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Village Technology Handbook

SECTION 1: WATER RESOURCES

Part 3: Water Storage and Water Power

FOREWORD

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

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

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

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

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

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

A NOTE ON USING THE HANDBOOK

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

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

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

Information on cooperatives is available from:

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

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

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

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

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

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

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

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

1. Be quantitative--give measurements, sketches or, when possible, photos.
2. Explain what materials are available and what limitations there are on cost.
3. Describe the best solution, if any, found so far in the area.
4. Explain any pertinent social or cultural conditions.
5. Indicate a deadline for action, especially if immediate attention is needed.
6. Don't expect miracles on the first reply. Successful problem-solving often takes a number of letters back and forth.

WHAT IS VITA?

VITA (Volunteers in Technical Assistance) was established in 1959 as a private, nonprofit 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

APPENDIX

Water Storage and Water Power

SPRING DEVELOPMENT

Springs, particularly in sandy soil, often make an excellent water source, but they should be dug deeper, sealed, protected by a fence and piped to the home. If fissured rock or limestone are present, get expert advice.

Tools and Materials

Hand tools for digging

Reinforced concrete

Screens

Pipes

Proper development of a spring will increase the flow of ground water and lower the chances of contamination from surface water.

Springs are usually either:

1. Gravity Seepage, where the water-bearing soil reaches the surface over an impermeable layer, or
2. 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.)

Dig a small hole near the spring to learn the depth to 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.

Usually the soil is dug to the hard, underlying part and a tank is made with watertight concrete walls on all but the uphill side (see Figures 1 and 2). 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 which can be fed by a perforated pipe which is 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:

- building a complete cover to stop surface pollution and keep out sunlight, which causes algae to grow.
- installing a locked manhole with at least a 5cm (2") overlap to prevent entrance of polluted ground water.
- installing a screened overflow which discharges at least 15cm (6") above the ground. The water must land on a cement pad or rock surface to stop the water from making a hole in the ground and to insure proper drainage away from the spring.
- arranging the spring so that sur-

face 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 insuring that it has to filter through 3 meters (10') of soil.

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

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 "Chlorination and Superchlorination.")

Source:

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

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

Acknowledgements

John M. Jenkins, III, VITA Volunteer, Marrero, Louisiana

Ramesh Patel, VITA Volunteer, Albany, New York

William P. White, VITA Volunteer, Brooklyn, Connecticut

CISTERNS

Cisterns for family use are most practical in areas of adequate rainfall and where ground water is difficult to obtain or where it contains too many minerals. A sealed well usually requires no filtration, no chemical disinfection and little upkeep, while a cistern needs all of these. Cisterns cost more to build than wells. Cistern water has few minerals, however, and is ideal for washing clothes.

A cistern water supply has four basic parts: tank, catchment area, filter and a pump. (Pumps are discussed in the section on "Water Lifting.")

Cistern Tank

The tank described here can be used for sanitary storage of rainwater for family use.

Tools and Materials

Tools and materials for reinforced concrete

Asphalt sealing compound

Screening

Pipe

The cistern tank must be watertight to prevent surface contamination from polluting the supply. Reinforced concrete is the best material because it is strong, it has a long life and it can be made watertight.

A manhole and drain must be provided so the tank can be cleaned. (See Figure 1.) A vent and a place through which chlorine can be added easily for disinfection are also necessary.

The size of the cistern depends on the family's daily needs and the length of time between rainy periods. If a family needs 94.6 liters (25 U.S. gallons) of water a day and there are 125 days between rainy periods, then the cistern must hold:

94.6 liters x 125 days = 11,835 liters

or

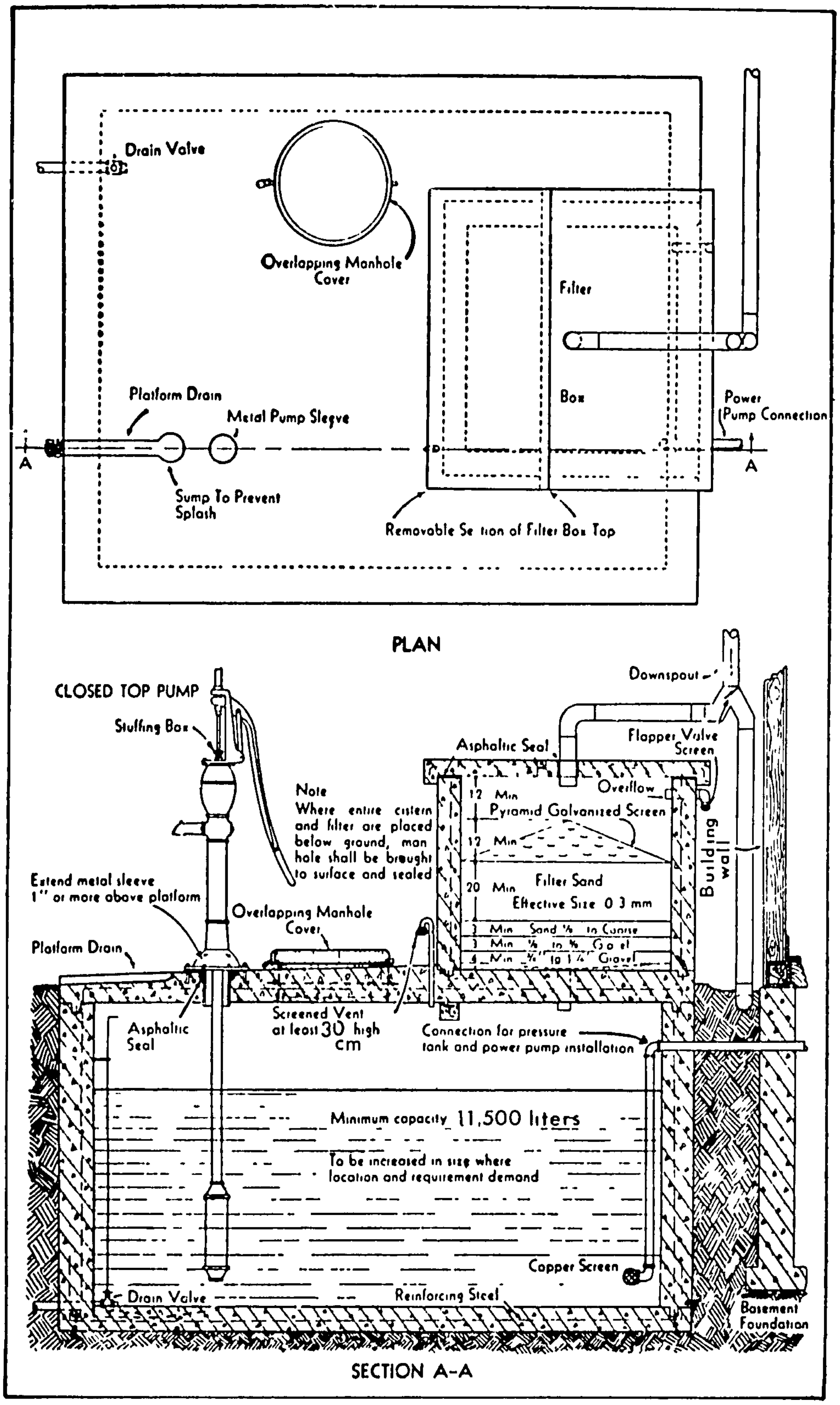
25 U.S. gallons x 125 days = 3,125 U.S. gallons

A cistern with an inside size of 2 meters x 2 meters x 2 meters (7 1/2' x 7 1/2' x 7 1/2') holds 11,355 liters (3,000 U.S. gallons).

To be sure that the cistern is watertight, use about 28 liters of water per 50kg sack of cement (5 1/2 U.S. gallons per 94 pound or one cubic foot sack when mixing the concrete. (See section on "Concrete Construction.") Tamp the concrete thoroughly and keep the surface damp for at least 10 days. If possible, pour the walls and floor at the same time. The manhole entrance must be 10cm (4") above the cistern surface and the cover should overlap by 5cm (2"). Slope the bottom of the cistern, making one part lower than the rest, so that water can be more easily siphoned or bailed out when the cistern is being cleaned. You can do this by scraping the bottom to the proper contour. Do not use fill dirt under the cistern because this may cause the cistern to settle unevenly and crack. A screened drain pipe and valve will make cleaning easier.

An overflow pipe is not needed if a roof-cleaning butterfly valve is properly used. If the overflow is installed, be sure to cover the outlet carefully with copper window screen. A screened vent is necessary if there is no overflow, to allow displaced air to leave the cistern. The hand pump must be securely mounted to bolts cast into the concrete cistern cover. The flanged base of the pump should be

FIG. 1 CISTERN WITH SAND FILTER (PUMP INSTALLATION OPTIONAL)



Reproduced from US Public Health Service, Joint Committee on Rural Sanitation (1950) *Individual water supply systems*, Washington, p 32 solid, with no holes for contamination to enter, and sealed to the pump cover, or the drop pipe must be sealed in with concrete and asphalt sealing compound.

A small pipe with a screwed-on cap is needed through which to measure the water in the cistern and to add chlorine solution after each rainfall. The amount of water in the cistern is measured with a stick marked in thousands of liters (or thousands of gallons). To disinfect after each rainfall, add a 5 parts per million dosage of chlorine (see section on "Chlorination").

A newly built or repaired cistern should always be disinfected with a 50 parts per million chlorine solution. The cistern walls and the filter should be thoroughly washed with this strong solution and then rinsed. A small-pressure system can be disinfected readily by pumping this strong solution throughout the system and letting it stand overnight.

Catchment Area

A catchment area of the proper size is a necessary part of a cistern water supply. Rainwater for a cistern can be collected from the roof of a house. The method given here for estimating catchment size should be checked against the actual size of nearby catchment installations.

Tools and Materials

Galvanized iron roof or equivalent

Trough collectors

Downspout

The catchment or collecting area should be a smooth, watertight material, like a galvanized sheet-metal roof. Wood or thatch roofs may taint the water and retain dust, dirt and leaves; water from these roofs contains more organic matter and bacteria than water from smooth surfaces. Stone, concrete and plastic film catchments are sometimes built on the ground. For family use, roofs are usually best because humans and animals cannot contaminate them.

To estimate your required catchment area, estimate the minimum yearly rainfall and the amount of water required by the family during one year. Sometimes, the government meteorological section can give you the minimum rainfall expected. If they cannot, estimate the minimum rainfall at two-thirds of the yearly average. Take the average amount of water needed by the family for one day and multiply it by 365 to learn how much is needed for one year. Then use the chart to find how much roofspace is needed (Figure 2). Add 10 percent to the area given by the chart to allow for water lost by evaporation and by discarding water at the beginning of each rainfall.

Example:

Suppose you have an average rainfall of 75cm a year and a family needs 135 liters a day, then:

2/3 x 75 = minimum annual rainfall of 50cm

365 x 135 liters/day = 49,275 liters a year.

Round this figure off to 50,000 liters a year. The example worked out on the chart shows that a catchment area of about 115 square meters is needed. Add 10 percent to this area to allow for water loss, giving a total required catchment area of about 126.5 square meters.

A collecting trough and downspout are needed. Be sure there is a good pitch to the trough so that the water flows freely and does not hold small puddles that can breed yellow-fever mosquitos and other insects. Troughs and downspouts need periodic inspection and cleaning. If you extend the trough, it increases the catchment area.

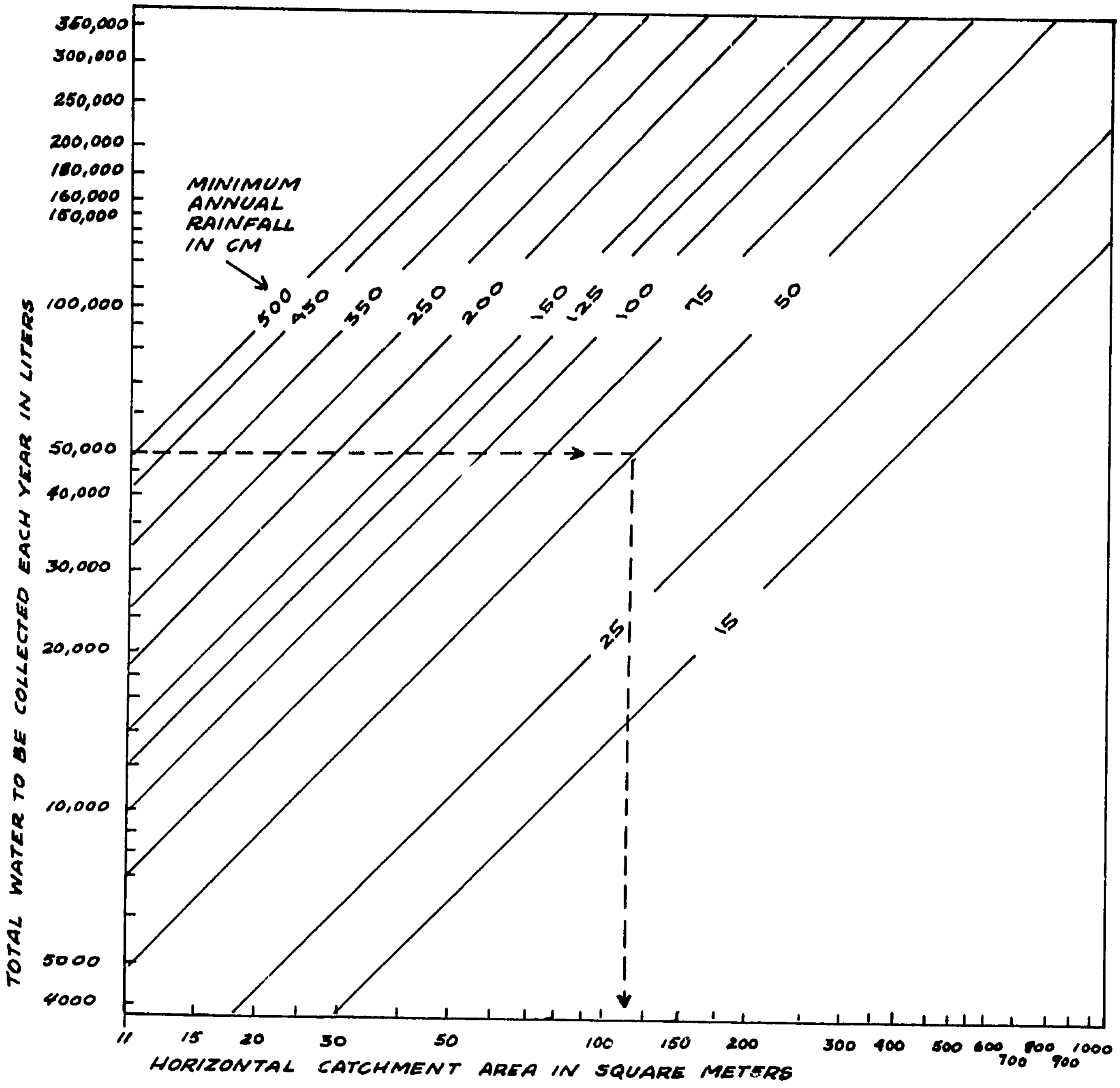

MINIMUM ANNUAL RAINFALL IN CM
500
450
350
250
200
150
125
100
75
50
25
15
360,000
300,000
250,000
200,000
180,000
160,000
150,000
100,000
50,000
40,000
30,000
20,000
10,000
5000
4000
11
15
20
30
50
100
150
200
300
400
500
600
700
800
900
1000
TOTAL WATER TO BE COLLECTED EACH YEAR IN LITERS
HORIZONTAL CATCHMENT AREA IN SQUARE METERS

FIGURE 2

Cistern Filter

The sand filter described here will remove most organic matter from water but it will not produce safe drinking water by removing all harmful bacteria. Water collected in the cistern tank should be chlorinated after each rainfall.

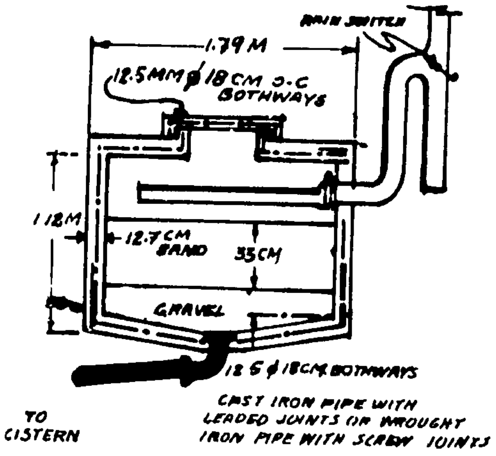


FIGURE 3

Tools and Materials

Tools and materials for making reinforced concrete

Screen

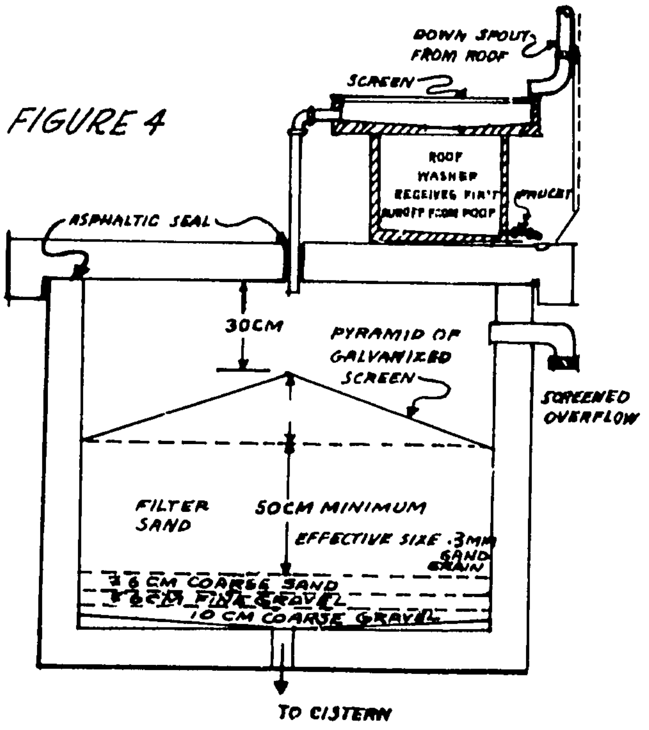
Fine, clean sand

Graded gravel

Asphalt sealing compound

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

FIGURE 4



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

If a filter is made too small to handle the normal rush of water from rainstorms, the water will overflow the filter or dig a channel in the sand, ruining the filter. The filter area should not be less than one-tenth of the catchment area. A typical filter would be 122cm x 122cm (4' x 4') for a family-sized unit where rainfall intensity is average.

About every 6 months, remove the manhole cover and clean the filter. Remove all matter from the splash plate and scrape off and remove the top 1.25cm (1/2") of sand. When the sand is down to 30cm (12") in depth, rebuild it with clean sand to the original depth of 46cm (18").

The first runoff from the roof, which usually contains a great deal of leaves and dirt, should be discarded. The simplest way to do this is to have a butterfly valve (like a damper in a stovepipe) in the downspout (see Figure 3). After the rain has washed the roof, the valve is turned to let the runoff water enter the filter. A semi-automatic filter is shown in Figure 4.

In building the filter, it is important to use properly-sized sand and gravel and to make sure the filter can be cleaned easily. The filter must have a screened overflow.

Sources:

Cisterns, State of Illinois, Department of Public Health, Circular No. 833.

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

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

SELECTING A DAM SITE

A water reservoir can be formed by building a dam across a ravine. The preliminary evaluation described here will help to determine whether or not a particular site will be good for building a dam. If the information collected in this investigation shows that the site has good possibilities, consult an expert before starting to build.

Materials

Maps

Rainfall data

Building a dam takes time, labor, materials and money. Furthermore, if a dam which holds more than a few acre-feet of water breaks, a great deal of damage could be caused. Therefore it is important to choose a dam site carefully, to guard against dam collapse, and to avoid excessive silting, porous soil, polluted water and lack of water because of a small catchment area.

One acre-foot of water equals 1 foot of water covering an acre of land (30cm of water covering 0.4 hectares). One acre-foot equals 1233.49 cubic meters.

Six factors are important in site selection:

1. Enough water to fill the reservoir.
2. Maximum water storage with the smallest dam.
3. A sound, leakproof foundation for the reservoir.
4. Reasonable freedom from pollution.
5. A storage site close to users.
6. Available materials for construction.

The annual rainfall and type of catchment (or natural drainage) area will determine the amount of water which the reservoir will collect.

Catchment Area

A catchment area with steep slopes and rocky surfaces is very good. If the catchment area has porous soil on a leak-proof rock base, springs will develop and will carry water to the reservoir, but more slowly than rocky slopes. Trees with small leaves, such as conifers, will act as windbreakers and reduce loss of water from evaporation.

Swamps, heavy vegetation, permeable ground and slight slopes will decrease the yield of water from a catchment area.

Rainfall

The average catchment area will, in a year, drain 5 acre-feet (6167.45 cubic meters) into a reservoir for every inch (2.5cm) of annual rainfall falling on a square mile (2.59 square kilometers); that is, about 10 percent of the rainfall.

Location

The best location for building a dam is where a broad valley narrows with steep sides and a firm base on which to build the dam (see Figure 1). Ground which contains large boulders, weathered or fissured bedrock, alluvial sands or porous rock is not good. The best bases for building a dam are granite or basalt layers at or near the surface or a considerable depth of silty or sandy clay.

Location of a dam upstream from its point of use can lower pollution and may allow for gravity feed of the water to its point of use.

It is best if stone is nearby when building a masonry dam. When building

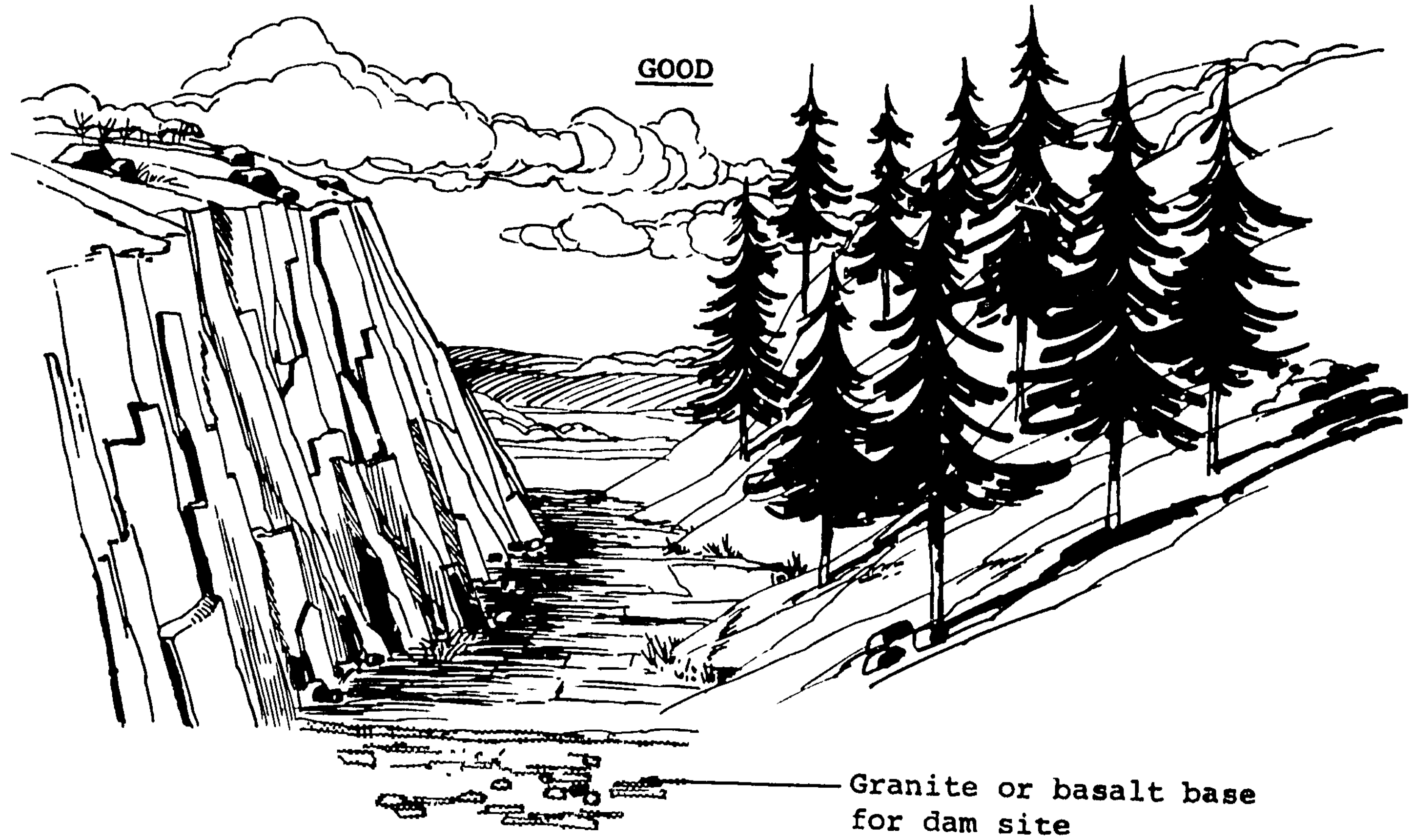
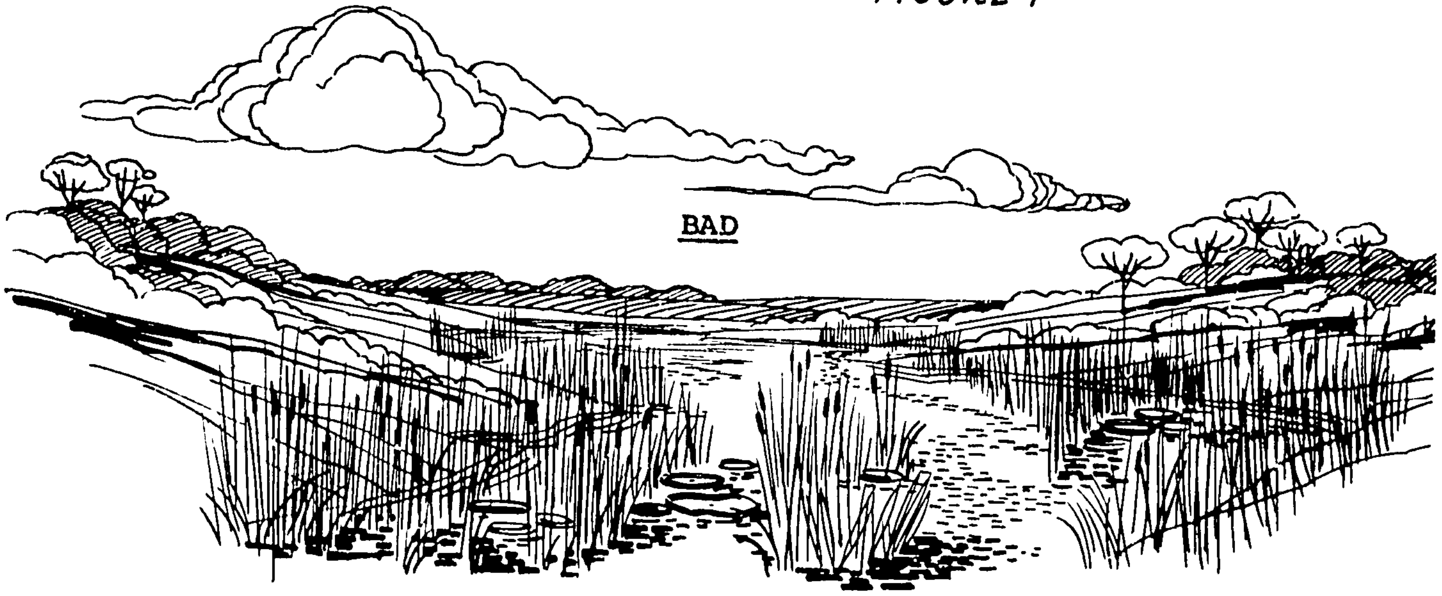


FIGURE 1



an earthen dam, rock will still be required for the spillway. The best soils to use for earth dams contain clay with some silt or sand. There should be enough of this soil close to the dam site for building the entire dam of reasonably uniform material.

Careful selection of the dam site will save labor and material costs and help insure a strong dam.

Source:

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

RECIPROCATING WIRE POWER TRANSMISSION FOR SMALL WATER WHEELS

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 mechanical power from small water 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 which pivots on a pole (see Figure 2). A wire is used to connect this frame to another 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 5 seconds. Sometimes power for several transmission wires comes from one larger water wheel.

FIGURE 1

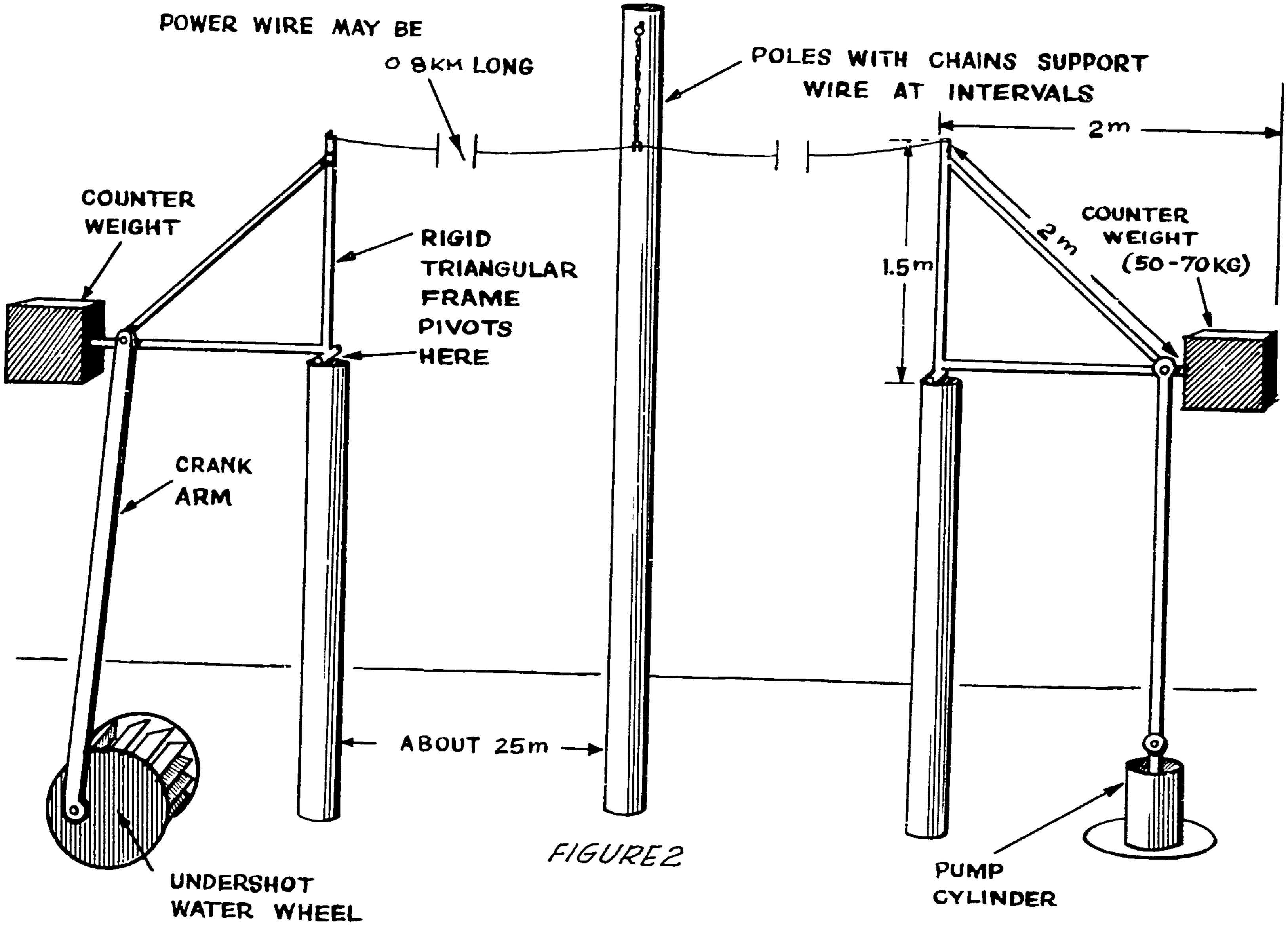

POWER WIRE MAY BE
0 8KM LONG
POLES WITH CHAINS SUPPORT WIRE AT INTERVALS
2m
COUNTER WEIGHT
RIGID TRIANGULAR FRAME PIVOTS HERE
1.5m
2m
COUNTER WEIGHT (50-70KG)
CRANK ARM
ABOUT 25m
UNDERSHOT WATER WHEEL
PUMP CYLINDER

FIGURE 2

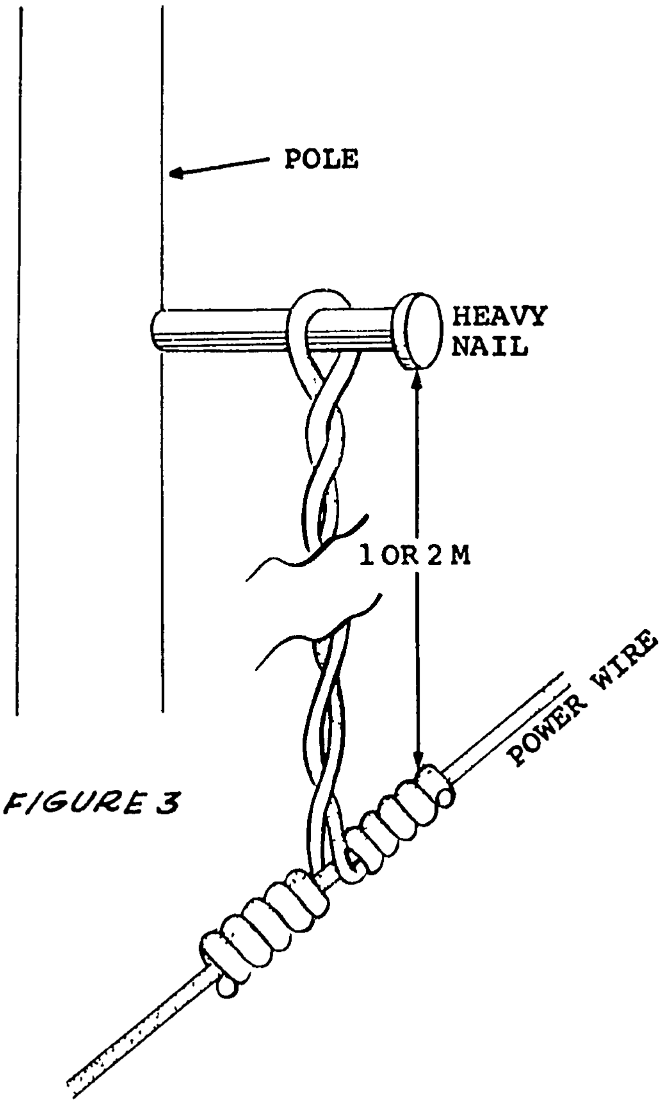


FIGURE 3

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.

Water Wheel

Figures 5, 6 and 7 show how to build and install a small water wheel made from wood and bamboo.

Source:

New Holland, Pennsylvania VITA Chapter.

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.

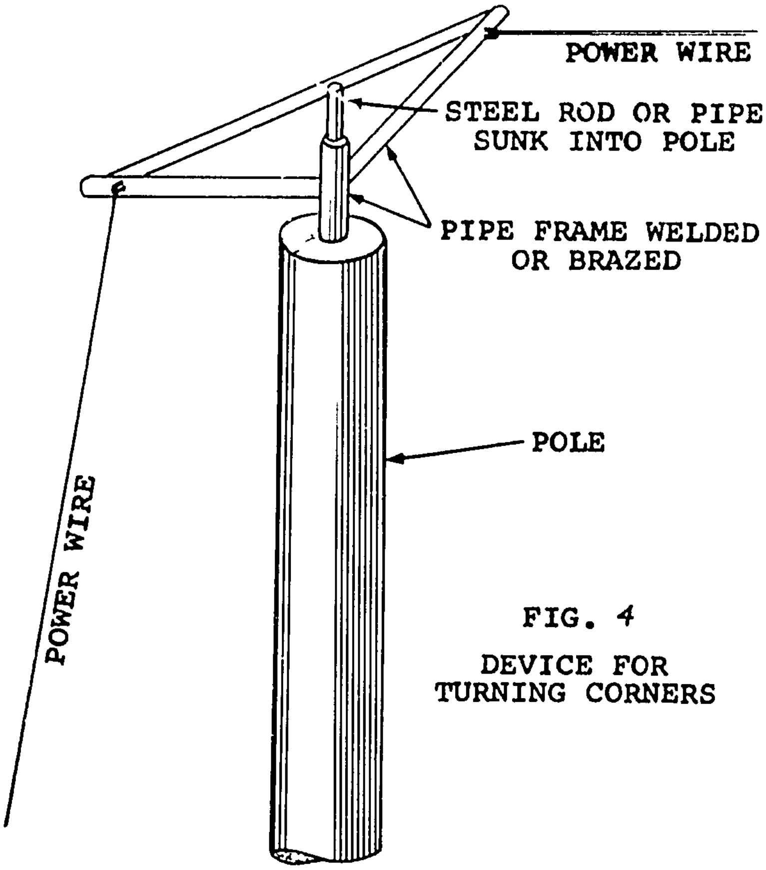


FIG. 4

DEVICE FOR TURNING CORNERS

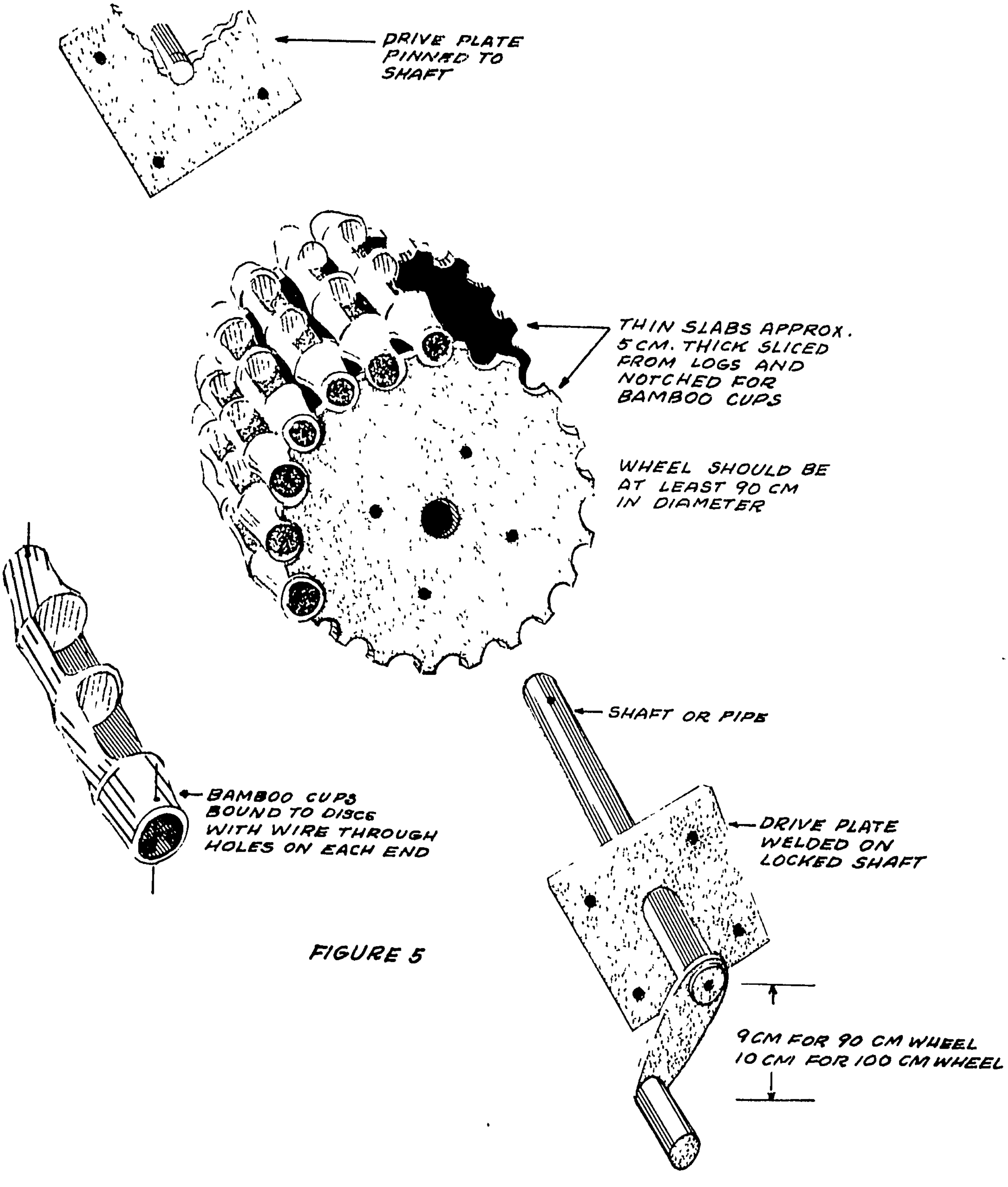

DRIVE PLATE PINNED TO SHAFT
THIN SLABS APPROX. 5 CM. THICK SLICED FROM LOGS AND NOTCHED FOR BAMBOO CUPS
WHEEL SHOULD BE AT LEAST 90 CM IN DIAMETER
SHAFT OR PIPE
BAMBOO CUPS BOUND TO DISCS WITH WIRE THROUGH HOLES ON EACH END
DRIVE PLATE WELDED ON LOCKED SHAFT
9 CM FOR 90 CM WHEEL
10 CM FOR 100 CM WHEEL

FIGURE 5

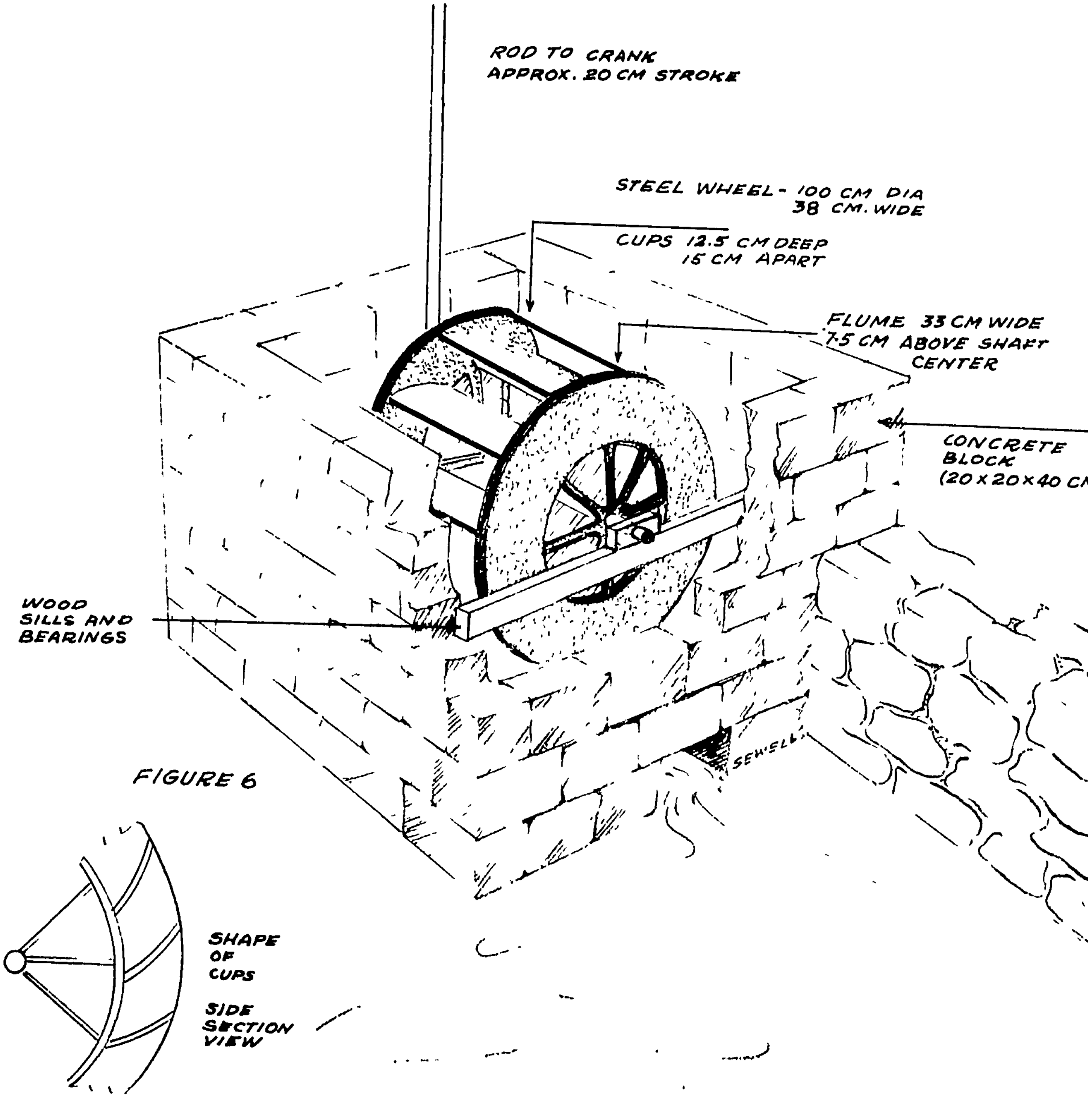
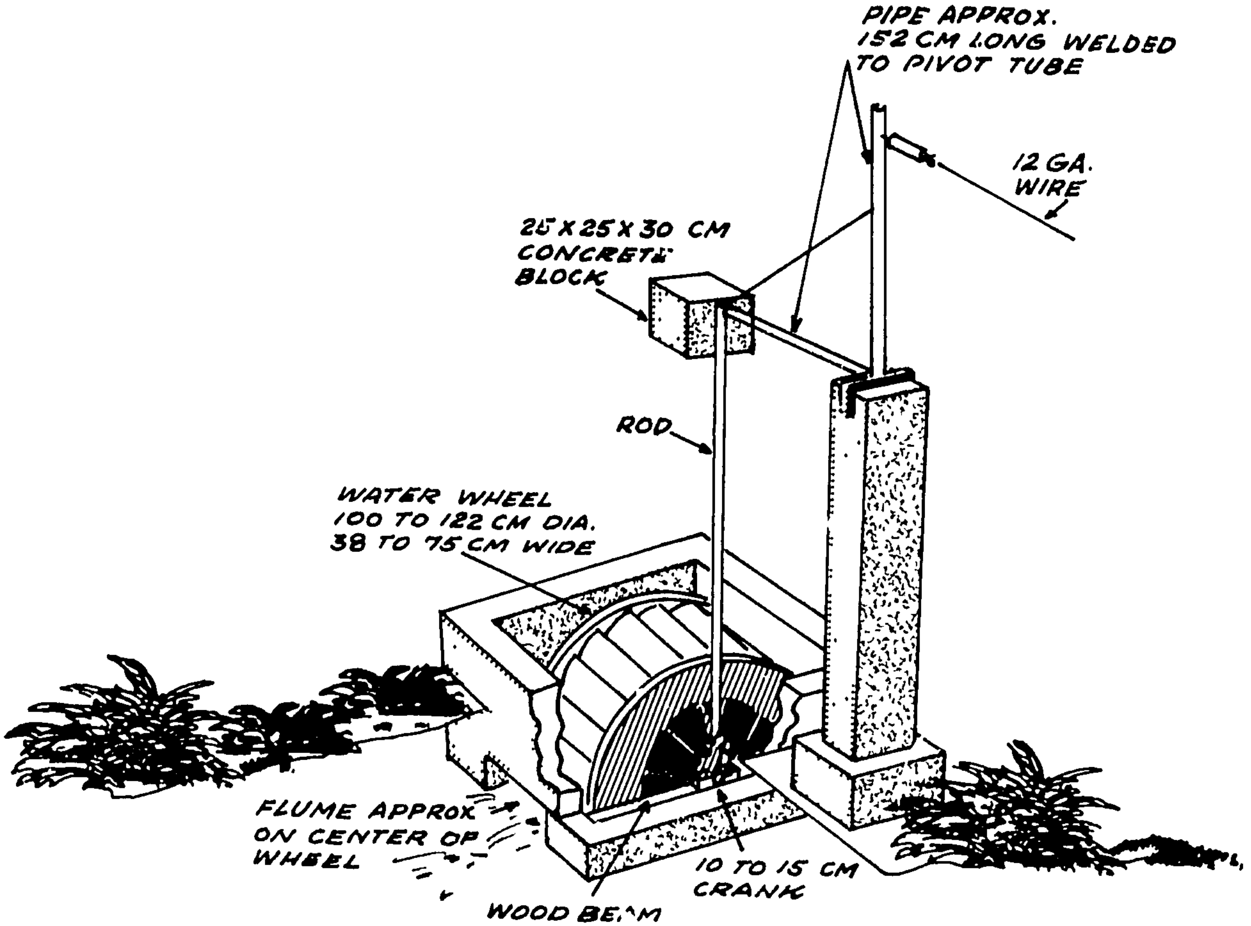

ROD TO CRANK
APPROX. 20 CM STROKE
STEEL WHEEL - 100 CM DIA
38 CM. WIDE
CUPS 12.5 CM DEEP
15 CM APART
FLUME 33 CM WIDE
7.5 CM ABOVE SHAFT CENTER
CONCRETE BLOCK
(20x20x40 C
WOOD SILLS AND BEARINGS
SEWELL
SHAPE OF CUPS
SIDE SECTION VIEW

FIGURE 6



NOTE: CRANK CAN
BE ADDED TO OTHER
END OF SHAFT AT 90°
ANGLE TO FIRST CRANK
TO ATTACH MORE POWER
TRANSMITTING WIRES

FIGURE 7

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	12· 92	124.46
50	127 00	129 54	132 08	134 62	137 16	139 70	142 24	144 78	147 32	149 86
60	152 40	154 94	157 48	160 02	162 56	165 10	167 64	170 18	172 72	175 26
70	177 80	180 34	182 88	185 42	187 96	190 50	193 04	195 58	198 12	200 66
80	203 20	205 74	208 28	210 82	213 36	215 90	218 44	220 98	223 52	226.06
90	228 60	231.14	233 68	236 22	238 76	241 30	243 84	246 38	248 92	251 46

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

cm.	0	1	2	3	4	5	6	7	8	9
0	inches	0 394	0 787	1 181	1 575	1 969	2 362	2 756	3 150	3.543
10	3.937	4 331	4 724	5 118	5.512	5 906	6 299	6 693	7 087	7 480
20	7.874	8 268	8 661	9 055	9.449	9 843	10 236	10 630	11 024	11.417
30	11.811	12 205	12 598	12 992	13 386	13.780	14 173	14.567	14 961	15 354
40	15 748	16 142	16 535	16 929	17 323	17 717	18.110	18 504	18 898	19.291
50	19 685	20 079	20 472	20 866	21 260	21 654	22 047	22.441	22 835	23 228
60	23 622	24 016	24 409	24 803	25 197	25 591	25 984	26.378	26 772	27.165
70	27.559	27 953	28 346	28.740	29 134	29.528	29 921	30 315	30 709	31.102
80	31 496	31 890	32 283	32 677	33 071	33.465	33 858	34 252	34 646	35 039
90	35 433	35 827	36 220	36.614	37 008	37 402	37 795	38 189	38 583	38.976

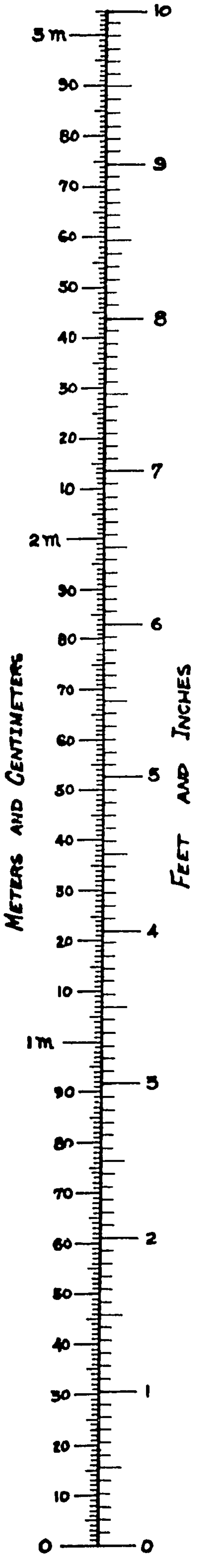

METERS AND CENTIMETERS
FEET AND INCHES
0
10
20
30
40
50
60
70
80
90
1m
10
20
30
40
50
60
70
80
90
2m
10
20
30
40
50
60
70
80
90
3m
0
1
2
3
4
5
6
7
8
9
10

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 5

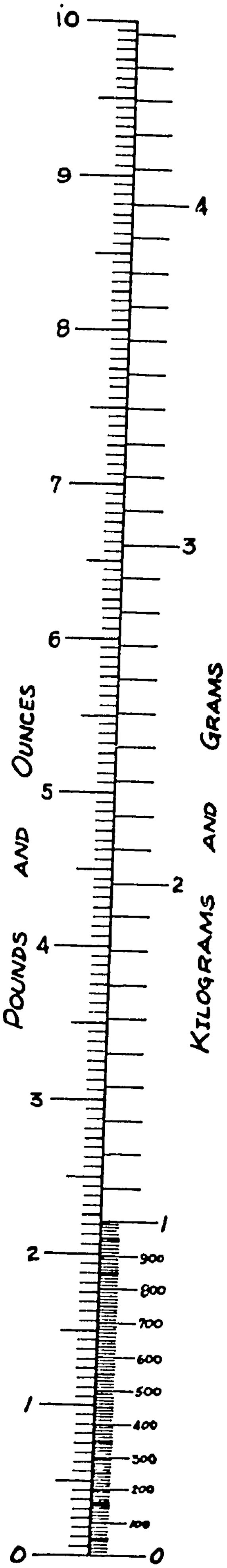


FIGURE 4

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

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)

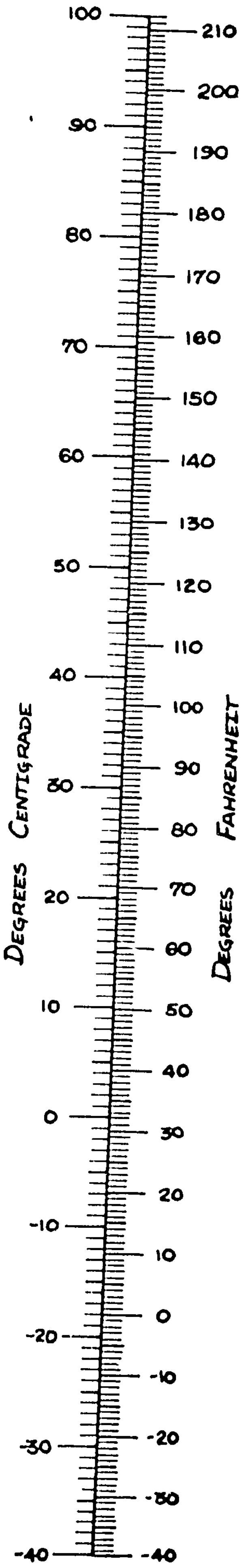
72F = 5/9 (72 -32)

72F = 5/9 (40)

72F = 22.2C

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

FIGURE 1



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