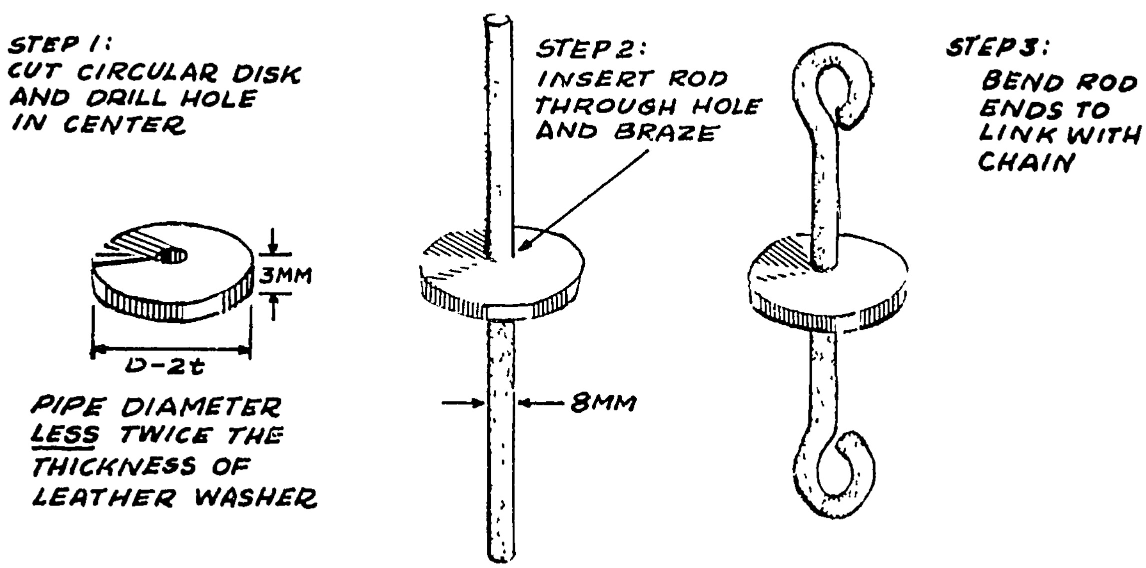


FIGURE 6
RETAINING PLATE

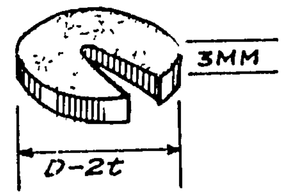


FIGURE 7
PISTON LINK
ASSEMBLED

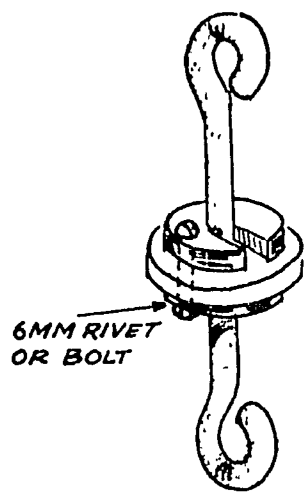
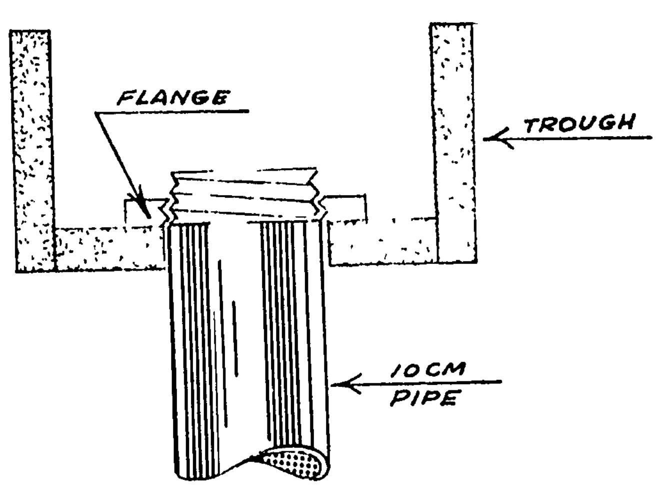


FIGURE 8 PIPE SUPPORT



INERTIA HAND PUMP

The inertia hand pump described here is a 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 which can be easily worked by a tinesmith (24 to 28-gage 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.

Tools

Soldering equipment, Drill and bits or punch, Hammer, Saws, Tinsnips, Anvil (railroad rail or from pipe)

Materials for 1-meter (3.3') pump:

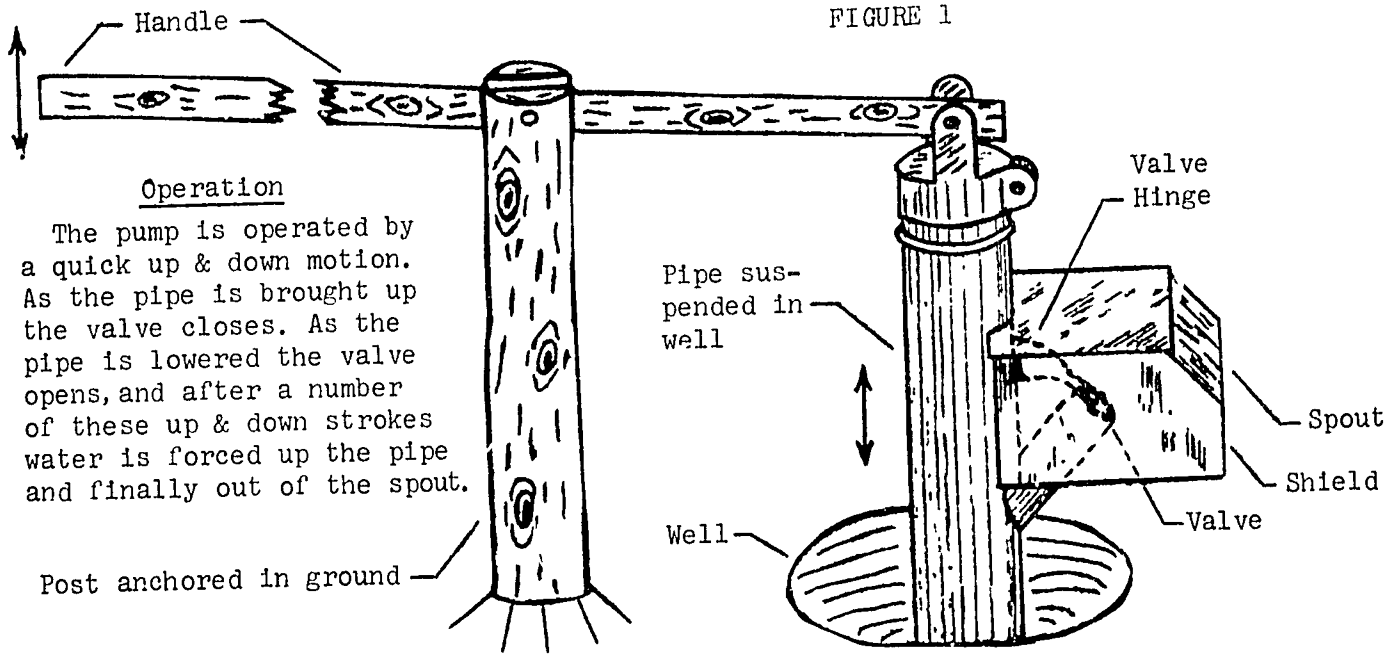
Galvanized iron (24 to 28 gage).
- Shield: 61cm x 32cm, 1 piece (2' x 12 5/8")
- Shield cover. 21cm x 22cm, 1 piece (8 1/4" x 8 5/8")
- Pipe: 140cm x 49cm, 1 piece (55 1/8" x 19 1/4")
- Top of pipe 15cm x 15cm, 1 piece (6" x 6")
- "Y" Pipe: 49cm x 30cm, 1 piece (19 1/4" x 12")

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

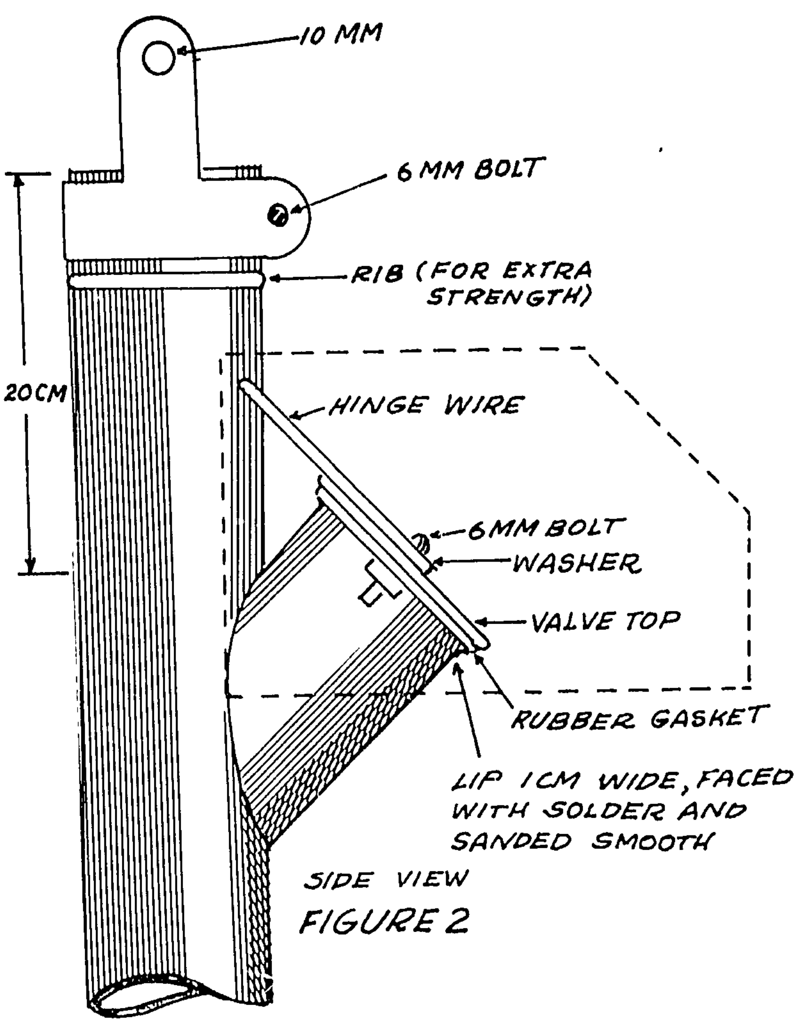
This pump can also be made from plastic pipe or bamboo.

FIGURE 1

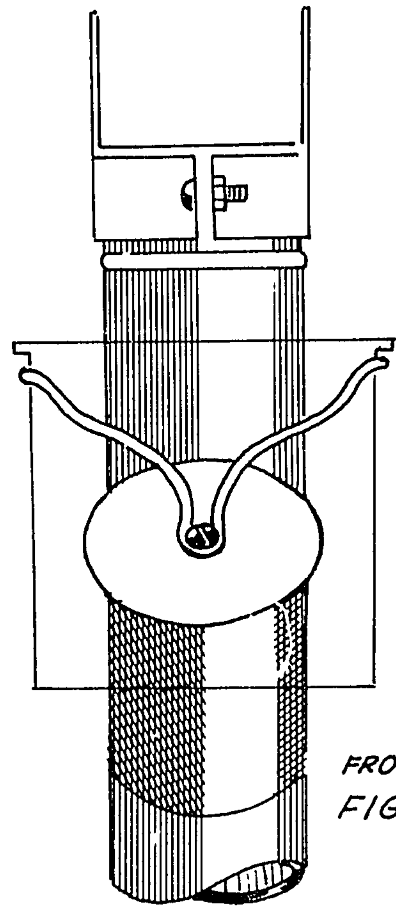


Operation

The pump is operated by a quick up & down motion. As the pipe is brought up the valve closes. As the pipe is lowered the valve opens, and after a number of these up & down strokes water is forced up the pipe and finally out of the spout.



SIDE VIEW
FIGURE 2



FRONT VIEW
FIGURE 3

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 2. The air which stays in the pipe above this junction serves as an air 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 operator will soon get the "feel" of his particular pump.

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.

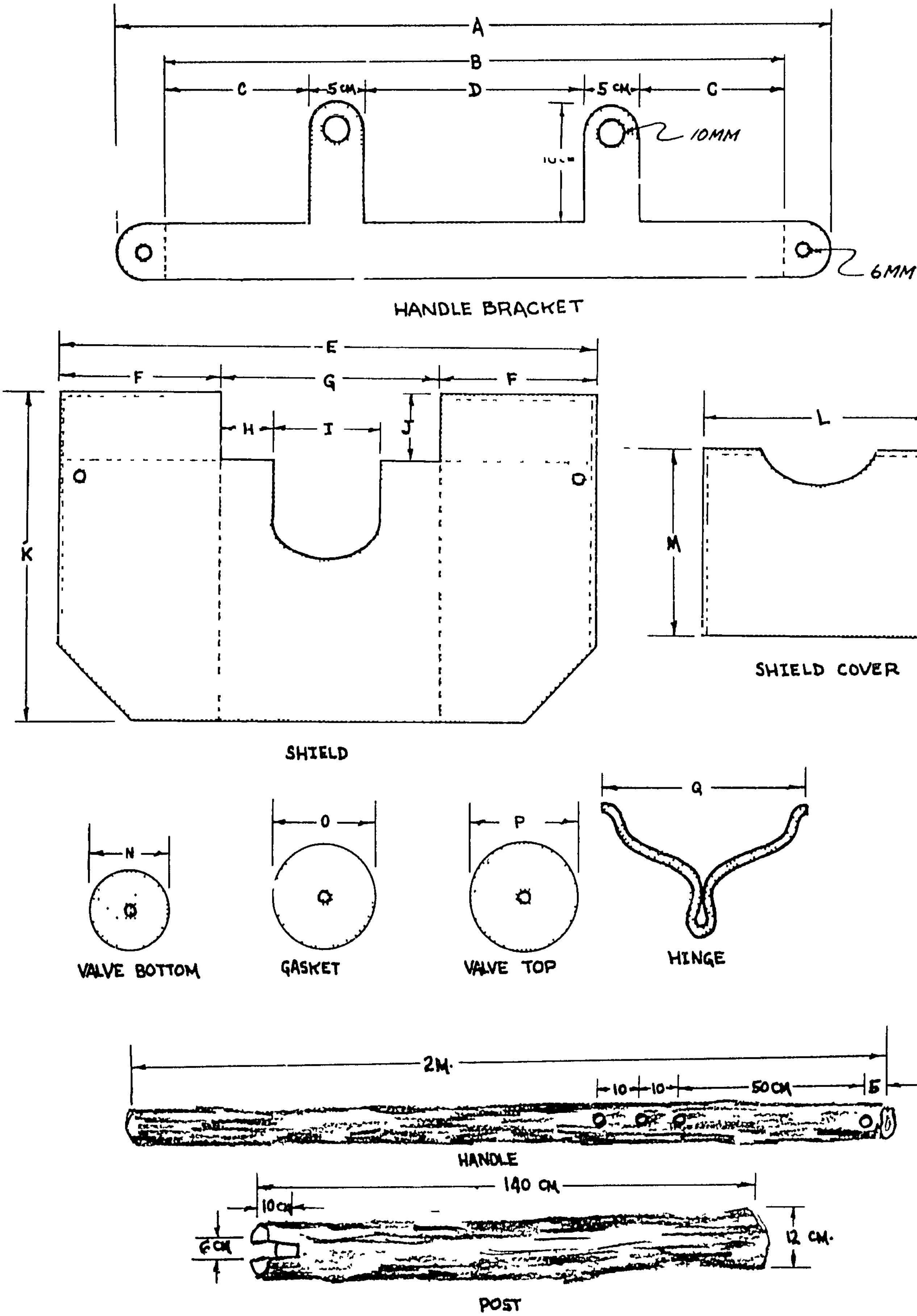

A
B
C
5 CM
D
5 CM
C
10MM
6MM
HANDLE BRACKET
E
F
G
F
H
I
J
K
L
M
SHIELD COVER
SHIELD
N
O
P
Q
VALVE BOTTOM
GASKET
VALVE TOP
HINGE
2M.
10
10
50CM
5
HANDLE
140 CM
10 CM
6 CM
12 CM.
POST

FIGURE 4

FIGURE 5

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		3½	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			

FIGURE 6

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

Figure 5 gives the dimensions of parts for pumps of three different sizes. Figure 6 shows the pumping capacity for each size.

Source:

Dale Fritz, VITA Volunteer, Washington, D.C.

HANDLE MECHANISM FOR HAND PUMPS

The wearing parts of this durable hand-pump handle mechanism are wooden (see Figure 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). Figure 2 shows a pump with this handle mechanism which is being manufactured by F. Humain 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

Hardwood: 86.4cm x 6.4cm x 6.4cm (34" x 2 1/2" x 2 1/2")

Mild steel rod: 19mm (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")

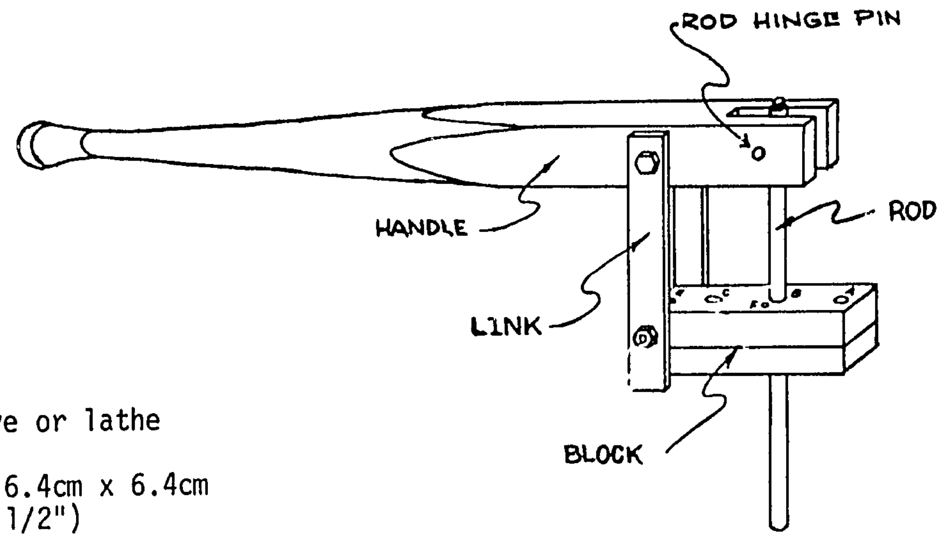


FIG 1

BOLT HARDWARE

Number of bolts reqd.	Dia. mm	Length mm	Number of nuts reqd.	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 your pump
1	12.5	?	1	1	0	Rod to piston

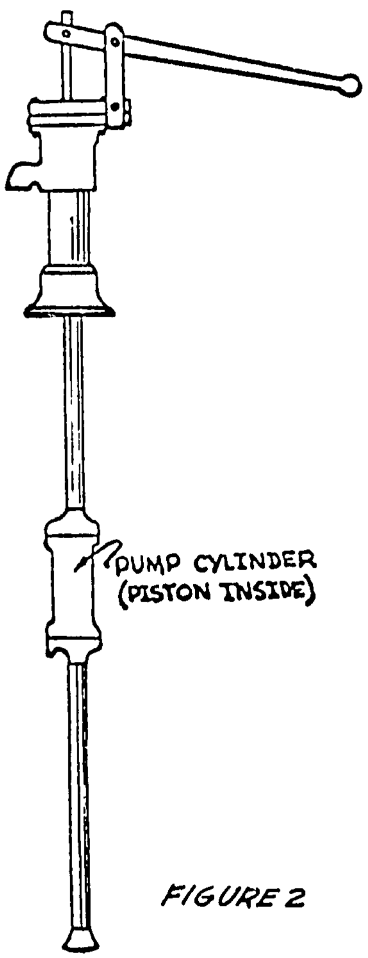


FIGURE 2

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.

Rod. The rod is made of mild steel as shown in Figure 4. A 10mm (3/8") 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 which connects the rod to the handle (see Figure 1). The end of the rod 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.

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 2 1/2" x 2 1/2"). Next holes A, B, C, and D are drilled

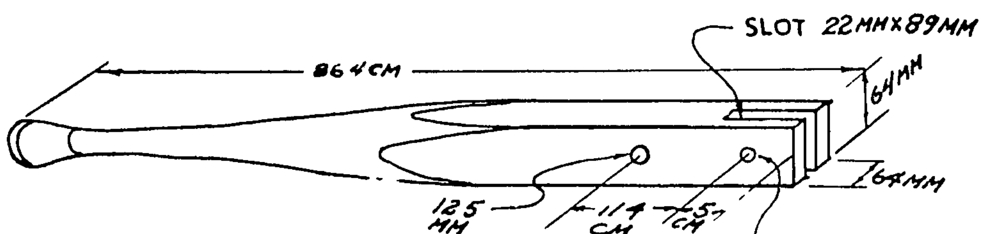


FIG 3
HANDLE

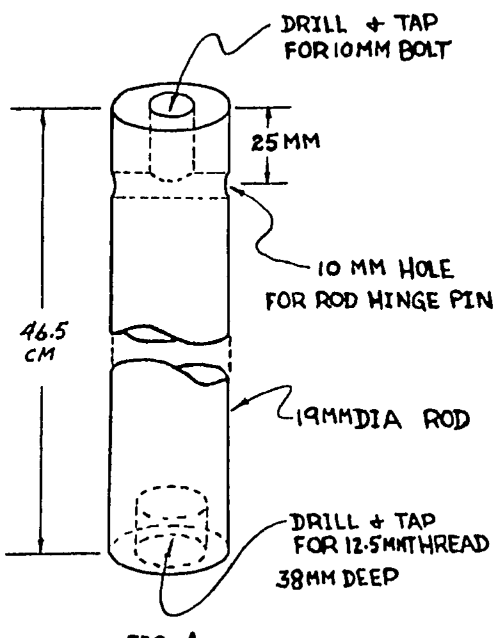


FIG 4
ROD

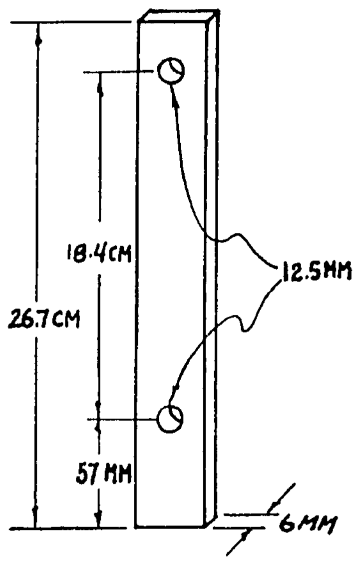


FIG 5
LINK

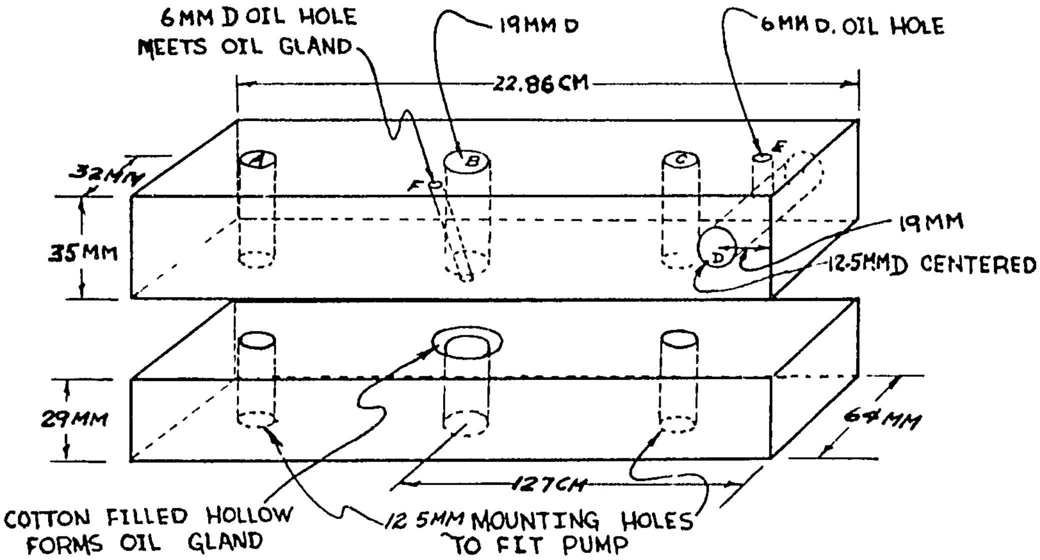


FIG 6
BLOCK

perpendicular to the block as shown in Figure 6. The spacing of the 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 (1 3/8") 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 secord 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:

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

USING A HYDRAULIC RAM

A hydraulic ram is a self-powered pump which uses the energy of falling water to lift some of this water to a level above the original source. This entry explains the use of commercial hydraulic rams, which are available in some countries.

Tools and Materials

Commercial hydraulic ram

Steel pipe and fittings

Pipe wrenches

Materials to make a small dam or reservoir

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:

1. Water flows through the drive pipe (D) and out the outside valve (F).

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

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

4. The flow stops.

5. The check valve (B) closes.

6. 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

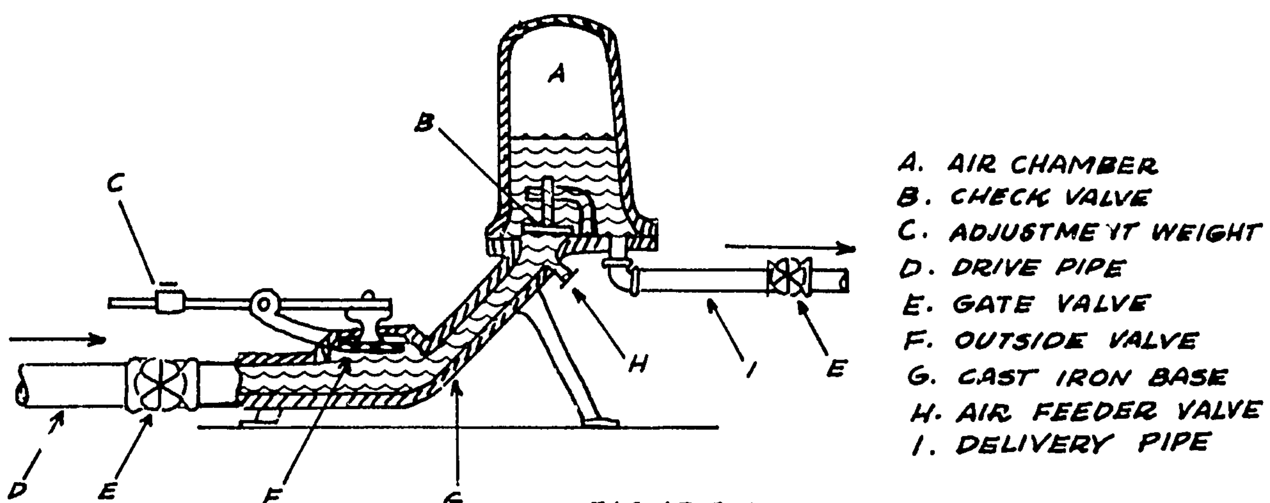
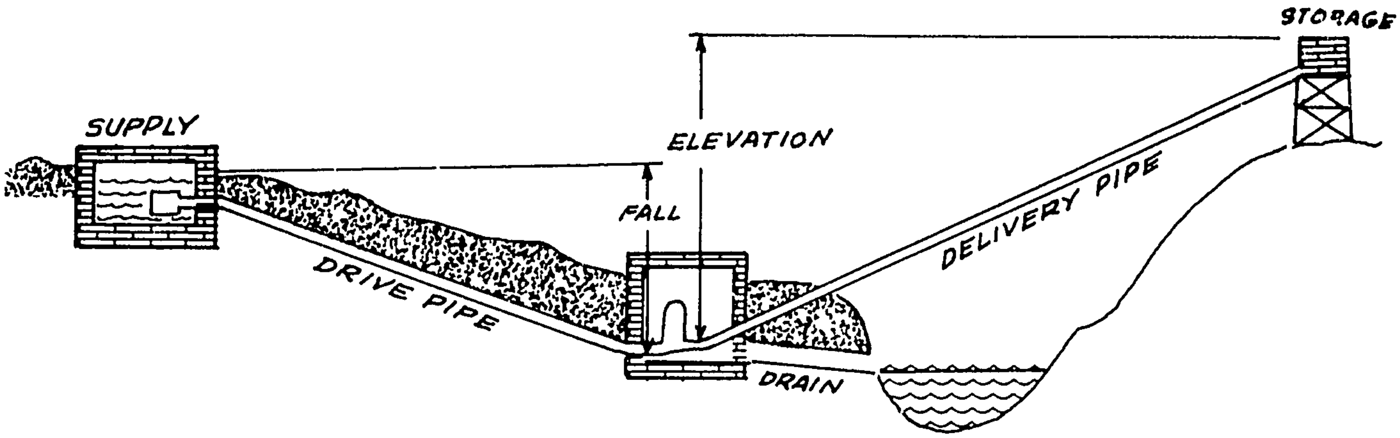
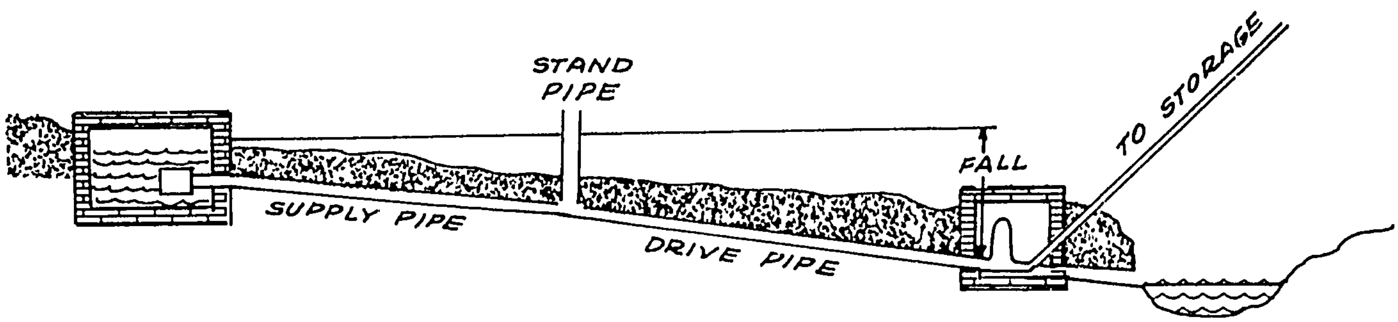


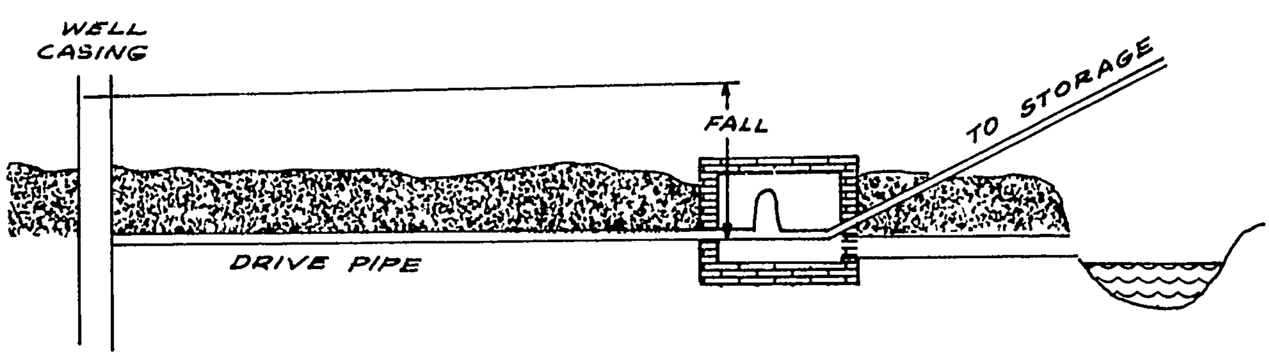
FIGURE 1



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

distance from the source to the ram is greater than 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 small ram which will raise water about 45 meters (150') is about U.S. $150, not including the cost of the pipe and installation. 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:

$$\text{Capacity (gallons per hour)} = \frac{V \times F \times 40}{E}$$

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, VITA Chapter

Rife Hydraulic Engine Manufacturing Company, Box 367, Millburn, New Jersey, U.S.A.

The Hydraulic Ram by W. H. Sheldon, 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.

APPENDIX

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

LENGTH CONVERSION

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

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

Example:

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

FIGURE 1

Equations:

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

FIGURE 2

INCHES INTO CENTIMETERS
(1 in. = 2.539977 cm.)

inches	0	1	2	3	4	5	6	7	8	9
0	cm	2 54	5 08	7 62	10 16	12 70	15 24	17 78	20 32	22 86
10	25 40	27 94	30 48	33 02	35 56	38 10	40 64	43 18	45 72	48 26
20	50 80	53 34	55 88	58 42	60 96	63 50	66 04	68 58	71 12	73 66
30	76 20	78 74	81 28	83 82	86 36	88 90	91 44	93 98	96 52	99 06
40	101 60	104 14	106 68	109 22	111 76	114 30	116 84	119 38	121 92	124 46
50	127 00	129 54	132 08	134 62	137 16	139 70	142 24	144 78	147 32	149 86
60	152 40	154 94	157 48	160 02	162 56	165 10	167 64	170 18	172 72	175 26
70	177 80	180 34	182 88	185 42	187 96	190 50	193 04	195 58	198 12	200 66
80	203 20	205 74	208 28	210 82	213 36	215 90	218 41	220 98	223 52	226 06
90	228 60	231 14	233 68	236 22	238 76	241 30	243 84	246 38	248 92	251 46

CENTIMETERS INTO INCHES
(1 cm. = 0 3937 in.)

cm.	0	1	2	3	4	5	6	7	8	9
0	inches	0 394	0 787	1 181	1 575	1 969	2 362	2 756	3 150	3.543
10	3 937	4 331	4 724	5 118	5 512	5 906	6 299	6 693	7 087	7 480
20	7 874	8 268	8.661	9 055	9 449	9.843	10 236	10 630	11 024	11.417
30	11 811	12 205	12 598	12 992	13 386	13.780	14 173	14 567	14 961	15 354
40	15 748	16 142	16 535	16 929	17 323	17 717	18 110	18 504	18 898	19 291
50	19 685	20 079	20 472	20 866	21 260	21 654	22 047	22 441	22 835	23 228
60	23 622	24 016	24 409	24 803	25 197	25 591	25 984	26 378	26 772	27 165
70	27 559	27 953	28 346	28 740	29 134	29 528	29 921	30 315	30 709	31.102
80	31 496	31 890	32 283	32 677	33 071	33 465	33 858	34 252	34 646	35 039
90	35 433	35 827	36 220	36 614	37 008	37 402	37 795	38 189	38 583	38 976

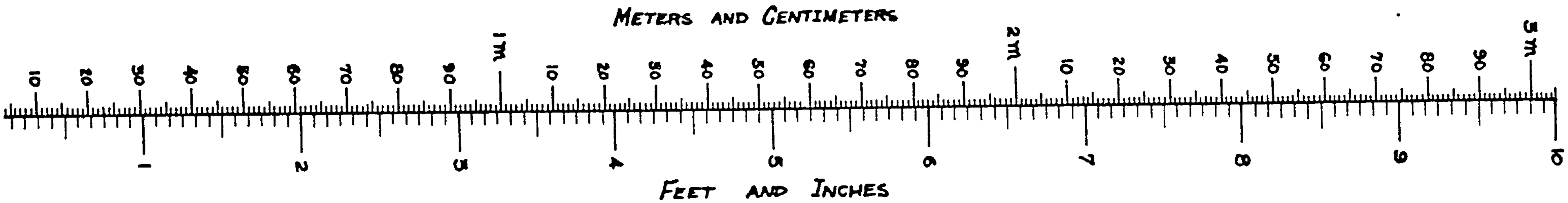


FIGURE 3

WEIGHT CONVERSION

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

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

Equations:

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

FIGURE 4

KILOGRAMS INTO POUNDS
(1 kg. = 2 20463 lb.)

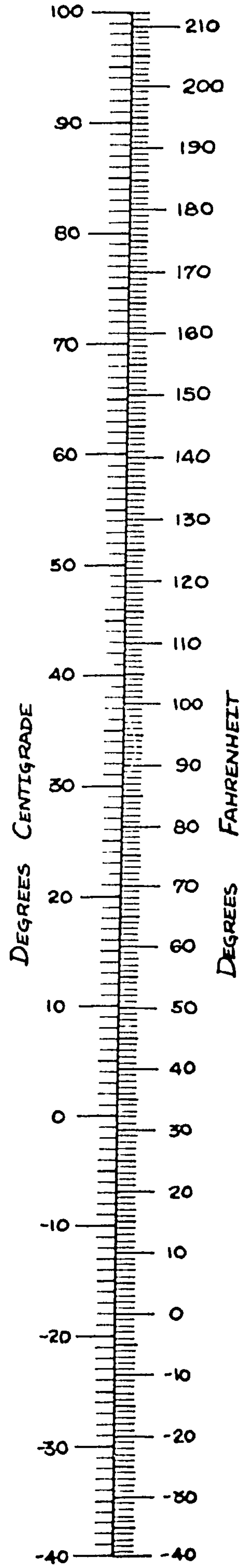
kg	0	1	2	3	4	5	6	7	8	9
0	lb	2 20	4 41	6 61	8 82	11 02	13 23	15 43	17 64	19 84
10	22 05	24 25	26 46	28 66	30 86	33 07	35 27	37 48	39 68	41 89
20	44 09	46 30	48 50	50 71	52 91	55 12	57 32	59 53	61 73	63 93
30	66 14	68 34	70 55	72 75	74 96	77 16	79 37	81 57	83 78	85 98
40	88 19	90 39	92 59	94 80	97 00	99 21	101 41	103 62	105 82	108 03
50	110 23	112 44	114 64	116 85	119 05	121 25	123 46	125 66	127 87	130 07
60	132 28	134 48	136 69	138 89	141 10	143 30	145 51	147 71	149 91	152 12
70	154 32	156 53	158 73	160 94	163 14	165 35	167 55	169 76	171 96	174 17
80	176 37	178 58	180 78	182 98	185 19	187 39	189 60	191 80	194 01	196 21
90	198 42	200 62	202 83	205 03	207 24	209 44	211 64	213 85	216 05	218 26

POUNDS INTO KILOGRAMS
(1 lb. = 0 45359 kg)

lb	0	1	2	3	4	5	6	7	8	9
0	kg	0 454	0 907	1 361	1 814	2 268	2 722	3 175	3 629	4 082
10	4 536	4 990	5 443	5 897	6 350	6 804	7 257	7 711	8 165	8 618
20	9 072	9 525	9 979	10 433	10 886	11 340	11 793	12 247	12 701	13 154
30	13 608	14 061	14 515	14 969	15 422	15 876	16 329	16.783	17 237	17 690
40	18 144	18 597	19 051	19 504	19 958	20 412	20 865	21 319	21 772	22 226
50	22 680	23 133	23 587	24 040	24 494	24 948	25 401	25 855	26 308	26 762
60	27 216	27 669	28 123	28 576	29 030	29 484	29 937	30 391	30 844	31 298
70	31 751	32 205	32 659	33 112	33 566	34 019	34 473	34 927	35 380	35 834
80	36 287	36 741	37 195	37 648	38 102	38 555	39 009	39 463	39 916	40 370
90	40 823	41 277	41 730	42 184	42 638	43 091	43 545	43 998	44 452	44 906

FIGURE 5

FIGURE 1



TEMPERATURE CONVERSION

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

Equations:

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

Degrees Fahrenheit = 1.8 x (Degrees Celsius) +32

Example:

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

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

72F = 5/9 (72 -32)

72F = 5/9 (40)

72F = 22.2C

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

Conversion Tables

Units of Area

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

Units of Volume

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

Units of Weight

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

Conversion Tables

Units of Pressure

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

* at 62 degrees Fahrenheit (16.6 degrees Celsius)

Units of Power

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