Deutsches Zentrum für Entwicklungstechnologien
Centre allemand d'inter-technologie appropriée
Centro Alemán para Tecnologías Apropiadas

an Appropriate Technology Exchange

in

Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ), GmbH

WATER PUMPING SYSTEMS
USING
RENEWABLE ENERGIES

S 2/2 12/78

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German Appropriate Technology Exchange

in: Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ), GmbH
Postfach 5180, D-6236 Eschborn 1
D-6236 Eschborn 1 Dag-Hammarskjöld-Weg 1
(bei Frankfurt am Main)

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PREPARED BY Gabriele Heber, Dipl.-Chem.

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Q U E S T I O N - A N D - A N S W E R - S E R V I C E

for "appropriate technologies"

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The activities of the question-and-answer-service are geared to the actual technological requirements indicated by the enquiries received from developing countries. At the same time, the demand for particular solutions is determined with the aid of a questionnaire distributed to institutions in developing countries dealing with situation-related solutions. Parallel to this, the questionnaire also makes it possible to ascertain solutions already available within these institutions. The question-and-answer-service relies not least on the documentation on newly-developed or traditional technologies supplied to it by such possessors of know-how.

When answering enquiries the question-and-answer-service uses documentation resources built up in this way. The information accumulated there on particular technological problem areas is - if frequently requested - combined to form "modules".

These answer packages, intended for dispatch, contain, where possible, technical descriptions and design drawings and are thus directly application-related, i.e. they provide an outline of technologies suitable for self-construction. The know-how of national research institutions and universities, with whom GATE works in close cooperation, is drawn upon to help answer specific enquiries, which can often be expected as feedback from the communication started with "modules".

In the event of enquiries dealing with typical problems encountered by a number of developing nations, but for which no suitable solution is available or can be obtained, GATE has the opportunity to suggest appropriate R & D measures to various sources of finance.

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3973

WITH THE MODULES EDITED WITHIN THE QUESTION-AND-ANSWER-SERVICE WE AIM TO GIVE AND COMPILE INFORMATION ON VILLAGE-LEVEL-TECHNOLOGY. WE TRY TO STIMULATE THE DEVELOPMENT OF MAINLY RURAL AREAS WITH A STRONG EMPHASIS ON THE SELF-HELP CONCEPT.

BY NO MEANS DO WE INTEND TO PRESENT A SORT OF RECIPE FOR AN APPROPRIATE WAY OF DEVELOPMENT OR FINAL TECHNICAL SOLUTIONS WHICH WE CONSIDER TO BE THE ANSWER TO THE PROBLEMS CONCERNING THE QUESTION OF DEVELOPMENT IN RURAL OR SUBURBAN AREAS.

KNOWING WELL THAT INFORMATION IS THE FIRST STEP WHEN CHOOSING ACTIVITIES AND THAT - ESPECIALLY IN THE FIELD OF TECHNOLOGY - THERE IS A GREAT AMOUNT OF INFORMATION AVAILABLE, WE TRIED TO SELECT SOME OF THE SPECIFIC TECHNOLOGY NEEDS OF THE MAJORITY OF PEOPLE IN DEVELOPING COUNTRIES. THESE PEOPLE LIVE IN AREAS WITH A LACK OF WATER SUPPLY, SANITATION FACILITIES, APPROPRIATE HOUSING POSSIBILITIES, WHERE GENERALLY THE FOOD PRODUCTION IS LOW AND INEFFICIENT, THE ENERGY DEMAND IS NOT AT ALL MET AND THE MAJORITY OF PEOPLE IS ONLY PARTLY OR NOT AT ALL EMPLOYED.

THE SELECTION OF TOPICS WITHIN OUR INFORMATION SERVICE NORMALLY IS THE RESULT OF AN EVALUATION OF INQUIRY-STATISTICS, I.E. AFTER HAVING RECEIVED SEVERAL QUESTIONS IN THE FIELD OF SOLAR COOKER, FOR INSTANCE, WE DECIDED TO COMPILE THE INFORMATION CONCERNING THIS TOPIC AND EDITED THE "SURVEY OF SOLAR COOKERS".

THUS, THE FEEDBACK WE GET FROM INSTITUTIONS AND INDIVIDUALS IN THE THIRD WORLD PLAYS AN IMPORTANT RÔLE FOR THE QUALITY OF OUR MODULS AND THEIR ORIENTATION TO PRACTICAL WORK. THEREFORE WE ASK YOU NOT JUST TO READ OUR INFORMATION BUT WRITE BACK TO US AND TELL US YOUR OPINION AND CRITICISM.

AS YOU CAN IMAGINE, THIS IS THE BEST WAY FOR US TO CHECK THE QUALITY AND EFFICIENCY OF OUR QUESTION-AND-ANSWER-SERVICE. AND FOR YOU IT COULD BE OF HELP, TOO, BECAUSE WE MIGHT SUPPLY YOU WITH MORE DETAILED INFORMATION WHEN WE KNOW MORE ABOUT THE SITUATION YOU ARE IN AND TAKE INTO CONSIDERATION YOUR SPECIFIC PROBLEMS.

IN ADDITION, THE EXPERIENCE YOU HAVE GAINED AND INFORMED US ABOUT, MIGHT BE USEFUL FOR OTHERS. HAVING CONTACTS WITH MANY ORGANISATIONS IN DIFFERENT PARTS OF THE WORLD WE ARE IN A POSITION TO FORWARD YOUR IDEAS AND PROPOSALS IN THE FIELD OF TECHNOLOGY TRANSFER AND APPROPRIATE TECHNOLOGY.

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QUESTIONNAIRE

MODULE No. ______ DATE ______________

1. How did you get this information?

o I made a request at GATE and asked for it

o Someone else gave it to me (Who was it? ______________________)

o or:

2. Did you read the complete module?

o yes, from the beginning to the end

o only in parts

o only the parts I was specially interested in

o or:

3. What is your opinion about it?

a) general understanding

o difficult o just right o easy

b) theory and basic knowledge

o too much of it o just right o too few

c) orientation to practical work

o lacking o limited o just right

d) language, over-all presentation

o appropriate for your needs o too complicated

e) what else do you think is worth mentioning?

(Please use back page for additional remarks and suggestions!)

4. Do you see any practical application for the received information?

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I. A General View of Water Pumps Using Renewable Energies

In this chapter short information about the different types of water pumps is given. Mostly these pumps are used for drinking water supply and irrigation.

The necessary energies for the described pumps are belonging to the so-called renewable energies: man, animal, or water power, but also wind and solar energies.

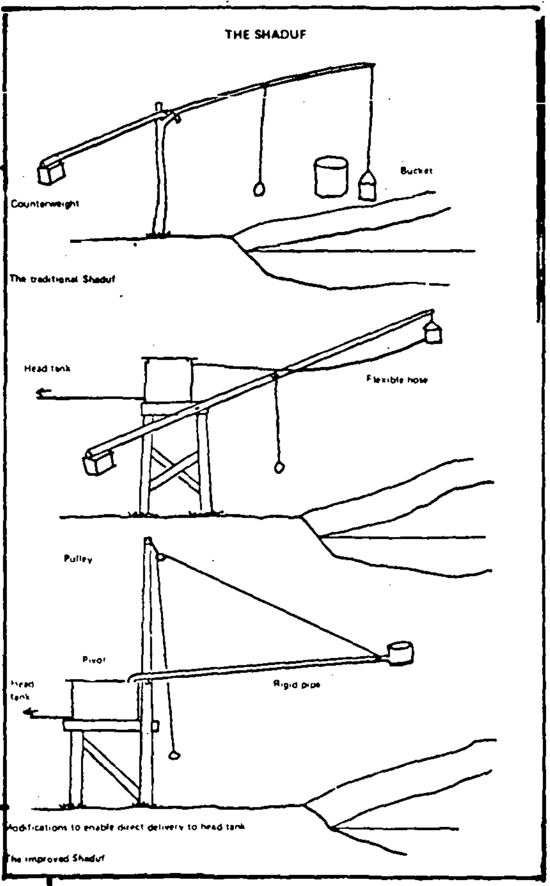
This general view mainly refers to the following book: "Hand Pumps for Use in Drinking Water Supplies in Developing Countries", published by the UNEP and the WHO, Technical Paper no. 1o, Juli 1977, Netherlands, [x)] which is highly recommended for more intensive studies of the problem.

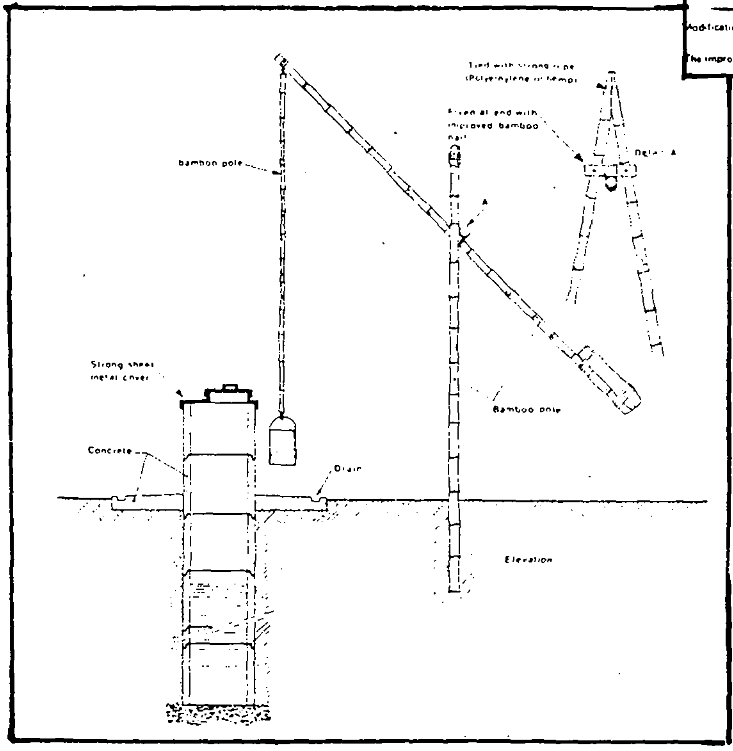
[x)] Postal address: IRC, P.O. Box 14o
2260 AC Leidschendam, the Netherlands

A. Different Types of Water Pumps

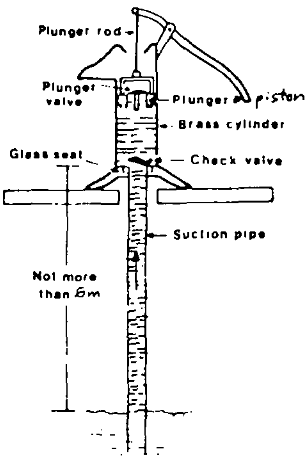
1) Traditional Water Lifting Devices

There are a lot of water lifting devices which have a long tradition and are made from indigeneous material. One example is given here with the "Shaduf", a counter-weighted bailer.





2) Shallow Well Pump



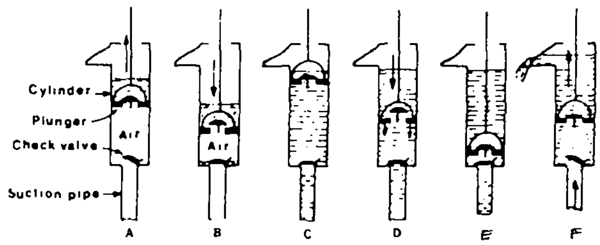
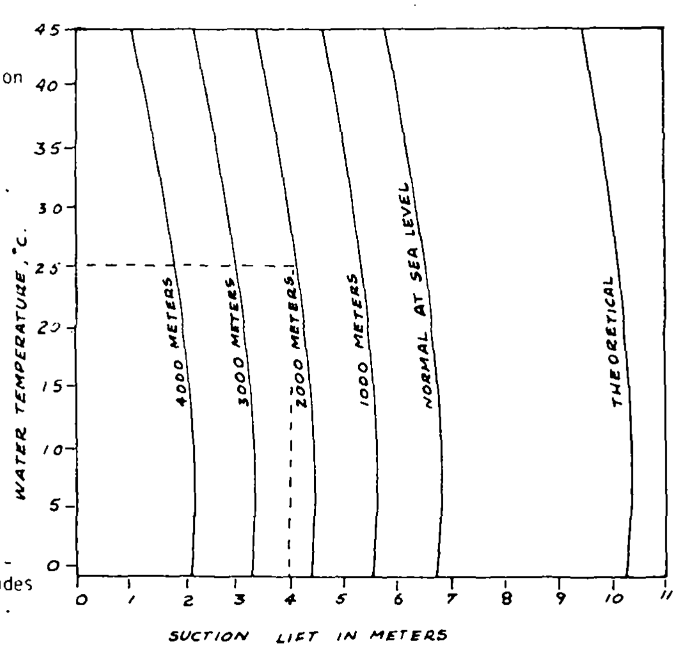


ILLUSTRATION OF OPERATION OF PLUNGER-TYPE PUMP

Shallow well pumps are suctions pumps and use atmospheric pressure to lift the water by producing a partial vacuum with the piston. The theoretical max. lift for a suction pump is about 1o meters, but due to frictional resistance and inefficiencies in pump design and operation the practical maximum lift is about 6 m or less. It depends on the altitude above sea level and the temperature of the water (see table and figure). The graph shows under which conditions the lift pump works, otherwise the priciple of a deep well pump should be used.

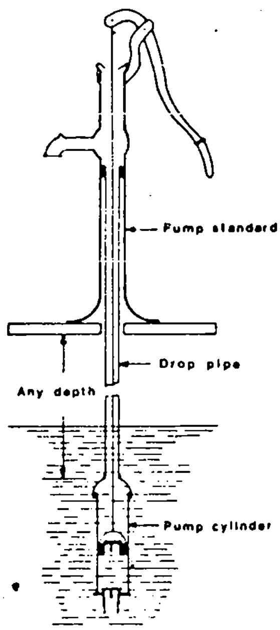
Example:

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



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

3) Deep Well Pump

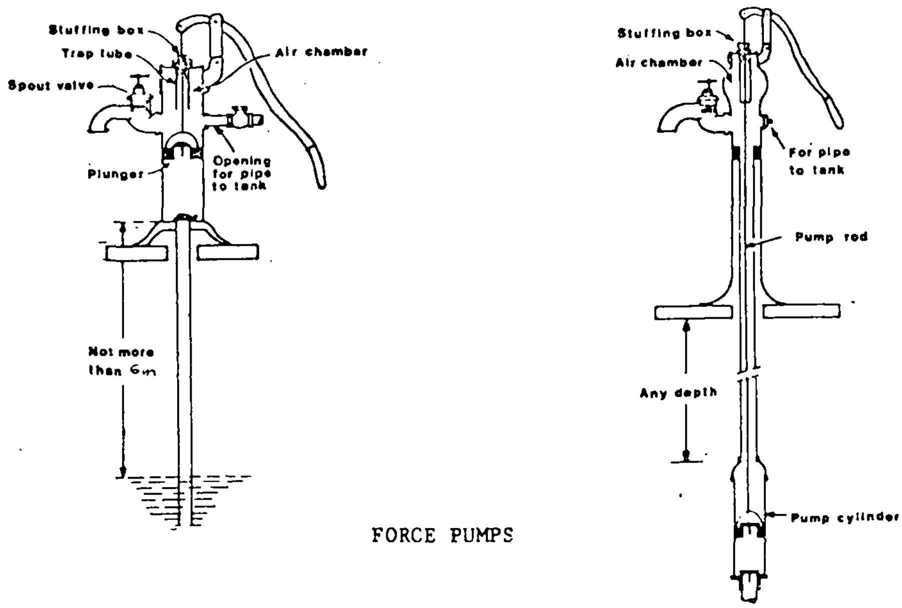


The principle of operation is the same as desribed for the shallow well pump, the difference is the location of the cylinder which is installed below the lowest water level.

Pump discharge depends on the diameter of the piston, the length of the stroke and the number of strokes per minute. If the water level is less than 9 m below the surface of the ground, the cylinder could be up to 11 - 12 cm in diameter. If the water level is farther from the surface, the long column of water that must be lifted becomes heavy and a great effort is required to operate the pump. The greater the distance to the water level, the smaller the diameter of the piston should be, so it is not too hard to pump. It is also possible to vary the distance from the well to the post supporting the pump handle to give better leverage. The closer the handle pivot is to the well, the easier it will be to pump, but the length of stroke will be smaller and so will the discharge.

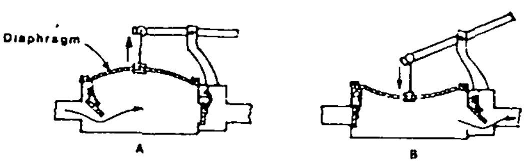
4) Force Pumps

Force pumps are designed to pump water from a source and to deliver it to a higher elevation or against pressure. They are used primarily to pump water into reservoirs and pressure tanks. All pressure-type water systems use force pumps. They are enclosed so that the water can be forced to flow against pressure. They are available for use on shallow or deep wells.



FORCE PUMPS

5) Diaphragm Pump

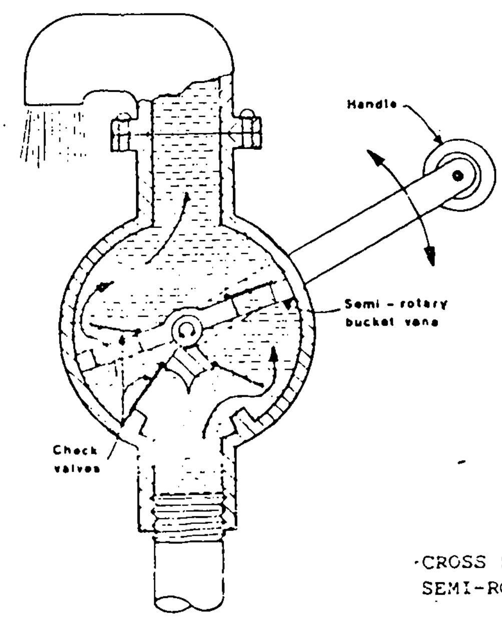


CROSS-SECTION OF A DIAPHRAGM PUMP

The diaphragm pump is a suction typepump. As the diaphragm (an elastic membrane) is lifted, liquid is drawn in through the inlet valve at the left. When the diaphragm is depressed, liquid is forced out at the right. It will pump the largest quantity of water, but can only operate when the water level in the well is not more than about 4 meters below the pump. This type is often used for irrigation.

6) Rotary Pumps

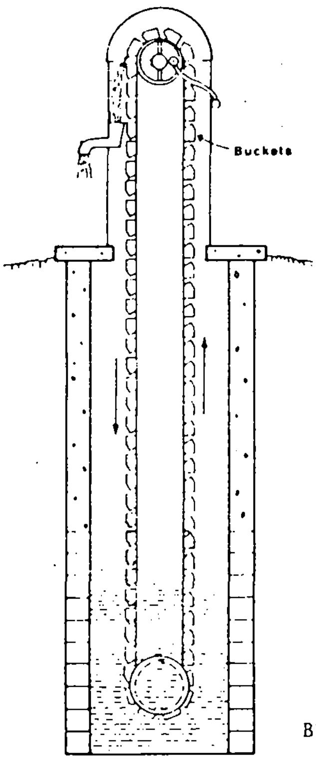
Rotary pumps are more efficient than the above mentioned types because there is a permanent flow of pumped water. But the construction is a bit more complicated and there is a greater risk of malfunction with impured water.



CROSS SECTION OF SEMI-ROTARY PUMP

7) Bucket and Chain Pumps

Small buckets attached to an endless chain are rotated over sprockets as shown so that each bucket dips water from the source at the bottom, carries it to the top, and empties it into the spout as it passes over the top sprocket.

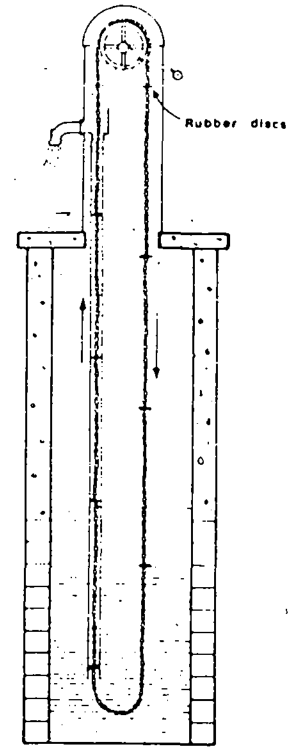


In the chain pump rubber discs attached to an endless chain running over a sprocket at the top are pulled upward through a pipe to lift water mechanically up to the spout.

Both are mostly used on cisterns and shallow dug wells.

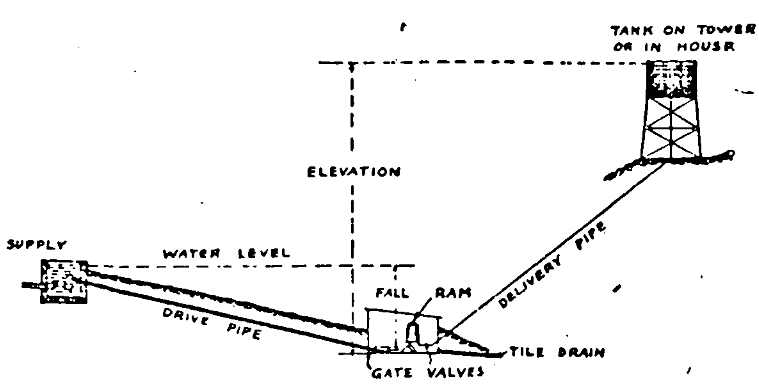
BUCKET PUMP

CHAIN PUMP

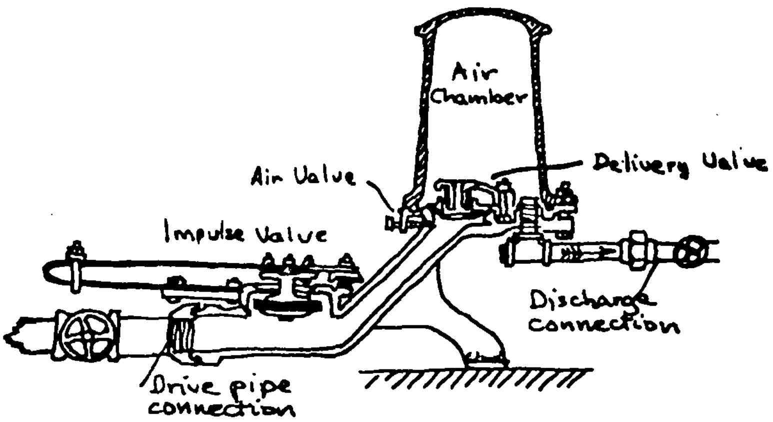


8) Hydraulic Ram

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.



The water starts to run down through the drive pipe, going faster and faster until it forces the impulse valve to close suddenly. The weight of moving water, suddenly stopped, creates a pressure and forces some of the water past the delivery valve and into the air chamber, compressing the air more and more till the kinetic energy of the moving water is spent. The compressed air acts as a spring and forces the water up the delivery pipe to the storage tank.



9) Wind-Pumping-Systems

In areas which have a sufficient annual wind supply water pumping is a very useful way to use wind energy, because the machine will run the whole day and work whenever there is enough wind.
During windless periods it should be possible to operate the pumps by men or animals.

Several of the hand-pumps discussed here can easy be adapted for windmill drive. Also here it is necessary to decide between high quality, factory made equipment which can be made locally, often from local materials, but using some imported components and which make demands on local people both for operation and maintenance.

Only a few, simple mechanisms will be mentioned here:

1. The Cretan sail-windmill with a piston pump or an Archimedian screw (see figures on page 34).

2. The Lubing windmill pump, a 4- or 6-bladed windwheel which is self-directing in the wind. This model can be connected with a piston suction pump or a deep well pump.

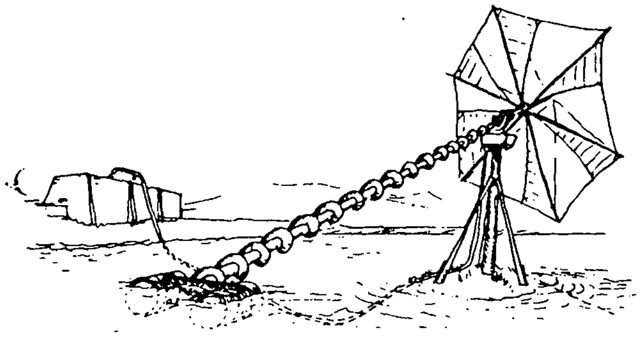
3. The GS-windmill and waterpump, a 2-bladed windwheel combined with a suction or a deep well pump (see figure).

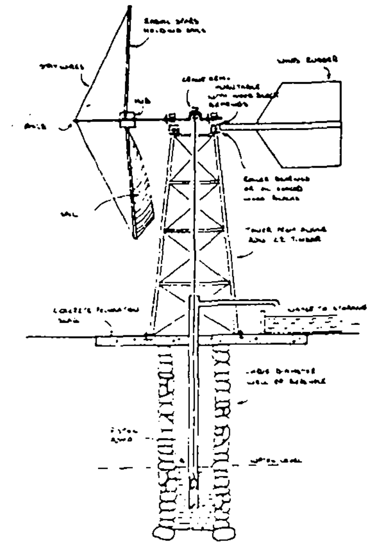
4. The Sahores windmill, suitable for construction in a rural situation. It has 16 small canvas sails in a 3-metre diameter wheel and needs much less adjustment than the sails of the Cretan machine (the sail turns away from the wind automatically).

   It is easy to construct but parts have to be replaced frequently. (Developed with the help of the World Council of Churches, plans available from CCPD, P.O. Box 66, Geneva, Switzerland.)

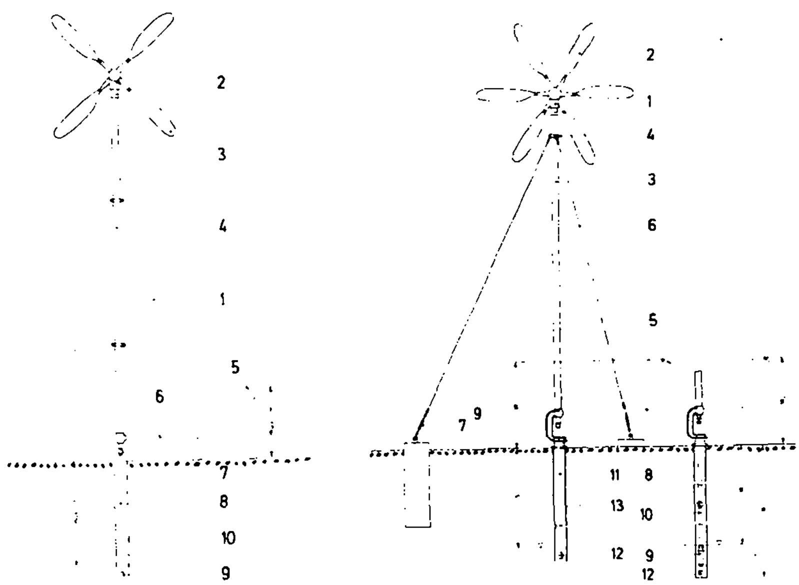
There are several other types of wind pumping systems. For further information on wind energy and source lists please contact our institution.

(1.) Cretan windmill
with Archemidian screw

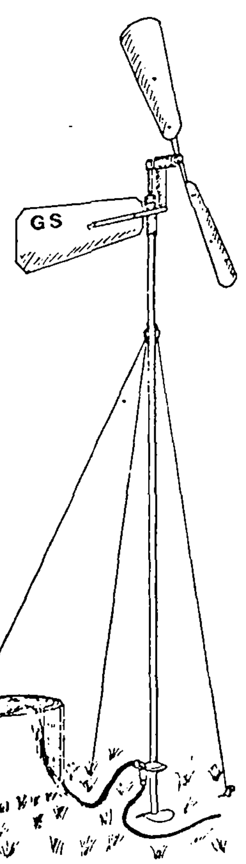




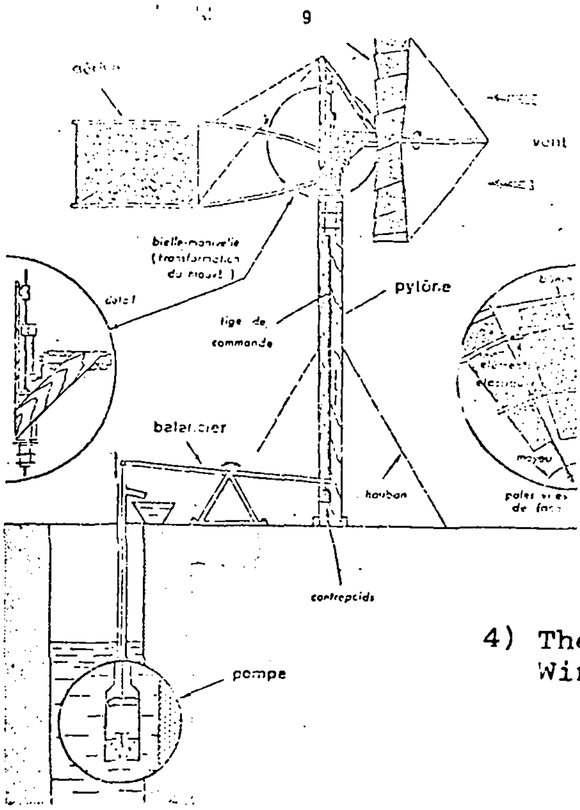
Cross section through typical
Cretan Wind Pump with piston
pump (1)



(2) LUBING windmill



(3) GS-windmill
and waterpump



4) The Sahores
Windmill

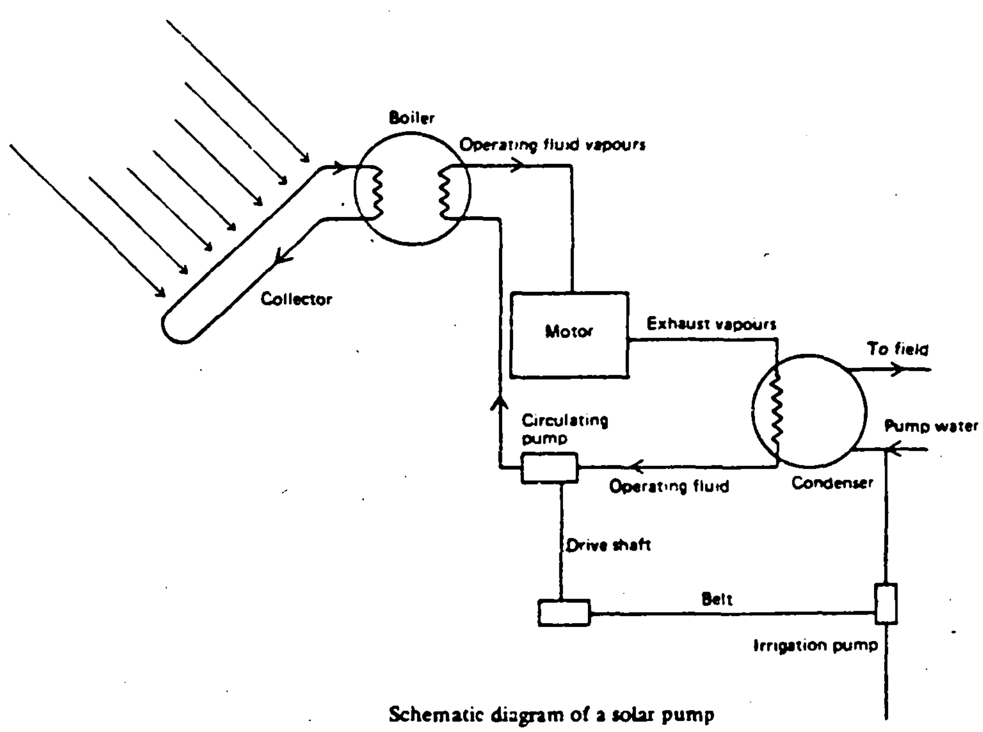
10) Sun Powered Water Pumps

Solar energy is perhaps the largest and most permanent source of power available to man, but the great difficulty is to convert solar energy into a different form of energy that canbe stored and used.

At the present moment most of the existing solar water pumps are expensive and very complex although new discoveries and mass production will inevitably bring the price down.

Even if there are some solar water pumps produced in small series one can say that all the obtainable pumps are in an experimental stage.

The principle of the operation of a solar water pump shows the following picture.



Schematic diagram of a solar pump

First there are large flat collecting plates underneath which are jackets containing water. The water heats up to a temperature of about 80° C and then circulates to a storage tank. The heat of water is transmitted to a liquid gas (e.g. butane) which evaporates and expands, and so drives an engine which is connected with the water pump. The cold pumped water condenses the gas, and the cycle can begin anew.

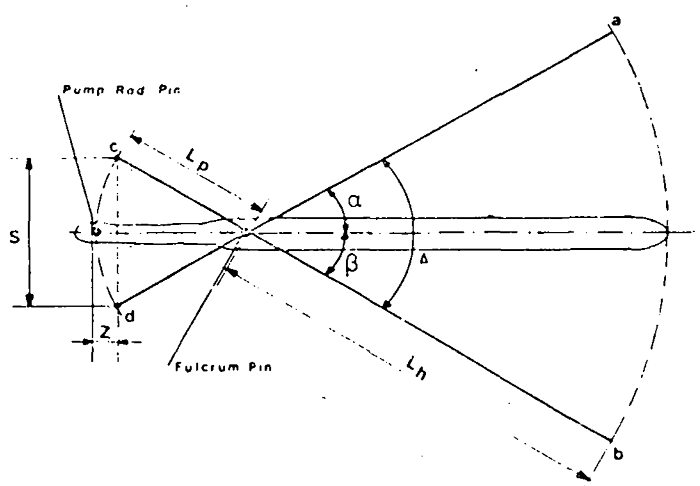
Further information about solar energy you can get from our institution.

B. Pump Components

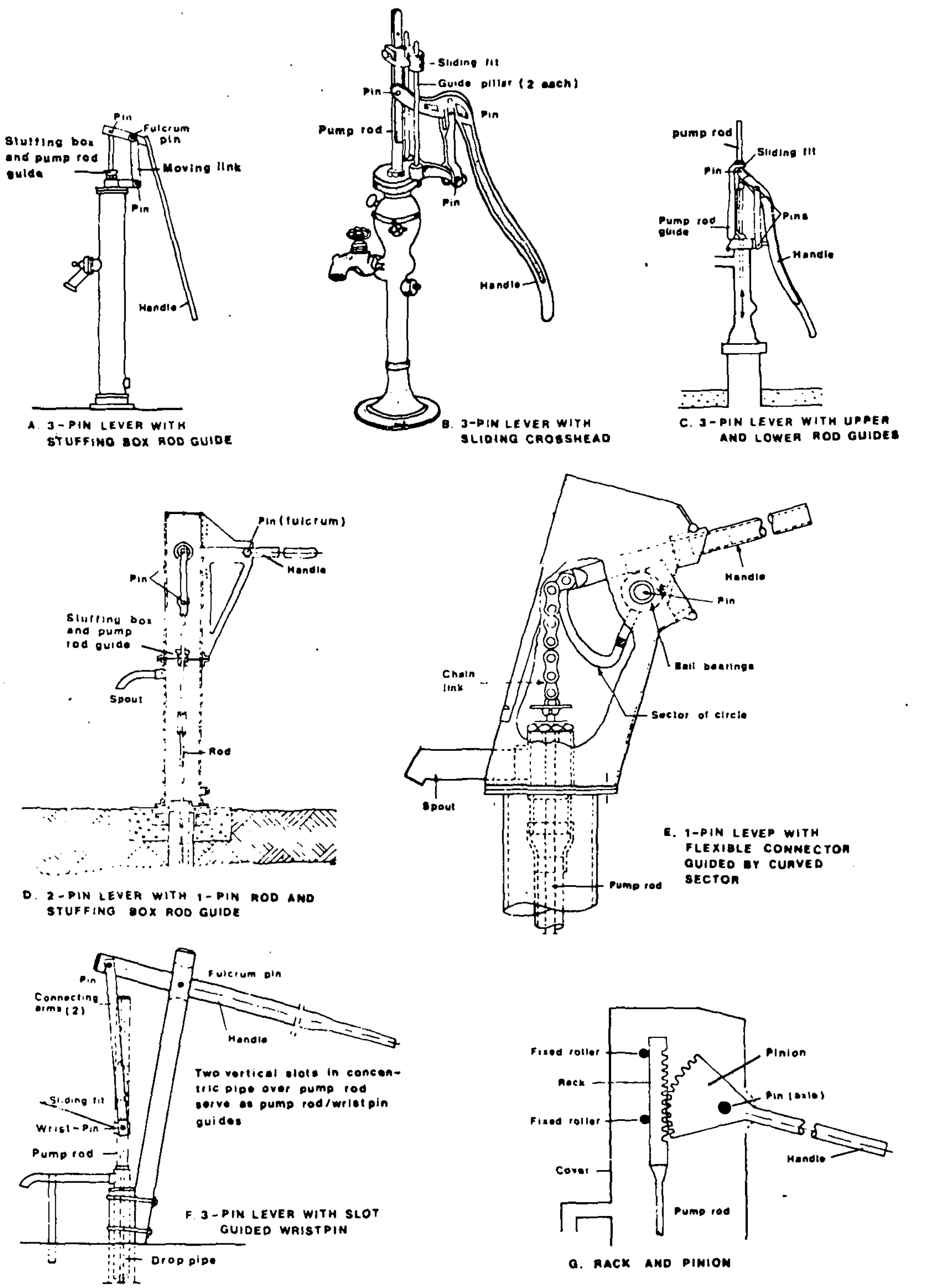
1) The Handle

The figure below illustrates the simplest type of handle mechanism: a one piece handle with two connecting pins, one at the pump rod, the other at the fulcrum. This is a common arrangement for shallow well pumps.

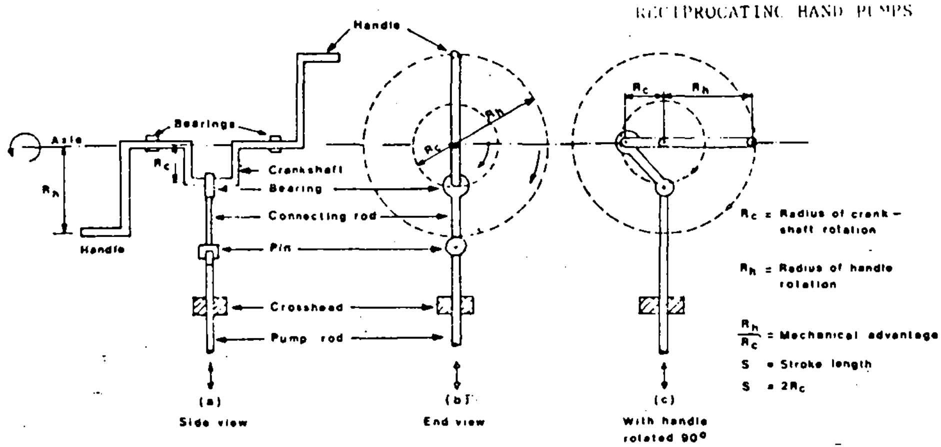
Note in the figure that the arc cd swept by the pump rod pin defines the vertical distance S, equivalent to the plunger stroke length, and a horizontal distance Z. That is, the top of the pump rod moves horizontally as well as vertically. Because the drop pipe and the pump cylinder are fixed in place, the lower end of the pump rod (attached to the plunger) although free to move vertically is not free to move horizontally. Thus if Z is too large the pump rod will strike the drop pipe (or the pump stand wall, depending on relative dimensions). A second problem is that the horizontal movement of the pump rod makes sealing the top of the pump stand assembly against contamination difficult. A third problem is that the resulting angular tilting of the plunger may cause excessive wearing of the plunger cup seals. A fourth problem, related to the second above, is that the top of the pump must be sealed for force pumps.



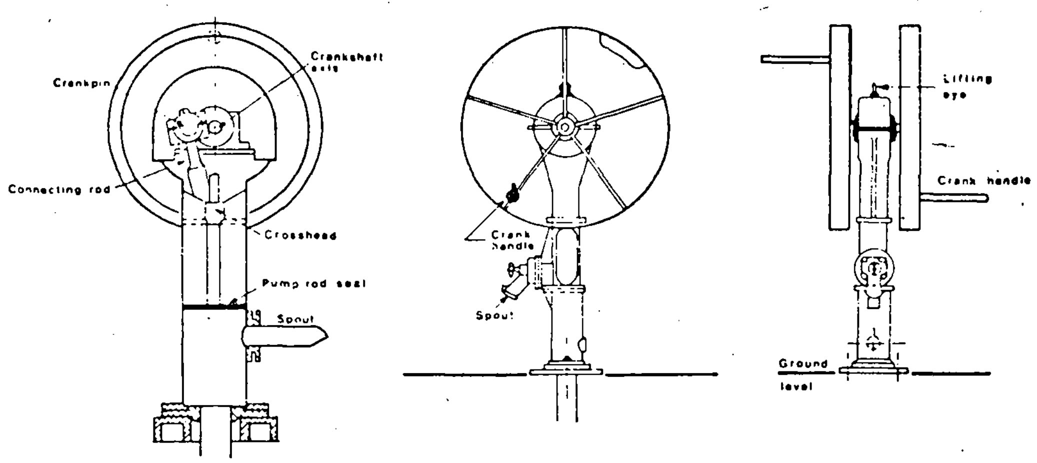
HANDLE GEOMETRY



LEVER AND LINKAGE MECHANISMS FOR VERTICAL OPERATION OF PUMP RODS WITHOUT LATERAL MOVEMENT



TYPICAL IN-LINE SLIDER CRANK MECHANISM



(d)
Cutaway view of typical unit (Deplechin)

(e)
External view of typical unit . (Godwin)

The figure illustrates for rotary crank or wheel operated hand pumps how the pump rod motion can be restricted to the vertical plane. For these pumps, the lower end of the rod or link connecting the crankshaft to the pump rod is restricted to the vertical plane by the crosshead while the upper end of the connecting rod is free to follow the rotating crankshaft. Bearings are used at each point of relative motion between components. The mechanism shown, the rotating in line slider crank, is perhaps the most common in use for rotating rather than reciprocating handles.

The mechanisms shown are intended to eliminate lateral movement by the pump rod. In doing so most of them introduce lateral stresses to the top of the pump rod. These stresses are increased with poor alignment, poor lubrication, and poor maintenance. Rotating handles, generally more costly, usually distribute the lateral forces more uniformly with lower maximum stresses. The kinetic energy stored in the wheel usually makes operation easier.

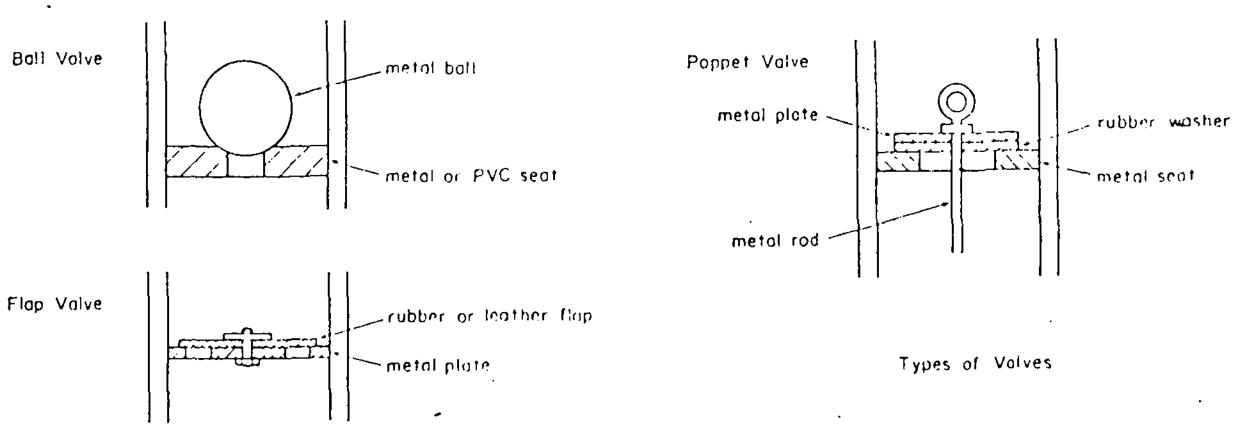
2) Valves

Reciprocating hand pumps generally contain two valves within the cylinder: one valve in the plunger assembly, the other in the bottom or suction end of the cylinder. Both the plunger valve and the suction valve are check valves, that is, valves restricting flow to one direction, in the case of wells, vertically up.

Ball valves: rather than a disc, the valve opening is closed by a ball made of metal or of other material of appropriate specific gravity. The ball is usually guided by a ribbed cage. These valves are sometimes recommended for use with deeper wells.

Flapper valve: a valve in which a flexible, hinged, horizontal disc, generally made of leather, opens and closes over the valve opening. This is the oldest and least expensive pump valve also and is still widely used as a suction check valve in shallow well pumps. Its major disadvantage is the need for relatively frequent replacement of the leather flappers. Reinforced neoprene is a promising flapper material in this regard.

Poppet valve: a rising and falling horizontal metal disc covers the valve opening and is guided by a vertical stem or spindle concentric with its center. A section through the disc and stem - usually formed in one piece - forms a "T".



Types of Valves

3) Cylinders

The cylinder is a pipe or tube which houses the plunger assembly and the suction (foot) check valve. The water seal formed by the moving contact between the cylinder wells and the plunger cup seal(s) creates the partial vacuum which makes suction lift possible.

The cylinder length is a function of the stroke length which is typically 12,5 to 25 cm for hand pumps, up to several times longer for windmill pumps. Additional length is required for caps and for the plunger and suction valve assemblies, for tolerances in measurement of drop pipe and pump rod lengths, and to prevent operator abuses such as driving the plunger into the suction valve with excessive handle lift. Cylinders which wear rapidly are sometimes constructed double length allowing the plunger depth to be reset and pumping to be continued without pulling and replacing the cylinder. Standard cylinder lengths available range from about 25 to 11o cm.

Cylinder diameter generally decreases with increased pumping head. Typical standard diameters range from about 7 to 1o cm for shallow wells down to 5 cm or less for deeper wells. Standard cylinders are available in diameters as small as 4 cm which will fit into a 5 cm diameter well.

Cylinders may be located in one of three places depending on suction lift and type of pump or well construction:

(1) Pump stand location: for shallow wells with suction lifts the cylinder may be an integral part of or a liner inserted in the pump stand. Pumps with cylinders located in the pump stand frequently have difficulty holding their priming water. Also, repeated wetting and drying of pump leathers shortens their useful life and increases maintenance requirements. However this configuration of pump stand and cylinder is the lowest in initial cost and its components are the most readily accessible for maintenance.

(2) Drop pipe location: for deep wells the cylinder must be located in the well, preferably below the water table. In conventional practice the cylinder is suspended from the drop pipe. Cylinders for use with drop pipes are commercially available in two basic types: closed-type and open-type cylinder.

(3) Well casing location: in wells cased with smooth pipe of appropriate diameter, the pipe casing itself can serve as the well cylinder. In some wells a short length of brass or brass-lined steel pipe may be inserted in the well casing to serve as the cylinder. In this type of installation the well casing also serves as the drop pipe. This technique was common during the heyday of wooden pumps and holds promise today with development of new well casing pipe materials, especially pipe of polyvinyl chloride (PVC).
The drop pipe can similarly be simultaneously used as the cylinder. Drop pipes are usually mandatory for hand pumps atop dug wells due to their large diameter.

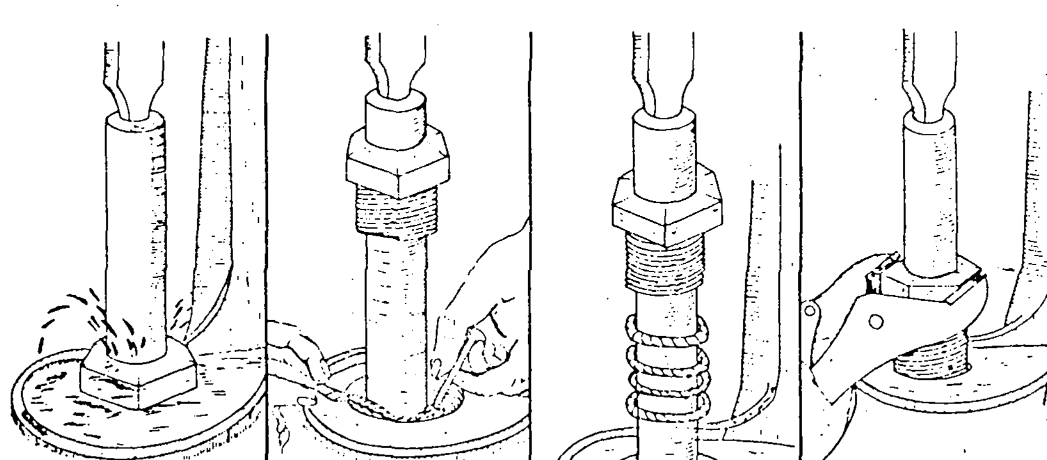
COMMON HAND PUMP TROUBLES AND REMEDIES

TROUBLE	LIKELY CAUSE	REMEDY
1. Pump handle works easily but no water delivered.	A. No Water at the source. Well dry.	Rehabilitate well, or develop a new source or sources of water.
	or	
	B. Level of water has dropped below suction distance of pump.	Can be checked with vacuum gauge or with weighted string. Reduce pumping rate or lower pump cylinder.
	or	
	C. Pump has lost its priming.	Prime the pump. If the pump repeatedly loses its priming it may be periodically pumping the well dry, the suction line may be leaking, or the suction valve or discharge check valve may be leaking. Repair line or valve. Also check 1-A and 1-B.
	or	
	D. The cylinder cup seals ("leathers") may be worn out	Renew the cylinder cup seals ("leathers").
	or	
	E. The valves or valve seats may be worn or corroded.	Renew valves and repair or renew seats.
	or	
	F. With a deep-well plunger pump the plunger rod may be broken.	This trouble would be indicated by the pump running freer and and probably quieter. Turn the pump over by hand and note if there is resistance on the upstroke. Broken rods must be renewed and this usually means pulling the drop pipe and cylinder out of the well.
	or	
	G. Shutoff valve may be closed (force pump).	Open valve
	or	
	H. Hole in suction pipe.	Renew suction pipe. Cylinder may be lowered below water level in well.
	or	
	I. The suction pipe may be plugged with scale or iron bacteria growth or sediment.	Can be checked with vacuum gauge. Remove suction pipe and clean or renew.
	or	
	J. The pump cylinder may be cracked.	Renew the cylinder.
	or	
	K. Leak at base of cylinder.	Renew cylinder gasket.
	or	
	L. One or more check valves held open by trash or scale.	Remove valves and inspect for trouble. With deep-well plunger pumps this may mean pulling the pump cylinder or plunger and valves out of the well.

TROUBLE	LIKELY CAUSE	REMEDY
2. Pump runs but delivers only a small amount of water.	A. Plunger leathers badly worn (plunger and piston pumps).	Renew leathers.
	or	
	B. Well not yielding enough water.	Decrease demands or establish new sources of water.
	or	
	C. Cracked cylinder (plunger or piston pump).	Renew cylinder.
	or	
	D. Check valve(s) leaking.	Repair valve(s).
	or	
	E. Screen or suction valve may be obstructed.	Remove and clean.
	or	
	F. Suction pipes are too small.	Can be checked with vacuum gauge. Install pipe with larger diameter, or for deep well pump, lower pump cylinder below water level in well.
	or	
	G. Suction valve(s) may be out of order.	Repair valve(s).
	or	
	H. Cracked drop pipe or coupling.	Renew drop pipe or coupling.
3. Pump needs too many strokes to start.	A. Pump has lost its priming.	Prime the pump. If the pump repeatedly loses its priming, it may be periodically pumping the well dry, or the suction line or the suction valve may be leaking. Repair or renew line or valve.
	or	
	B. The cylinder cup seals ("leathers") may be worn out.	Renew the cylinder cup seals.
4. Handle springs up after down stroke.	A. Suction pipe plugged up below pump cylinder.	Remove pump and clean out suction pipe. If well has filled with dirt up to suction pipe, the well should be cleaned out or the pipe cut off.
	or	
	B. Plunger check valve fails to open or to close.	Repair check valve.
	or	

TROUBLE	LIKELY CAUSE	REMEDY
4. Handle springs up after down stroke (continued)	C. Suction pipe too small.	Replace with larger suction pipe.
	or	
	D. Water too far below pump (suction pipe too long).	Place cylinder nearer water.
5. Leaks at stuffing box	A. Packing worn out or loose.	Renew or tighten packing. Leave packing nut loose enough to allow a slow drip of water. The water serves as a lubricant.
	or	
	B. Plunger rod badly scored.	Renew plunger rod.
6. Pump is noisy	A. Bearings or other working parts of the pump are loose.	Tighten or renew parts.
	or	
	B. Pump is loose on mountings.	Righten mountings.
	or	
	C. With deep-well plunger pumps having a steel plunger rod the rod may be slapping against the drop line.	Use a wooden rod or install guides for rod or straighten drop pipe if crooked.

HOW TO REPLACE WORN - OUT PACKING



THE PACKING IS WORN OUT THEREFORE WATER IS LEAKING OUT

TAKE OUT THE WORN-OUT PACKING

REPLACE WITH THE NEW PACKING

KEEP STUFFING NUT JUST TIGHT ENOUGH TO PREVENT WATER FROM LEAKING OUT AND PUT GREASE ON THE STUFFING NUT

SCHEDULE FOR MAINTENANCE OF SIMPLE HAND PUMPS

daily

1. lock and unlock the pump at hours agreed by the village.
2. clean the well-head.

weekly

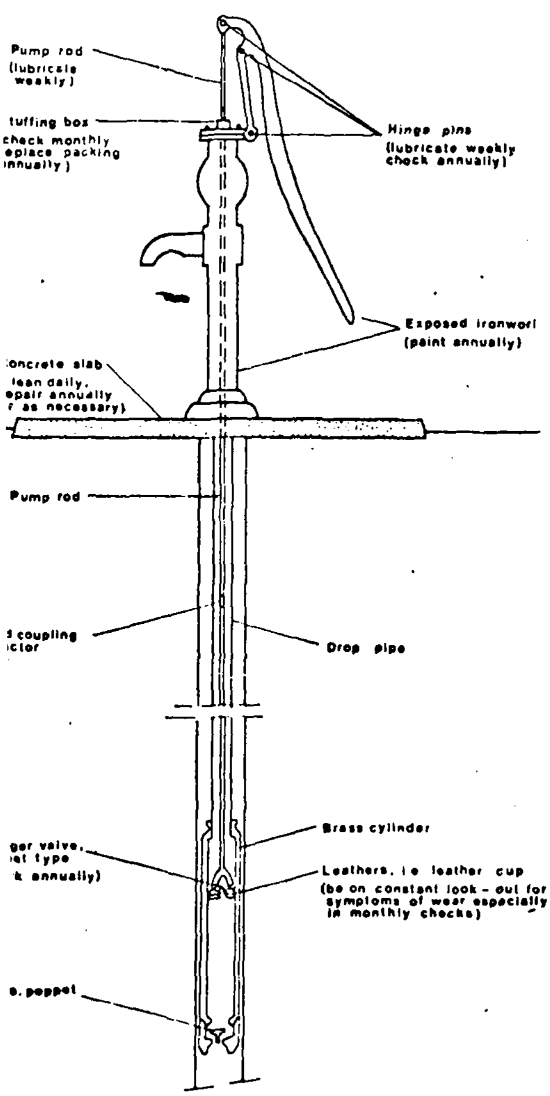
1. thorough clean-up of pump, well-head and surroundings.
2. oil or grease all hinge pins, bearings, and sliding parts, after checking that no rust has developed on them.
3. record any comments from users about irregularities in working (tightness of parts, leaks from stuffing box, fall-off in water raised). Correct these when possible.

monthly

1. if necessary, adjust the stuffing box or gland (this does not apply to the Craelius pump). Usually this is done by tightening the packing nut. This should not be too tight - there should be a slight leak when the adjustment is correct.
2. check that all nuts and boits are tight, and check that there is no evidence of loose connections on the pump rods.
3. check for symptoms of wear at the leathers, noting any comments from users about any falling off in the water raised. If the pump fails to raise water when worked slowly (e.g., at 10 strokes per minute), replace the leathers.
4. carry out all weekly maintenance tasks.

annually

1. paint all exposed parts to prevent development of rust.
2. repair any cracked concrete in the well-head and surrounds.
3. check wear at handle bearings and replace parts as necessary. On the Craelius pump, worn bushes can be replaced by short sections of pipe of suitable diameter.
4. check plunger valve and foot valve; replace if found leaking.
5. check the pump rod and replace any defective lengths or connectors.
6. replace packing at the stuffing box or gland (does not apply to the Craelius pump).
7. carry out all monthly maintenance tasks.



from: "Hand Pumps"
published by United Nations Environment Programme (UNEP) and World Health Organisation (WHO)
Technical Paper No. 1o
July 1977, Netherlands
see also: "Hand Pump Maintenance"
An Oxfam document compiled by Arnold Pacey, Intermediate Technology Publcations, Ltd., London 1977

	Institution/Address	Device/Specification	Information Material/ Comments
1	VITA Volunteers in Technical Assistance 3706 Rhode Island Avenue Mt. Rainier Maryland, USA, 20822	Piston pump - shallow well pump - deep well pump	Details and construction description enclosed (page 36)
2	TOOL Mauritskade 61 a Amsterdam, Netherlands	Salawe or Shinyanga pump	Details and construction description enclosed (page 43)
3	Robert Tayabji UNICEF 9, Jorbagh New Delhi, India	Sholapur or Jalna pump - deep well hand pump	Details and short description enclosed (page 51)
4	Ets. Pierre Mengin B.P. 163 45203 Montargis, France	Hydro-pump Vergnet (Obervolta)	Details and description enclosed (page 54)
5	Chatiketu WHO, P.O.Box 765 Kano, Kano State, Nigeria	Wood and bamboo reciprocating pump	Only short information
6	Asian Institute of Technology P.O.Box 2754 Bangkok, Thailand	Inertia pump	Details and construction description enclosed (page 57)
7	Int. Rice Res. Institute P.O.Box 933 Manila, Philippines Asian Institute of Techn. P.O.Box 2754 Bangkok , Thailand	Two designs of diaphragm pumps	Details and construction description enclosed (page 65)
8	H. Dickinson & T.L. Winnington School of Engineering Sciences, University of Edinburgh,U.K.	Double acting lift pump	Only short information available
9	Petro Pump Carl Westmans Väg 5 S-13300 Saltsjöbaden Sweden	Petropump - diaphragm pump	Short description enclosed (page 77)

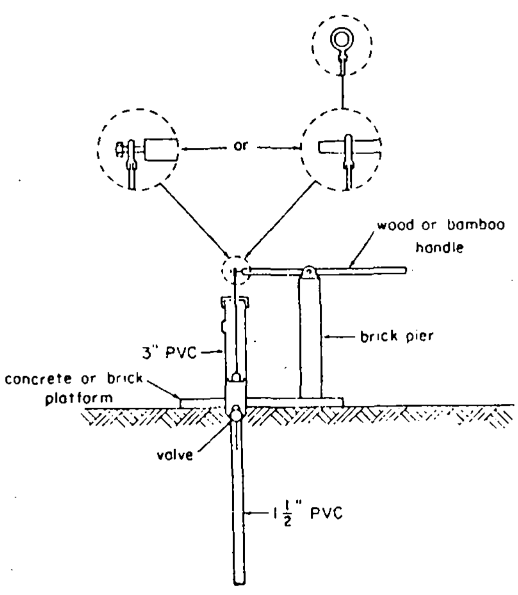
Water Supply and Sanitation		Pumps

	Institution/Address	Device/Specification	Information Material/ Comments
0	Robert G. Young VITA 3706 Rhode Island Av. Mt. Rainier Maryland, USA, 20822	Chain pump - shallow well pump (for irrigation)	Details and construction description enclosed (page 79)
1	S.B. Watt ITDG 9 King Street London WC 2 E 8 HN	Hydraulic ram	Details and construction description enclosed (page 83)
2	IPAT, TU Berlin Lentzeallee 86 D-1000 Berlin 33 W-Germany	Cretan sail-windmill with Archimedean screw	Information on Cretan Sail Windwheels enclosed (page 95)

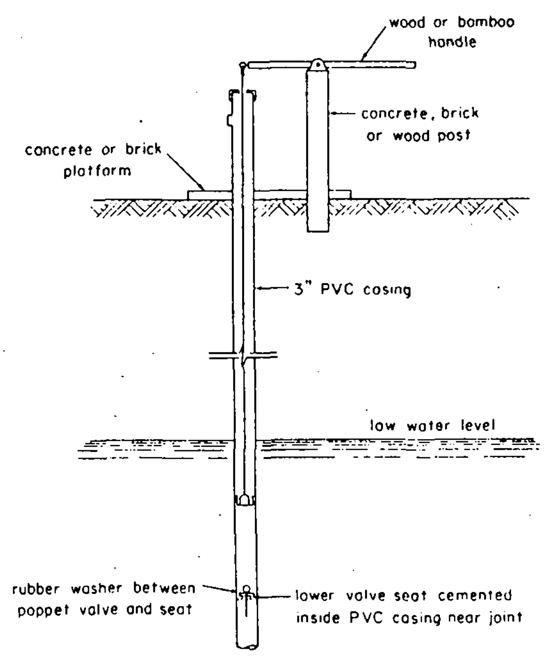
1) Piston Pump VITA, USA

This classical type of pump is used in most countries for family use and irrigation.

The piston pump may either be operated as a suction or shallow well pump or, if the water level is more than 6 m below the surface, the piston can be installed below the lowest water level and thus become a deep well pump.



Shallow Well Pump



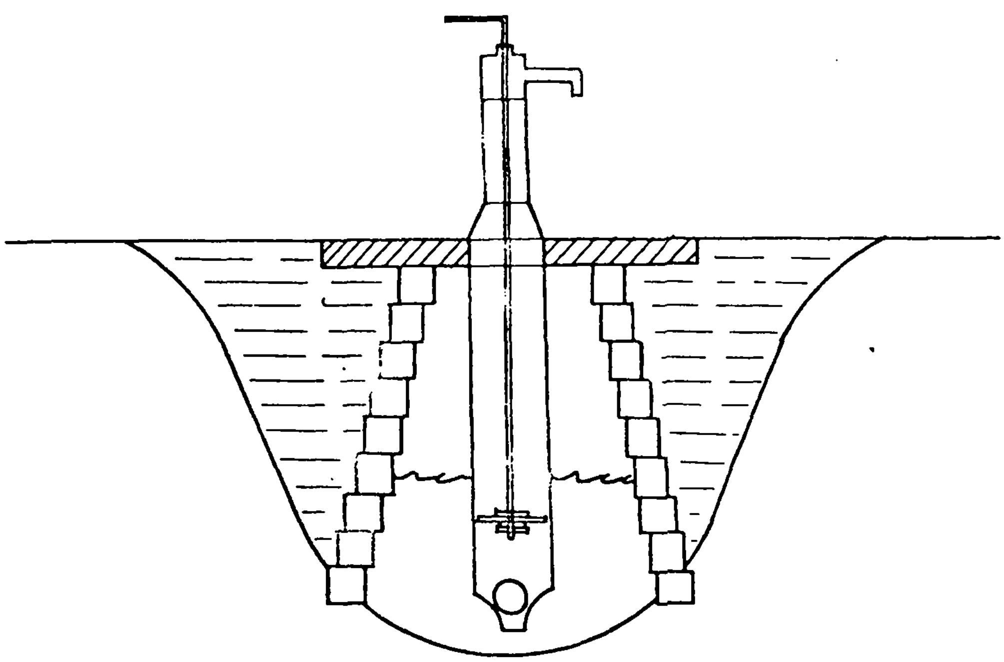
Deep Well Pump

It is possible to drive the piston pump by wind energy (pages 42-45)

For details see enclosures (page 36)

2) Shinyanga Pump TOOL, Netherlands
(also known as Salawe Pump)

The Shinyanga District Shallow Wells Project has created its own manufacturing facility. The pump has a wooden pumping head and uses a PVC plastic cylinder (Cast iron could not be used because of the pH = 3 of the groundwater in Shinyanga). Neoprene ball valves are used in both the plunger and suction check valves.
A standard industrial rubber piston with a steel core (cost 4 US $) imported from western Europe is used in lieu of the usual cup seals.



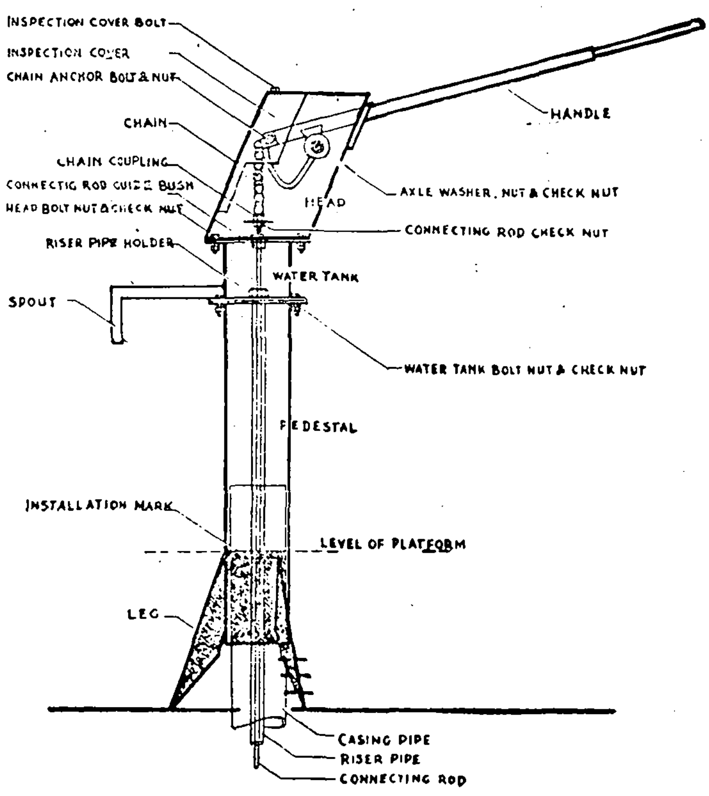
For details see enclosures (page 43)

APPROPRIATE TECHNOLOGIES Collection of available solutions		GATE
Water Supply and Sanitation		Pumps

3) Sholapur or Jalna Pump — R. Tayabji, India

Many breakdowns of deep well hand pumps occur in the handle assembly. The Sholapur-pump developed in India by a group of voluntary agencies can be expected to work for a year between overhands for maintenance. Locally manufactured it is being installed in Indian villages complete with 3o meters of drop pipe and pump rod for about US $ 235 per unit.

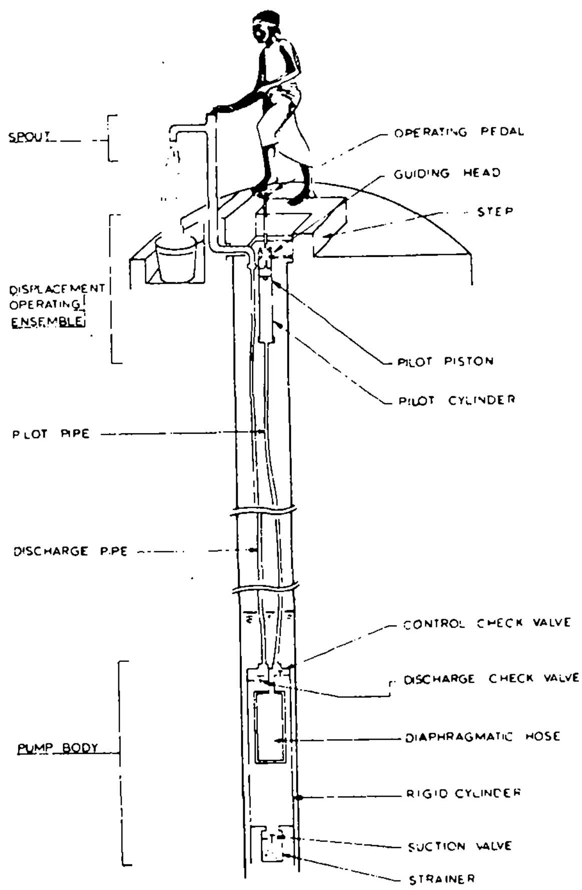
This pump has a single pivot action connecting the handle to the pump rod through a short length of motorcycle chain. All moving parts are enclosed in a steel housing (for details see enclosures page 51)



) Hydro-Pompe Vergnet   Pierre Mengin, France

This pump designed in Upper Volta uses a hydraulic pilot system operated by a foot pedal. The flexible hose inside the rigid cylinder is alternatively streched and contracted, thereby pumping water from the rigid cylinder to the surface. The pump can be fitted into a bore hole of 1o cm diameter.

bore hole depth (m)	2o	4o	6o
output (m^3/h)	1,5	o,7	o,5



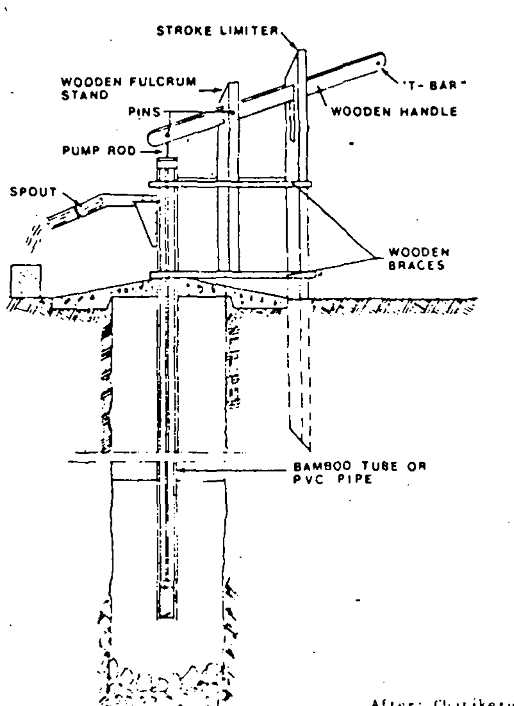
HYDRO - POMPE VERGNET
SCHEMATIC ARRANGEMENT

For details see enclosures (page 54)

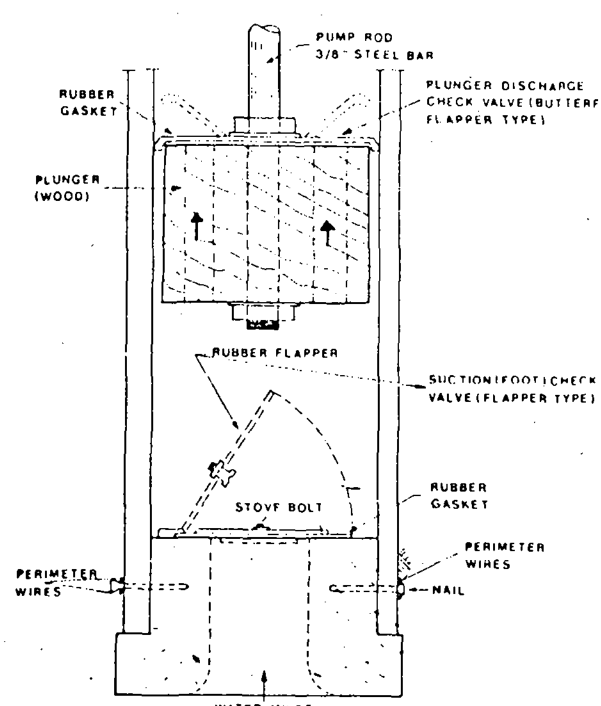
5) Wood and Bamboo Reciprocating Pump Nigeria

An example of a pump made by village artisans is the "DIY"-pump used in Nigeria (Chatiketu) in shallow wells.

One long unjointed length of bamboo can be used for the pipe, the handle is made from wood (see figure). A PVC plastic pipe may be substituted for the bamboo, because of the durability problem of wood (without a good maintenance lasting only a short time).



BAMBOO OR PVC PIPE HAND PUMP (GENERAL)



BAMBOO OR PVC PIPE HAND PUMP (VALVES)

) Inertia Pump AIT, Bangkok

Perhaps the simplest pumping device is the inertia pump, whose basic pump design was modified here by a bicycle-type drive and a flywheel to achieve more efficient pump performance.

The inertia pump is a device for lifting water short distances (1,5 m to 2,5 m).

There are four designs developed and tested which are described here.

For details see enclosures (page 57)

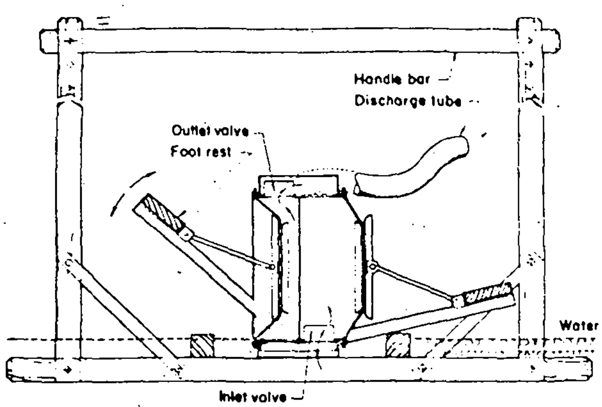
APPROPRIATE TECHNOLOGIES Collection of available solutions		
Water Supply and Sanitation		Pumps

AIT, Bangkok
IRRI, Manila

7) Diaphragm or Bellow Pump

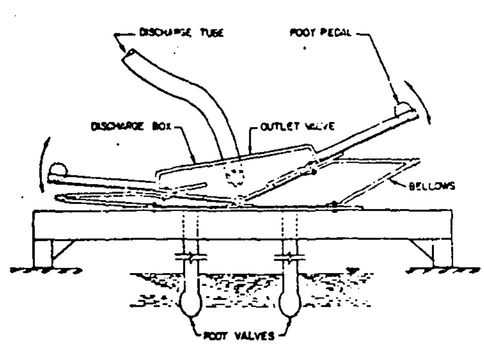
There are two types of double-chambered diaphragm pumps which are foot-operated. They are low cost pumps, simple to be manufactured by small machine shops.

The entire unit has about 2o resp. 28 kg, the pump capacity is about 75 to 120 liter/min to a haight of 2,5 to one meters.



1

Schematic drawing of the Diaphragm pump



MANUALLY OPERATED BELLOW PUMP
FOR RURAL COMMUNITY WATER SUPPLY

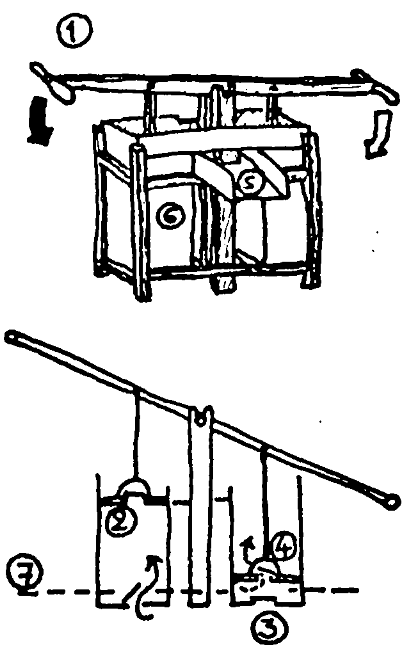
2

For details see enclosures (page 57)

) Double Acting Lift Pump — Dickingson & Winnington, Edinbourgh

This device is an example of rural technology used in China since a long time. The hand-operated pump can lift water to a height of about 12o cm from very shallow ponds or irrigation ditches. Its operation principle is similar to the diaphragm pump.

This lift pump can easily be constructed from wood by a carpenter.

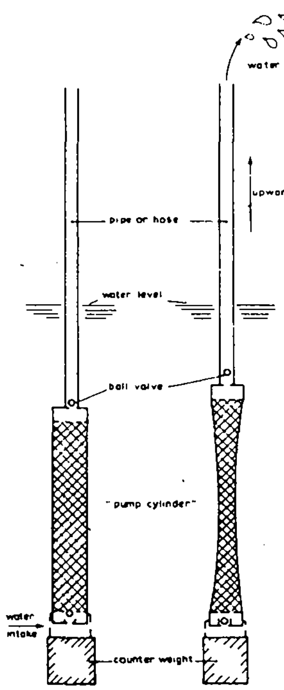


Double Acting Lift Pump

(1)	Handle	(4)	Plunger Valve
(2)	Piston	(5)	Water trough
(3)	Under-water inlet with valve	(6)	Piston box
		(7)	Water level

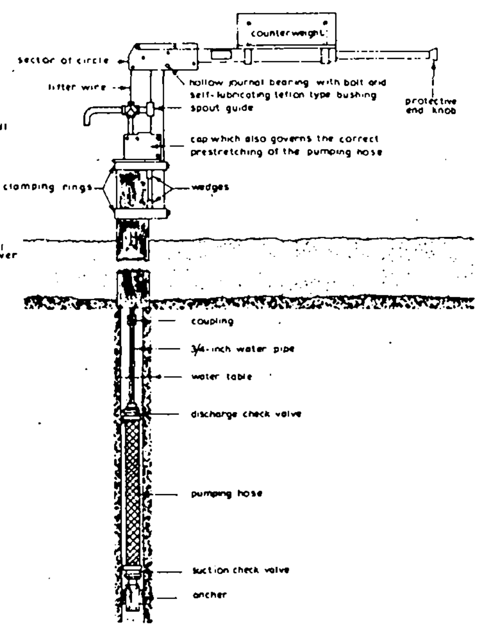
9) <u>Petro Pump</u> Sweden

Another type of a diaphragm pump is the petro pump which can be used in deep wells with the water level deeper than 7 meters. The pumping element consists of an elastic rubber hose reinforced by two layers of spirally wound brasscoated steel.
There are two types commercially available (expensive), but it may be difficult to make this pump-type by yourself.



principle of operation

note alternative method for fixing lower end of pump cylinder to well casing is by use of expanding wedges or jaws

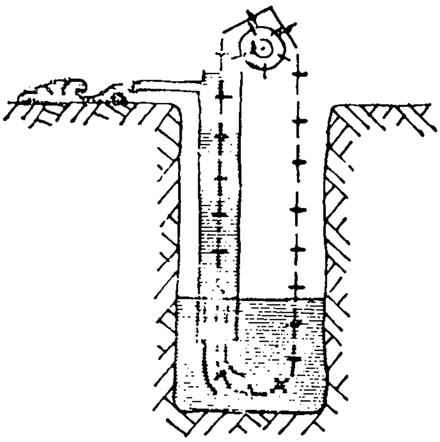


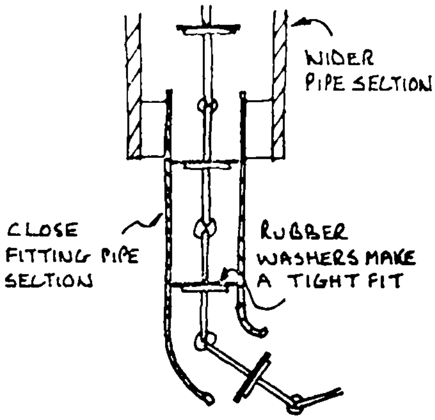
For details see enclosures (page 77)

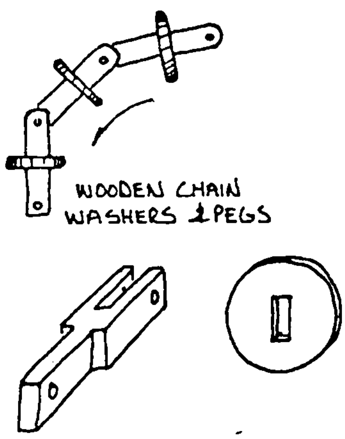
APPROPRIATE TECHNOLOGIES Collection of available solutions		
Water Supply and Sanitation		Pumps

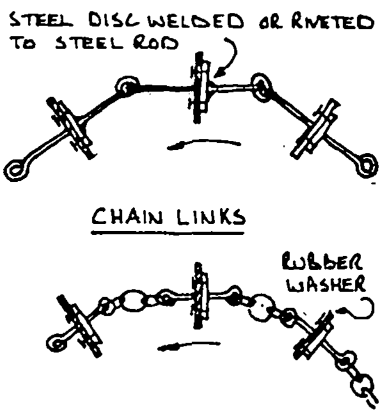
Chain Pump — R. Young, VITA, USA

The chain and washer pump is a pumping device that has been known and used for many centuries both in China and Europe. It can be powered by man or animal and is primarily a shallow well pump to lift water for irrigation. It works best when the lift is less than 6 meters. The water source must have a depth of about 5 chain links.
(For details: construction description and some other examples of chinese chain pumps, see enclosures, page 79)



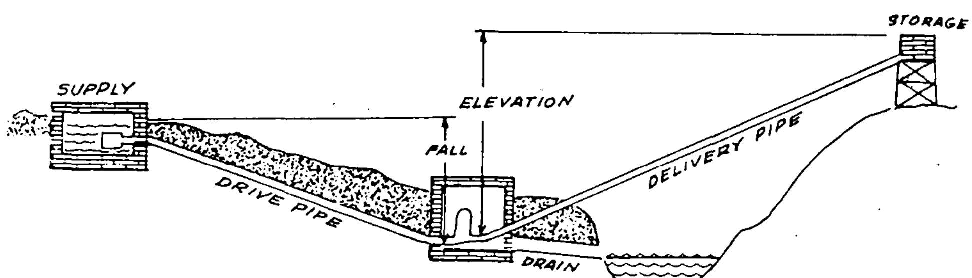




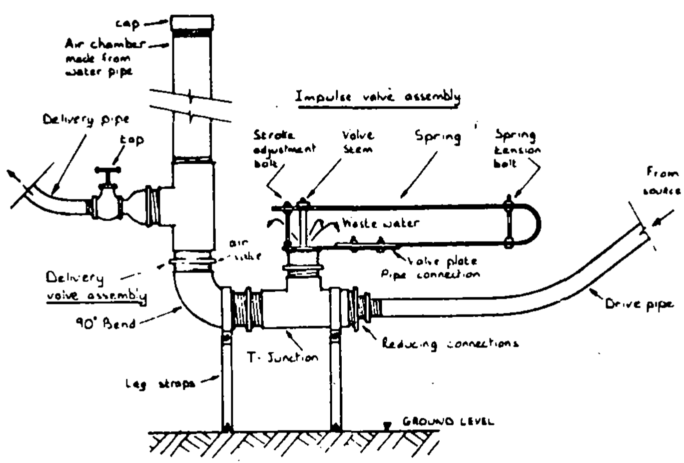


11) <u>Hydraulic Ram</u> ITDG, London

The hydraulic ram uses the power from falling water to force a small portion of the water to a height above the source. The described ram can be constructed from commercial pipe fittings. Detailed information about choosing a suitable site for the ram, installing and adjusting etc., and which sort of maintenance the pump needs are enclosed (page 83).



A. COMMON ARRANGEMENT OF DRIVE PIPE, RAM AND STORAGE



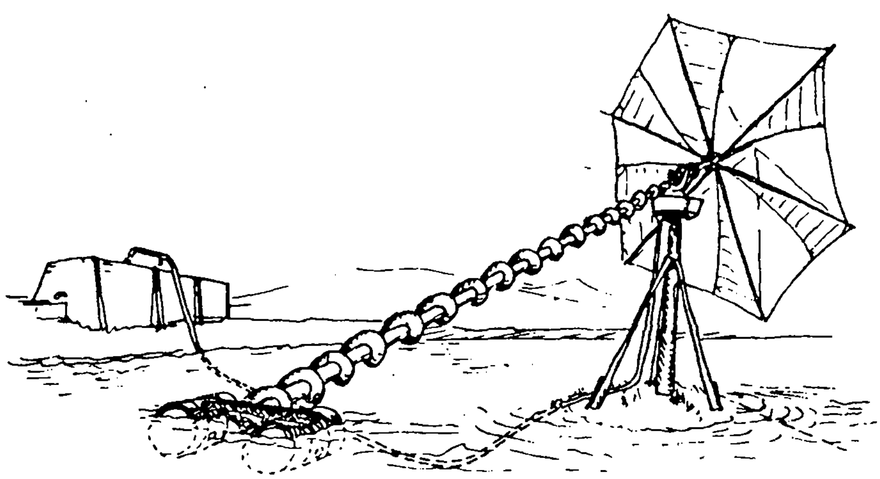
APPROPRIATE TECHNOLOGIES Collection of available solution		gtz
Water Supply and Sanitation		Pumps

2) Cretan Sail - Windmill with Archimedean Screw IPAT, Berlin

A large amount of water can be pumped from a medium depth using the Cretan sail - windmill.

The slow rotation of the windmill is directly transfered to the rotation of the Archemedian screw which consists of a flexible hose wound round the slanting axle of the windmill. The wind pumping system moves according to the direction of the wind around a fixed verical support in the water.

The system is mostly used for irrigation by pumping water from ditches, rivers or lakes and can be manufactured from simple local materials.



For some explanations to the Cretan sail-windmill see page 95.

C. Enclosures to No. 1

PISTON PUMP

1. Introduction

Manually operated pumps of various designs are used in most countries to lift relatively small quantities of water from wells for either family use and/or irrigation. There are two general types of pump, piston and diaphragm. Both types have two check valves, either on each side of the diaphragm (fig. 1) or one below the piston and the other incorporated into the piston (fig. 2). The diaphragm pump will pump the largest quantity of water, but can only operate when the water level in the well is within about 15 feet or less of the pump. It is a suction type pump. The piston pump may either be operated as a suction pump or, if the water level is more than about 20 feet below the surface, the piston can be installed below the lowest water level and thus become a deep well pump.

Shallow well or suction pumps use atmospheric pressure to lift the water by producing a partial vacuum with the diaphragm or piston. The theoretical maximum lift for a suction pump is 34 feet but, due to frictional resistance and inefficiencies in pump design and operation, the practical maximum lift is about 15 feet for the diaphragm and 20 feet for the piston.

Choice of pump is determined by the distance from the surface of the ground to the lowest water level in the well during the dry season. If this distance is less than about 15 feet, either a diaphragm or piston pump can be used. For domestic use, a piston pump is the best and will discharge about 5-15 gallons per minute. The diaphragm pump will pump up to 25 gallons per minute and can be used for irrigation and watering livestock. (The remainder of this paper will discuss exclusively the piston pump. More information about diaphragm pumps may be obtained from The Edson Corporation, 460 Industrial Park Road, New Bedford, MA 02745, USA.)

If the water level drops more than about 20 feet below the ground surface during part of the year, a piston pump is required with the piston located below the lowest water level.

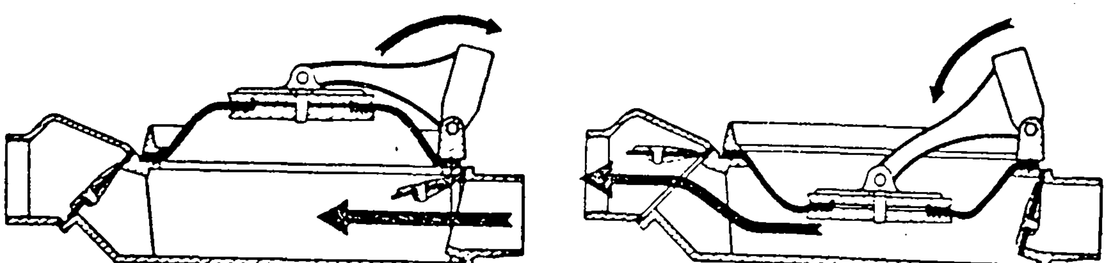


Fig. 1 Diaphragm Pump
(Courtesy Edson Corp.)

Pump discharge depends on the diameter of the piston, the length of the stroke and the number of strokes per minute. If the water level is less than 30 feet below the surface of the ground, the cylinder could be up to 4 or 5 inches in diameter. If the water level is farther from the surface, the longer column of water that must be lifted becomes heavier and a greater effort is required to operate the pump. The greater the distance to the water level, the smaller the diameter of piston should be, so it is not too hard to pump. It is also possible to vary the distance from the well to the post supporting the pump handle to give better leverage. The closer the handle pivot is to the well, the easier it will be to pump, but the length of stroke will be smaller and so will the discharge.

2. The Piston Pump

Piston pumps have a lower valve, a cylinder containing a piston with a valve incorporated in it, a rod to connect the piston to the handle, and a discharge pipe. The traditional pump stand is make of cast iron and supports the handle and contains the discharge spout. Direct suction pumps, or shallow well pumps, have the piston, lower valve and cylinder contained in the pump stand. Deep well pumps have the cylinder with piston and valves below the lowest water level in the well and suspended from the base of the pump stand by the discharge pipe.

The standard pump was designed for the use of a single family and the continual use in most villages causes it to wear rapidly. In attempting to prevent rapid wear, the pump has been modified to strengthen the wear points and this has resulted in a heavier, more elaborate and more expensive pump which is more difficult to maintain and repair. Pump cylinders were usually cast iron, but it is not possible to get the surface smooth enough to prevent rapid wear and replacement of the leathers or buckets. A brass cylinder or thin brass liner has been used and is much smoother than cast iron. An even better material is now available at lower cost - poly-vinyl-chloride (PVC) pipe. PVC pipe is available in most countries and is usually lower in cost than any other pipe material in sizes below 4 inches (100 mm) in diameter. The use of this material in wells makes it possible to develop a pump *that is much simpler, less expensive and easier to maintain and repair.* The pump stand has usually been cast iron and good quality cast iron is difficult to obtain from many local foundries and is now much more expensive than previously. The pump stand ordinarily supports the handle, but a simpler arrangement using local materials is to have the handle supported on a separate post beside the well and pump stand. The post supporting the handle can be made of concrete, bricks or wood, depending on local availability and cost. The handle can be made of wood that can be replaced locally when worn or broken. The attachment of the pump rod to the handle should have some play because the pump rod moves vertically while the end of the handle moves also a small distance horizontally as it describes a small arc. The handle should also have a stop on the support pier so it will not strike the top of the pump stand.

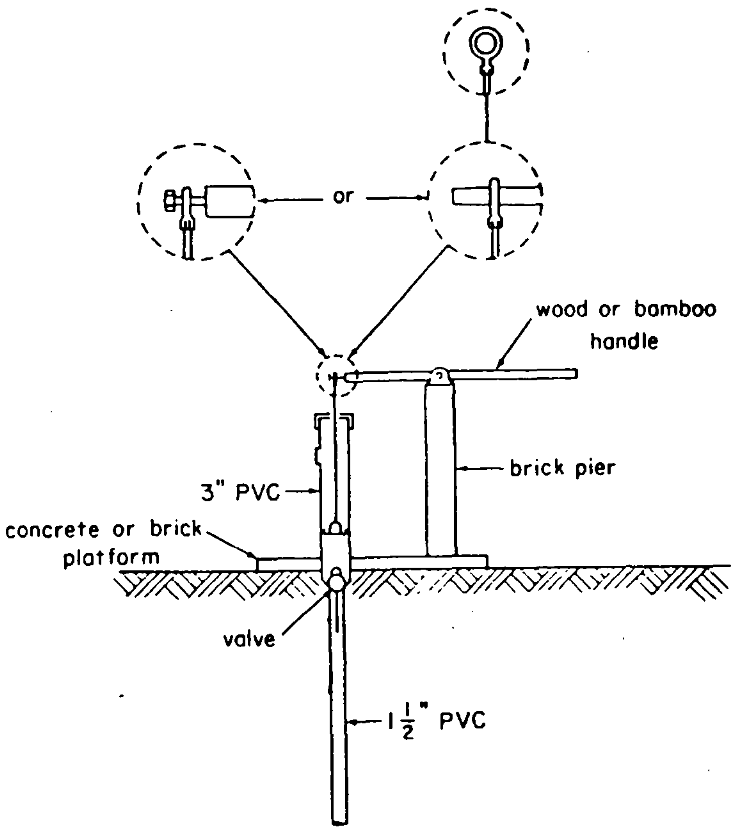


Fig. 2 Shallow Well Pump

on local availability and cost. The handle can be made of wood that can be replaced locally when worn or broken. The attachment of the pump rod to the handle should have some play because the pump rod moves vertically while the end of the handle moves also a small distance horizontally as it describes a small arc. The handle should also have a stop on the support pier so it will not strike the top of the pump stand.

The distance from the post supporting the handle to the pump can vary so as to get the best leverage, depending on the depth to water and on the weight of water, piston and rod to be lifted. The pump stand without the handle only provides a passage for the rod, a channel for the upward flow of the water, and a discharge spout. In shallow wells it also contains the cylinder and supports the suction pipe. Since the pump stand does not bear the load and stress caused by the handle, it need not be so strong and does not have to be of cast iron.

Three possible pump designs are presented. These pumps are designed to be inexpensive, simple, easy to repair, and make maximum use of local materials and skills. It is suggested that a local design should be developed using these ideas and several pumps should then be given a field test to work the "bugs" out of the design. Experimentation may be necessary to obtain a satisfactory attachment of the rod to the handle. Thought and careful field testing should lead to improvements in the design, lower cost, and easier repairs.

3. Shallow Well Pump

Fig. 2. The suction type pump is usually used with shallow wells but may also be used with deep driven, jetted or drilled wells where the pressure in the aquifer is enough to keep the water level at all times within 20-25 feet of the ground surface. The pump stand is a length of 3" PVC pipe which also serves as the pump cylinder. The well casing itself may be the suction pipe in the case of driven or small-diameter jetted or drilled wells. In the case of dug wells, the 1 1/2" suction pipe is suspended from the 3" PVC pump stand which in either case must be set firmly in the platform. The spout need only be a 2" hole in the side of the PVC pump stand with a small lip so the water will pour into a bucket or can.

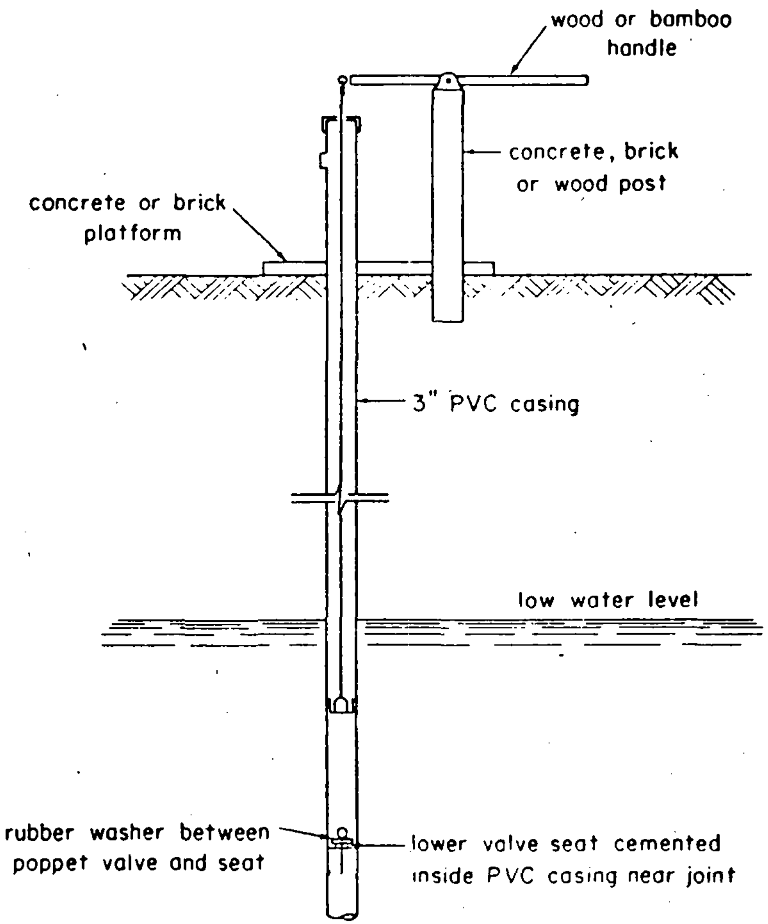


Fig. 3 Deep Well Pump

The top of the pump stand should be several inches above the spout and have a removable cap with a slot to allow for the small back and forth movement of the rod. To remove the piston and replace the leather bucket it is only necessary to disconnect the rod from the handle, remove the cap and pull out the piston. If the lower valve is a poppet type valve it can have a small loop at the top and can be fished out using a wire with a hook at the end.

If the PVC pump stand needs protection, a concrete pipe, brick pier or wooden post can be placed around it, with the spout extending beyond the protection. Such a pump will use a minimum of expensive materials and should be easily repaired.

4. Deep Well Pump in Cased Well

Fig. 3. PVC casing can be used in either jetted or drilled wells. In jetted wells the hole is full of water and the PVC casing can be placed in the hole with little possibility that there will be caving before the casing is in place. The same is true of wells drilled by the rotary process. With percussion drilled wells the best procedure is to drive a metal casing and then insert a PVC casing and screen after the aquifer has been penetrated. The metal casing is then removed to be used again. In wells with PVC casings, the PVC casing can also act as the cylinder.

If the water level is less than 50 feet below the surface, the handle support should be placed to enable the pumper to lift the column of water in a 3" PVC casing without too much exertion. If the water level is deeper than 50 feet, a 2 1/2" or 2" PVC casing may be required.

The lower valve seat can be of PVC and can be cemented inside the casing at a joint below the farthest travel of the piston.

Length of rod is chosen to place the piston below the lowest water level in the well. The piston may be standard, with one or two leathers. The rods can be metal or wood. The wooden rods have several advantages: they do not corrode, they are lighter in weight, and usually can be produced from wood available in the country, creating a small local industry and saving the foreign exchange which would be needed for imported metal rods. Because the wood rods are usually buoyant in water and have a greater diameter than metal rods, thereby displacing more water, a well having a deep water level would be easier to pump with wooden rods than with metal rods. The top of the well and the handle support are the same as in the suction type pump. It is easy to remove the rod and piston for repairs.

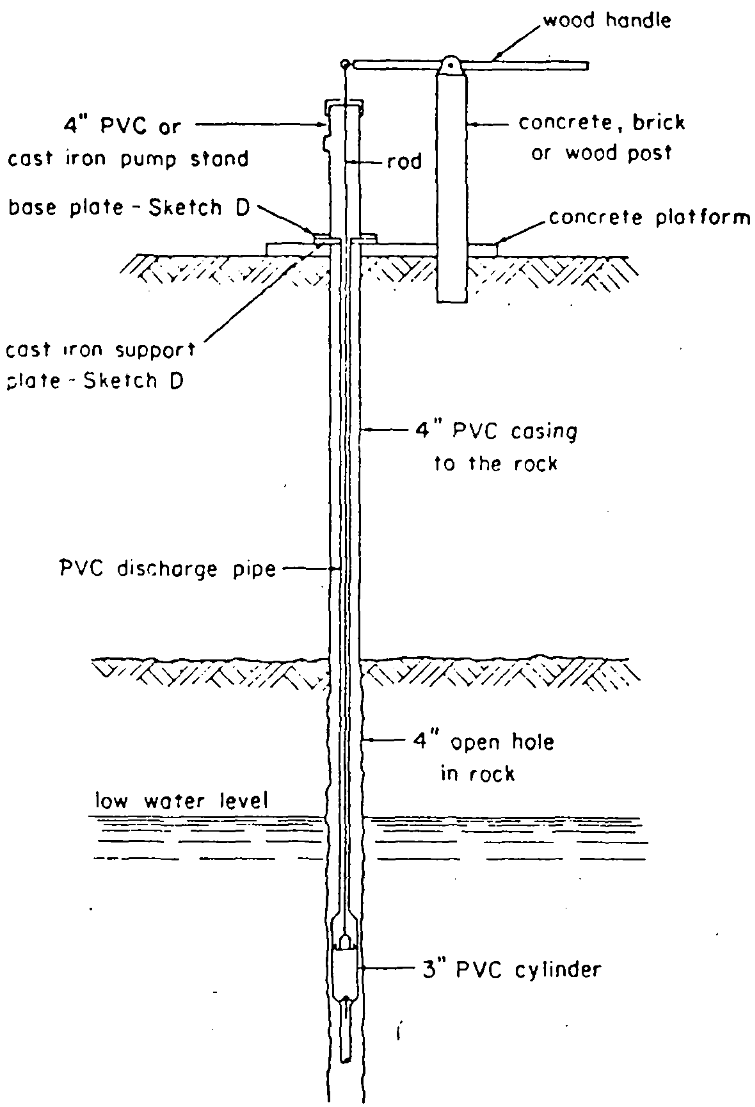


Fig 4 Deep Well Pump - Uncased Hole in Rock

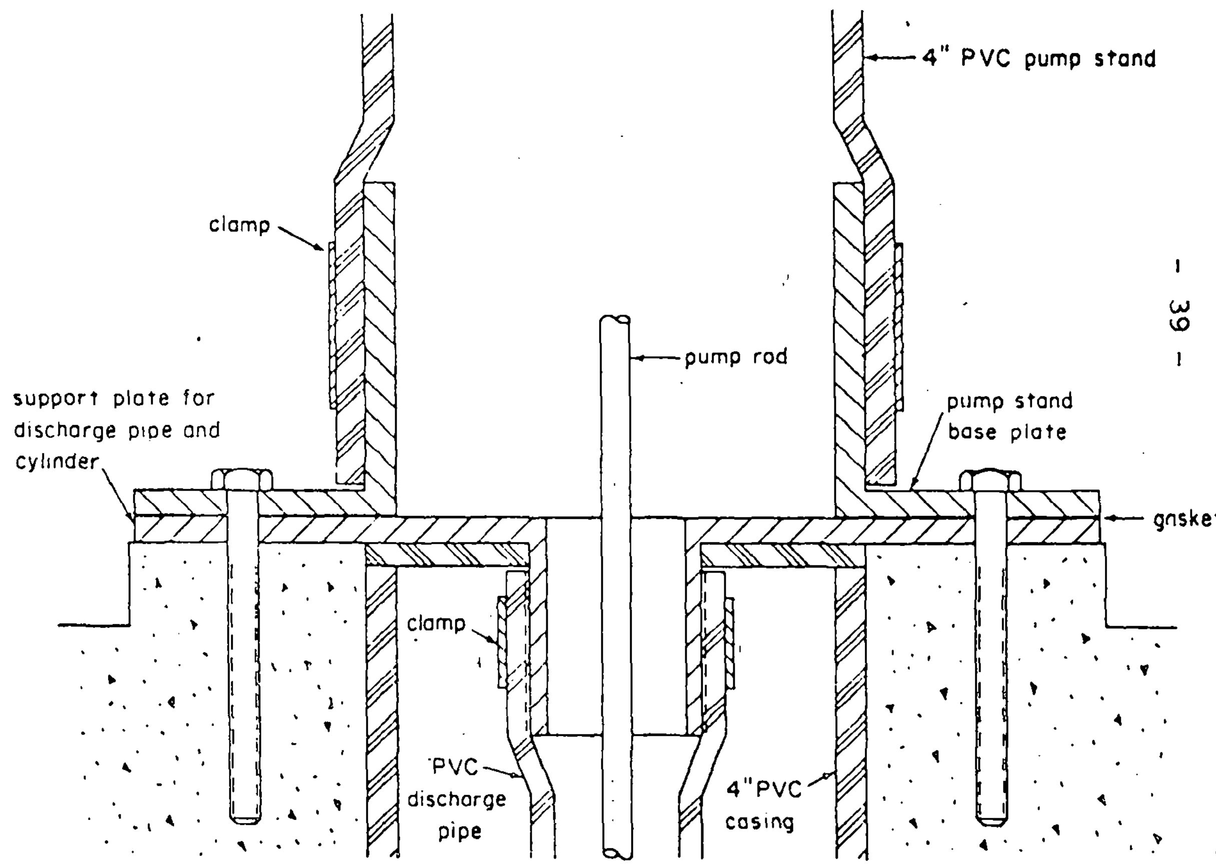


Fig. 5 Pump Base

5. Deep Well Pump in Uncased Well

Figs. 4 and 5. In this case the PVC casing only extends to the rock. The standard cylinder (PVC) is suspended by the discharge pipe from a support plate bolted to the platform. The pump stand can be cast iron, or PVC pipe clamped to a base plate, bolted to the platform.

The discharge pipe, if metal, would be threaded to the support plate. If PVC is used for the discharge pipe, which is preferable, the end can be heated and expanded slightly to slip over a short pipe extension of the support plate. The PVC pipe is clamped to the short pipe extension.

The cylinder can be of 3" PVC and will contain the lower valve and piston. The rod passes down through the discharge pipe. If the rod is of wood, care should be taken that the discharge pipe is large enough in inside diameter not to restrict the upward flow of water between the rod and the pipe.

The discharge pipe should have clamped or threaded joints every 20 feet so the pipe can be disconnected when it is necessary to remove the cylinder for repairs. A joint in the rod should be located at each joint in the discharge pipe. If the cylinder is of metal, it should have an inside sleeve of thin-walled PVC pipe to provide a smooth surface that will greatly prolong the life of the leather bucket.

6. Pump Components

The pump should be simple, dependable and as low in cost as possible. The object should be to develop a pump that can be produced in quantity by local technology to meet the needs of most of the rural population in the area. A pump similar to that shown in fig. 2 has been developed in Thailand at a cost of about US$20 which delivers about 15 US gallons per minute. It is being used for irrigation as well as for domestic purposes.

Pump components can usually be manufactured or fabricated in most countries. The parts are relatively simple and machine shops or small metal working factories or foundries can supply parts for a given design. Most countries now have plants to extrude PVC pipe, even where the raw material is imported. The seal between the piston and the cylinder wall is usually provided by a leather disc with a turned up edge called a "bucket". In some countries these are made of molded rubber. Quality control is important if good leather or rubber buckets are to be obtained. These

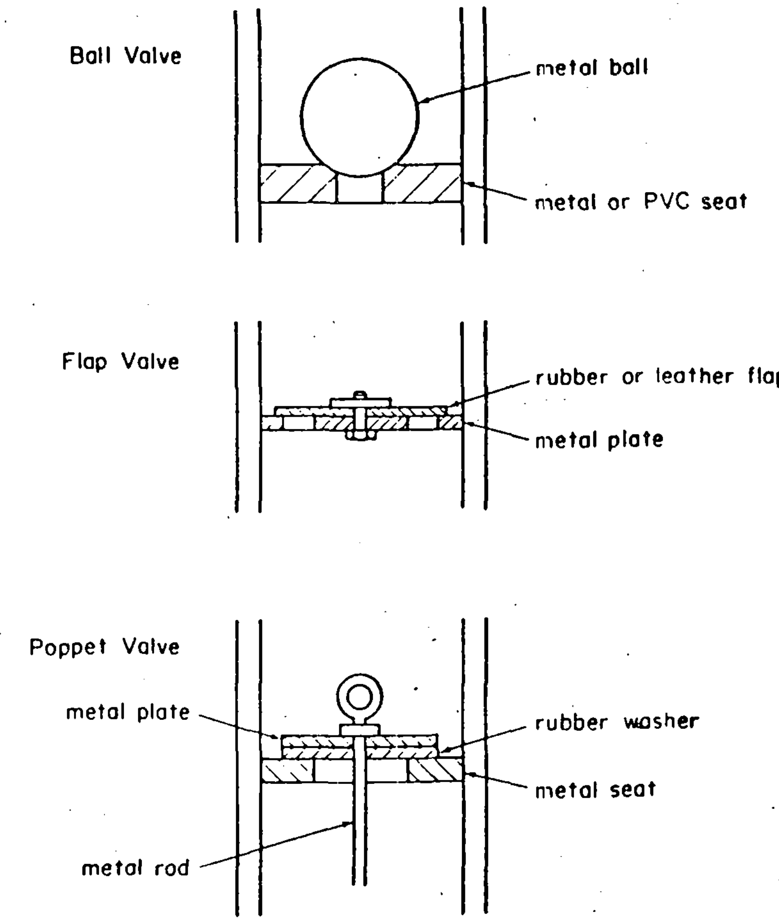


Fig 6 Types of Valves

are not expensive and if good ones cannot be obtained locally, they can be imported from many countries in the developing world, for example India, Pakistan, Korea, Thailand, and probably many others.

The lower valve can be a ball valve in a seat, a leather or rubber flap valve, or a poppet valve. (Fig. 6) If the lower valve seat is a PVC ring, it can be cemented inside the casing at a joint as the casing is assembled.

Another method has been used by Rev. George Cotter of the Buhangija Mission in Shinyanga, Tanzania. This is "to crimp or squeeze in place the plastic ring (PVC) which acts as a seat for the steel ball making the foot valve. Once the length of PVC pipe has been determined, the lower end is immersed in hot oil until soft, the ring is inserted an inch or two up the pipe, and common auto radiator hose clamps are used to squeeze the pipe above and below the ring position. The hose clamps can be used again and again as the PVC pipe will not return to its original shape once it has cooled. The easiest way to handle the hot oil is simply to have a paint can (or other metal container) of used engine oil. This can be reheated indefinitely." * He also suggests that the end of a section of PVC pipe can be softened and flared to fit over a metal pipe or another section of PVC pipe by this same method.

A simplified piston with a molded rubber bucket is used in Korea (fig. 7). This should be much less expensive to fabricate than the standard type piston with poppet valve.

7. Installation

Hand operated piston type pumps are the most common mechanical device for lifting water from both shallow and deep wells. Unfortunately, the standard pump designed for single family use does not stand up too well under 12-hour-a-day use in a village, and in many programs half or more of the pumps have failed before they have been in service 6 months.

Most villages have not established a responsible local official or committee to maintain the pump, and the lack of funds, tools and spare parts in the village complicate the problem. Usually a government agency has installed the well and pump and the villagers take the attitude, "It is a government well, let the government maintain it." In most countries, maintenance by the government is very expensive because it

* "Shinyanga Lift Pump", VITA Pub. No. 4311.6, Out of Print.

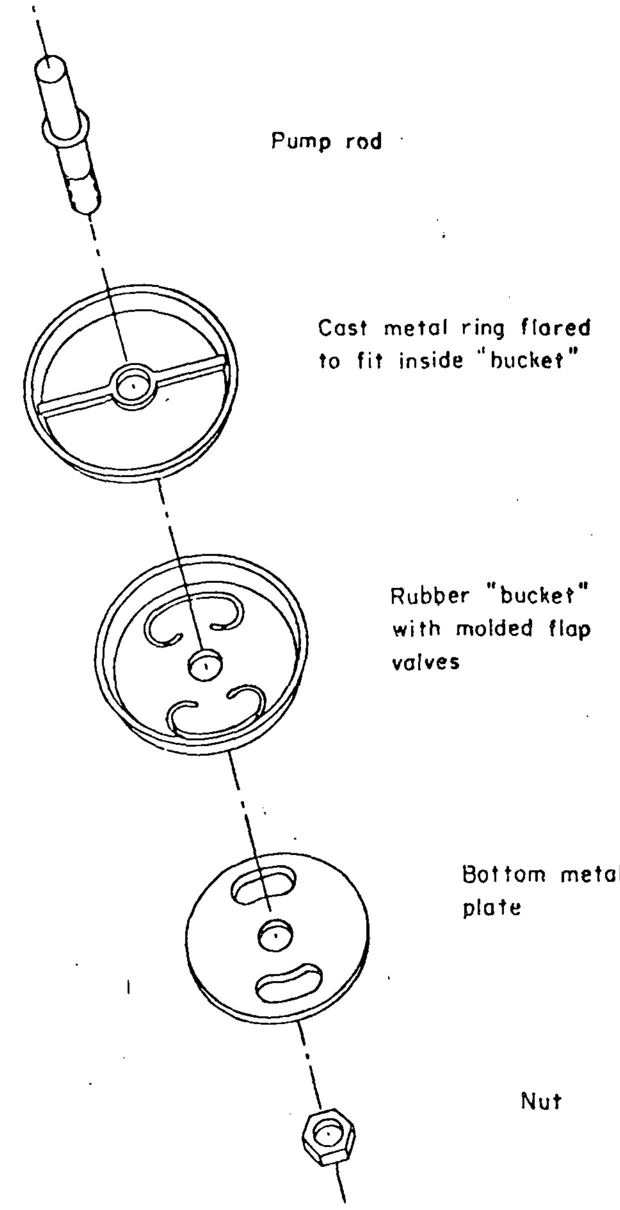


Fig. 7 Simplified piston with molded rubber "bucket"

means motor vehicles, drivers, mechanics, tools, fuel, and organization with administrative people, clerks, supervisors, storage of spare parts, and a method of notification for emergency repairs. Government maintenance is not required if a program is properly set up, pumps are designed for easy maintenance, and spare parts are readily available to the village. In most countries, lack of technical skills in the village to repair the pump is no longer a problem, because in most villages there are bicycles, motorcycles, and small gasoline or diesel engines to pump irrigation water or grind grain, and these devices are much more complicated than a hand pump. If the village can maintain these more sophisticated devices, it can maintain a hand pump.

A well and pump should not be installed unless the village, through its leaders, agrees that they want the well, they are willing to contribute labor, local materials and, if possible, some cash to the installation; and also will agree to pay for spare parts and repairs to keep the pump operating. Village ownership and responsibility for maintenance should be incorporated in a formal written agreement between the agency installing the well and the village leaders. The well should be turned over to the village in a public ceremony at which time the local official or water committee that will be responsible for the well should be presented with a copy of all the data on the well and pump, some spare parts, any special tools required, a repair manual for the pump, the name and address of the nearest place where additional spare parts can be obtained, and a name, address and phone number to notify in case a problem develops that is beyond the village capability.

VITA's Services

To provide more information or assistance on questions of small scale technology, VITA maintains a Technical Inquiry Service. Simply direct the inquiry to VITA, 3706 Rhode Island Avenue, Mt. Rainier, MD 20822, USA, giving all pertinent background information and data. VITA is an association of over 5000 volunteer engineers, scientists, farmers and technicians, who respond by mail and free of charge to inquiries from less developed areas.

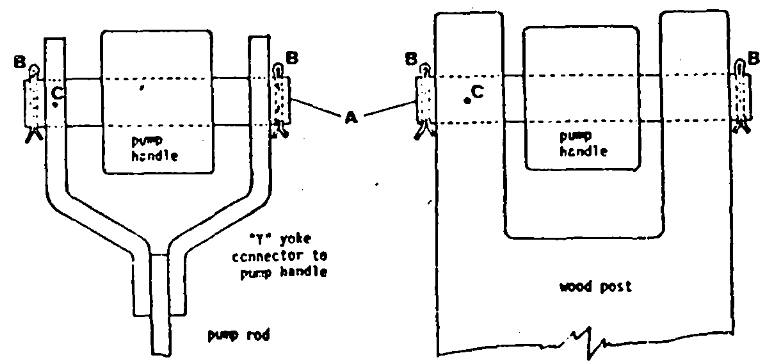
FROM: "Hand Pumps for Village Wells"
by C.D. Spangler
VITA, USA, 1975

An Improved Pump Handle Design

- C. D. Spangler, June 1976

I. HANDLE/PUMP ROD CONNECTION

II. HANDLE/SUPPORT POST CONNECTION



A Smooth metal rod that works as bearing. 5/8" in diameter.

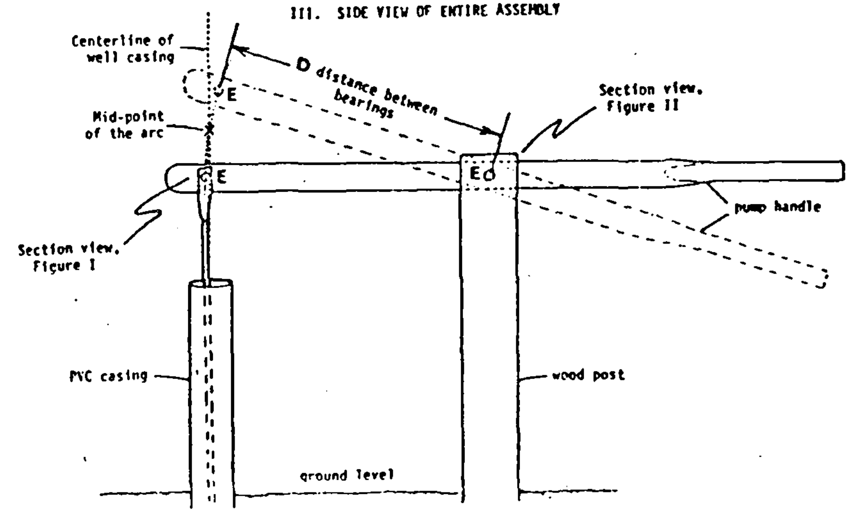
B Cotter pins to hold bearing in place.

C Pin through bearing and support so bearing will not rotate. The slight angular rotation will take place in the wooden handle, which is easy to replace when it wears.

D The distance along the handle between the bearing holes should be set so the mid-point of the arc through which the end of the handle travels is over the center of the well casing.

E The bearing holes in the handle should give a smooth, tight fit on the bearings. The holes should be soaked with used motor oil before installation, and after installation should be lubricated often with oil.

III. SIDE VIEW OF ENTIRE ASSEMBLY



The Salawepump

General

The Salawe pump is a simple pump with you can build yourself. Originally the pump was designed by Rev. G. Cotter M.M. for the inhabitants of Salawe Village in Tanzania.

Where/when to use? With this pump water can be pumped from a maximum depth of 6 meter (about 20 feet) for example in an existing pit or pool.

Essentials: You build two parts:

1. Pit of self-made bricks (maybe you got one already)
2. Pump, made from a steel pipe to be fastened in a cover plate.

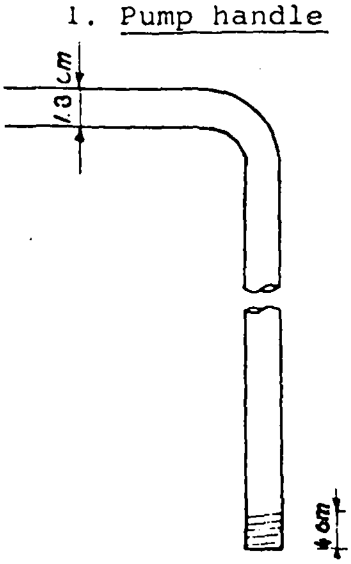
Advantages:

1. Clear water; There is protection against debris from leaves, children, animals etc.
2. Cheap; cost of materials: steel pipe plus two bags of cement, about US $ 40,-
3. Construction time two days: one day you make the bricks, the next day you build the pit and mount the pump.

Parts

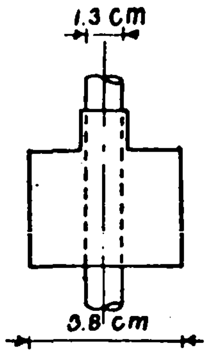
If the material is not available in the proper sizes, other sizes can be used; however, make sure that all parts fit together.

1. Pump handle



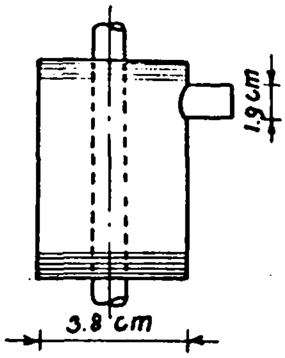
Made from a steel rod (as used in reinforced concrete), ½" or 1.3 cm in diameter. The bottom portion of the rod should be threaded over a length of 1½" (4 cm), so that parts nr. 12 through 16 which form the plunger and pressure valve can be screwed into the rod. The length of the rod is dependent on the depth of the pit and can easily be calculated. Remember that the rod better be too long than too short!

2. Stopping plug



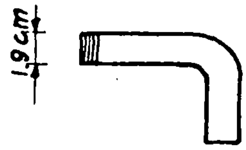
Diameter 1½" (3.8 cm). The pump handle fits through a ½" (1.3 cm) hole in the top. The stopping plug is screwed onto the:

3. T-piece



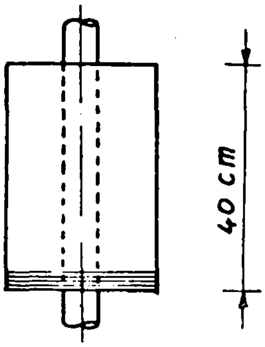
Dimensions 1½ x ¾" (3.8 cm x 1.9 cm). Attached to the side of the T-piece is the:

4. Tap



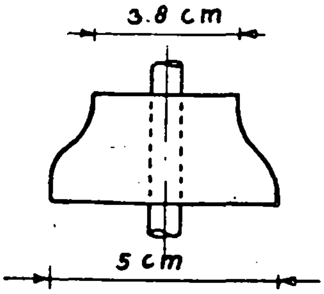
Size: ¾" (1.9 cm). Prevents the wasting of water.

5. Extension pipe



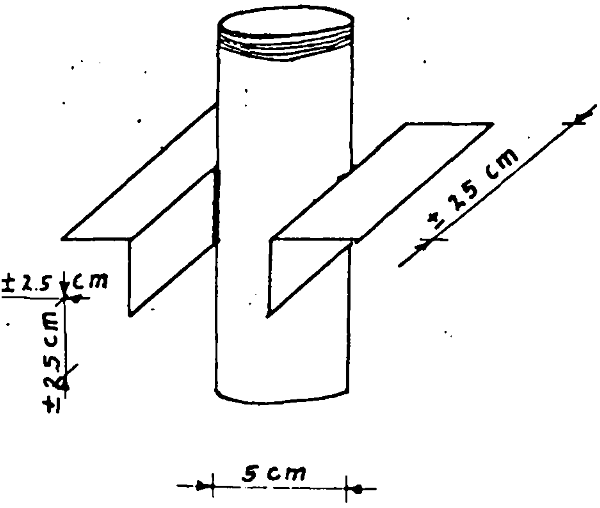
Diameter: 1½" (3.8 cm); length 15" (40 cm). Both ends of the pipe need to be treaded.

6. Tapering piece



Tapers from 2" (5 cm) to 1½" (3.8 cm)

7. Coupling piece

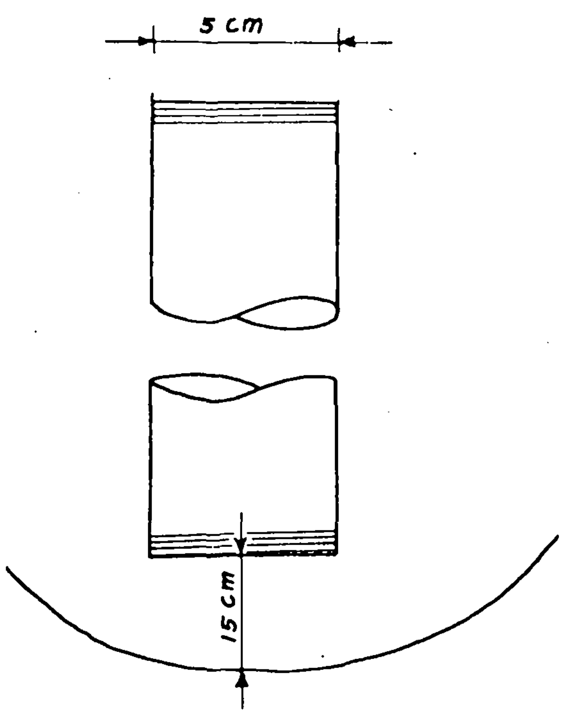


Diameter 2" (5 cm). This coupling piece is to be welded onto two strips of angeled steel, each 1" wide and about 10" long (2.5 x 25 cm). Instead of angeled steel, sturdy wire netting can be used. Welding is necessary because these parts will be cast in the cover plate and without welding the coupling piece would become detached too easily. During the welding operation care should be taken not to damage the internal thread; for example, put cotton waste inside.

8. Cover place

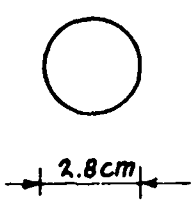
To cover the pit in order to keep out dirt. Made of concrete. For construction, see instructions under Pit Construction

9. Pump tube



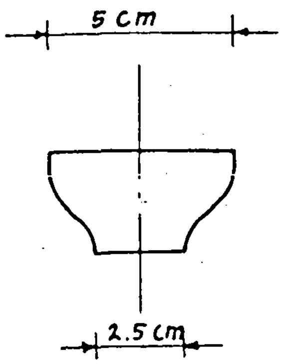
Consists of 2" (5 cm) diameter pipe.Again, the length of the tube is dependent on the depth of the pit, but should be shorter than the depth of the pit by 6" (15 cm). Once more, better too long than too short! The top of the tube has to be threaded and will be attached to the coupling piece. At the bottom will be the bottom valve (see also 11.

10. Steel ball



Part of the bottom valve. Diameter 1 1/8" (about 2.8 cm). Made from stainless steel, if possible. You can try several balls of different diameter to determine which one gives the best results.

11. Tapering piece

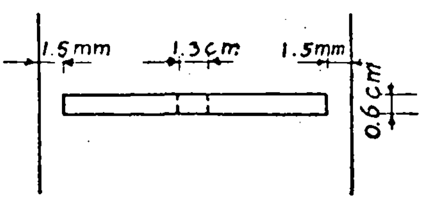


Tapers from 2" (5 cm) to 1" 2.5 cm).
Note: Parts nr. 10 and 11 constitute the bottom valve. Construction is as follows: After the pit has been built, cover plate nr. 8 with pump tube nr. 9 attached, will be placed on top of the pit. Pump tube nr. 9 will then be cut to the proper length such that the distance between the bottom of the tube and the bottom of the pit is 6" (15 cm). The bottom end of the tube must be threaded and the tapering piece screwed onto it. If threading is difficult, an alternative construction is possible (see under Bottom Valve).

12. Bolt

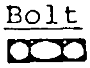
Attach and move to the end of the thread of the pump handle.

13. Steel ring



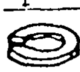
Inner diameter: ½" (1.3 cm). Attach to bottom of pump handle nr. 1. The outer diameter of the ring should be such that the clearance between the ring and the pump tube is about 1/16" (0.2 cm). Thickness of ring: about ¼" (0.6 cm).

14. Bolt



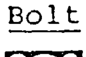
Attach to pump handle nr. 1 such that the ring is almost tight, but not quite.

15. Springtype ring



Supporting bolt nr. 14.

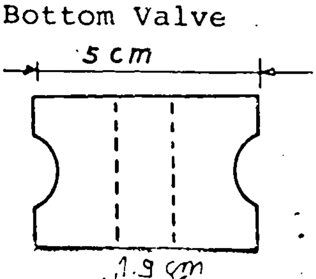
16. Bolt



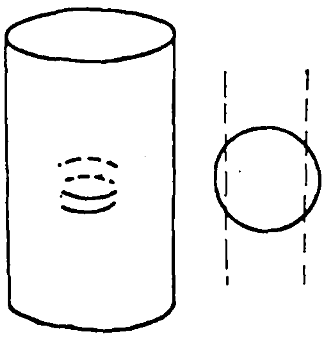
Tighten against ring nr. 15 and bolt nr.14. Make sure that ring nr. 13 is not entirely tight.

These are the parts of the pump. Now some remarks about the construction of the bottom valve.

Bottom Valve

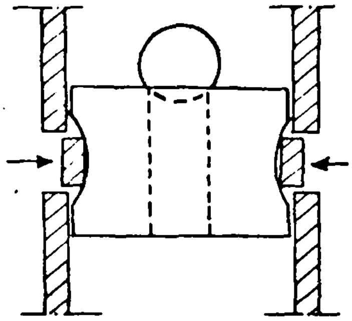


1. It is possible that no thread can be made to attach tapering piece nr. 11 to the pump tube. A similar construction can then be made using a plastic ring with outer diameter of 2" (5 cm), and inner diameter of 3/4" (1.9 cm) The ring



should be such that it can be fitted tightly into the pump tube, otherwise the bottom valve will leak.

2. After pump tube nr. 9 has been cut to the proper length, four cuts are made in the tube in a direction perpendicular to the length of the tube and at a distance of about ½ to 1" (1.3 to 2.5 cm) from the bottom of the tube.



3. The plastic ring, which should have a groove around the outside, is pushed inside the tube from the bottom side up. Then the tube is indented at the cuts and the ring should be tight.

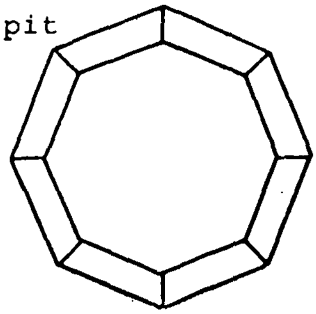
Construction of the pit

Before you install the pump, the pit should be built. This is to be done with trapezium-shaped bricks, made with concrete. There are two kinds of bricks: large ones and small ones. They are to be cast in wooden moulds (see figure 2).

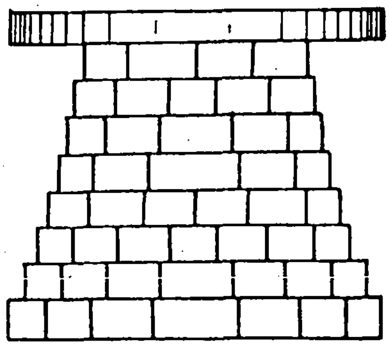
The shaping of the bricks

1. With the largest opening down, put the moulds on a smooth surface (like plywood).
2. Mix cement with sand (ratio 1 : 10)
3. Cast the mixture into the two moulds.
4. Press with a stick or something similar.
5. The moulds can be lifted immediately.

Construction of the pit

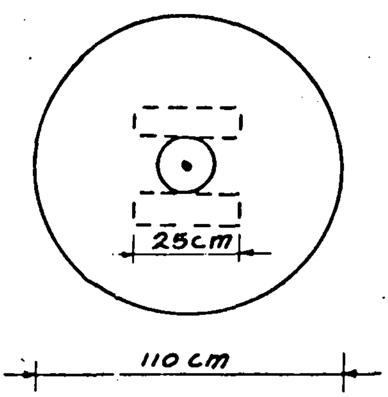


1. Remove the water from the pit (save two buckets full).
2. At the bottom of the pit, make a circle from 9 large bricks. Make sure the bricks are level, otherwise the construction will be tilted. No mortar is needed.



3. On top, make a circle of 8 large bricks and 1 small one, etc.
4. End up with a ring of 9 small bricks. If the top of the construction is not yet level with the ground, then continue with circles of 9 small bricks.
5. Fill up the exterior with sand or soil.

Cover plate 8



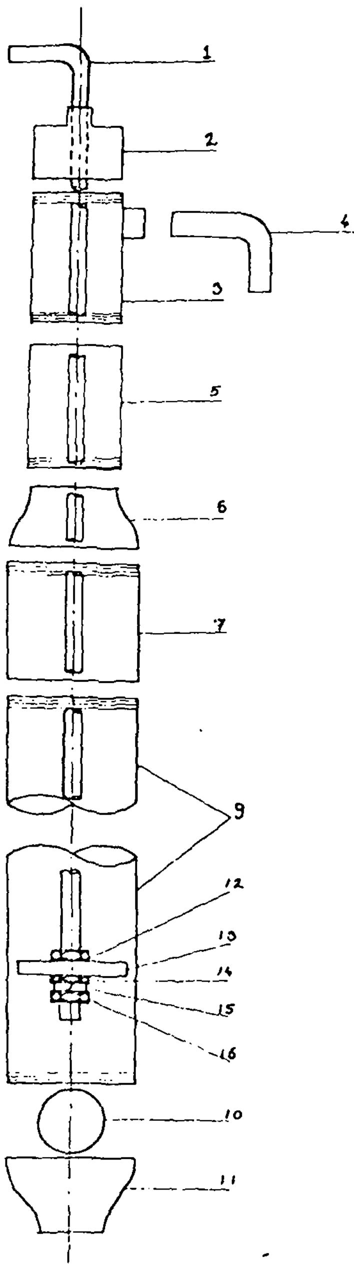
1. Make a circular mould from carton or tin with a diameter of 42" (110 cm) so that the plate will cover the pit. Height of the mould: about 2½" (6.3 cm).
2. Put the mould on a smooth surface.
3. Put coupling piece nr. 7 with welded strips in the center of the mould.
4. Fill with mixture of cement, gravel and sand (ratio 1:2:4). Keep the coupling piece straight and keep the cement out of it (cover with paper).

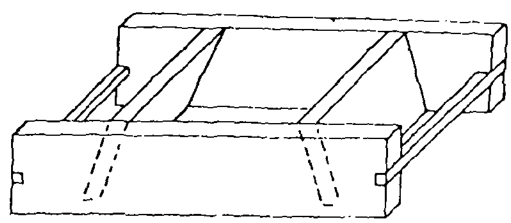
You can reinforce the cover plate by incorporating a piece of sturdy wire netting.
Place the wire just off the bottom, on some gravel.

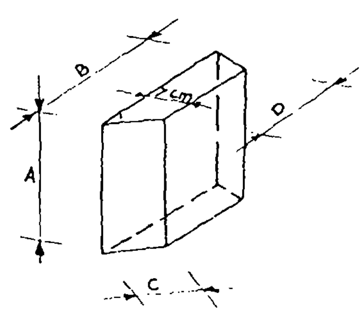
Mounting the pump

1. Mount pump tube nr. 9 into cover plate nr. 8.
2. Mount the bottom valve according to one of two methods.
3. Deposit cover plate with pump tube and bottom valve on the pit.
4. Attach parts nr. 2 through 6 to each other, pull the pump handle through and attach parts nr. 12 through 16.
5. Sink the pump handle with all parts attached into the pump tube nr. 9 until it rests on the bottom valve.
6. Mount tapering piece nr. 6 on the cover plate and tighten.
7. Lift pump handle nr. 1 about 2 to 3" (5 to 8 cm) and bend the top part. This way one prevents damaging the bottom valve when the pump is in use.

Now the pump is ready for operation.
Pour two buckets of water in the pump tube (this can be done by turning the tap nr. 4 upwards or by loosening the stopping plug nr. 2).
If the handle is moved up and down rapidly, the water will pour out of the tap. The water will be dirty at first, but this will get better in several days.





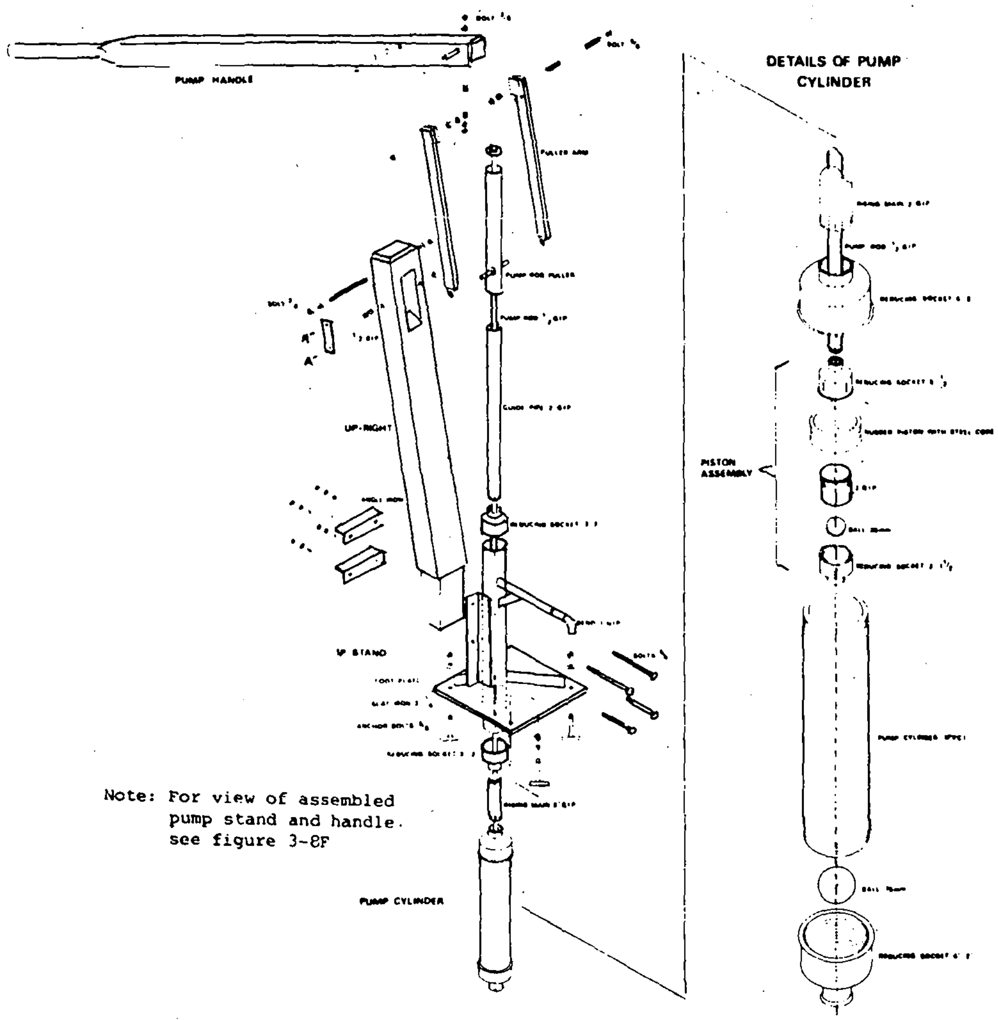


Dimensions for:

	Large bricks	Small bricks
A	6" (15 cm)	6" (15 cm).
B	15¼" (38 cm)	11½" (28.6 cm)
C	3" (7.5 cm)	3" (7.5 cm)
D	13" (32.5 cm)	9¼" (23.1 cm)

from: "The Salawepump", Construction Manual, TOOL, Amsterdam 1975

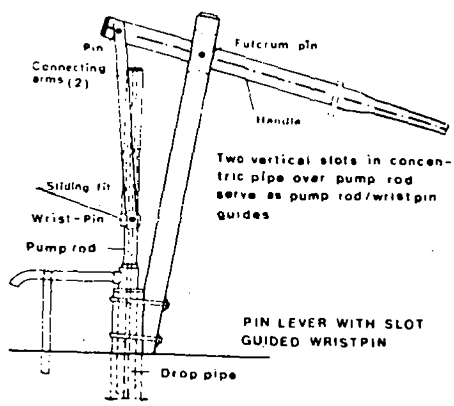
Construction of the wooden handle



Note: For view of assembled pump stand and handle. see figure 3-8F

Courtesy: Shinyanga Shallow Wells Project

SHINYANGA HAND PUMP



PIN LEVER WITH SLOT GUIDED WRISTPIN

SHOLAPUR-TYPE PUMPHEAD

Contact Agency : Robert Tayabji, UNICEF, 9, Jorbagh, New Delhi.

Introduction : A very successful pumphead was designed by War On Want Mission at Jalna, Maharashtra. It was further refined by Sholapur Well Service, Sholapur and UNICEF, and became known as Sholapur-type pump. This is a submergible type pump whose valve remains submerged in the water surface and is linked to the operating handle by means of a connecting rod. Therefore, it does not depend on the suction head of the water and can be made to draw water from any depth. UNICEF has further improved the pumphead of the Sholapur-type pump.

Description of the pump : A complete pump is shown in Plate LIVB. The main parts are the head, the water tank, the pedestal, and the casing pipe through which the connecting rod goes down to the surface of the water and gets connected to the piston with valve which draws water. When the handle is pressed down, the piston goes up and allows the water to get into the casing pipe. After a few operations of the pump the water is drawn up to the water tank from where it comes out through the spout. Since the water volume on both the sides of the piston is balanced, no extra effort is required to operate the handle and it works smoothly and easily.

Sholapur-type pumphead : All pumpheads employ mechanisms to transfer the movement of the handle to the connecting rod, and thence to the piston and valve. Traditional pumpheads have a complex arrangement of levers, pivots and sliding parts, which must be cleaned and oiled regularly. In the Sholapur pumphead, a totally enclosed mechanism has been provided which uses heavy-duty roller chain, thus making it more durable and improving the reliability and efficiency of the pumphead. The essential features of the pumphead are the three parts, which are as follows :

(i) The *head* which contains the handle and working mechanism.

(ii) The *water tank* or reservoir, which ensures a steady flow of water from the pump and thus helps to prevent spillage and waste.

(iii) The *pedestal or stand*, which supports the water tank and head. The pedestal is made from steel pipe and is thus lighter and sturdier than the cast iron bodies of traditional designs. The pedestal has three projecting legs which are anchored in the cement of the platform.

Installing a pumphead : In installing a pumphead, the pedestal is first fitted over the casing pipe of the tube-well. The three legs are then embedded in a cement foundation. Cement fills the space between the casing pipe and the pedestal and hardens there. This ensures that waste water cannot enter the tube-well and contaminate it. The handle is at a convenient height for the operator, the pivot being about 102 cms. (40") above the platform.

Hand pump conversion head: Most handpump breakdowns are caused by mechanical failures of the moving parts. The cast iron body of the Sholapur pumphead seldom needs replacement as it has no moving parts. Its purpose being merely to support the mechanism above. It is possible to change the pumphead of a traditional design by a conversion head of the Sholapur designs. Conversion heads incorporate the Sholapur mechanism which is more efficient, rugged and reliable than the conventional type. The UNICEF and the Sholapur Well Service have prepared drawings and specifications according to which the conversion heads can be manufactured easily. The handpump repair and substitution of a conversion head entails the following :

(a) Installation of conversion heads on an ordinary pump

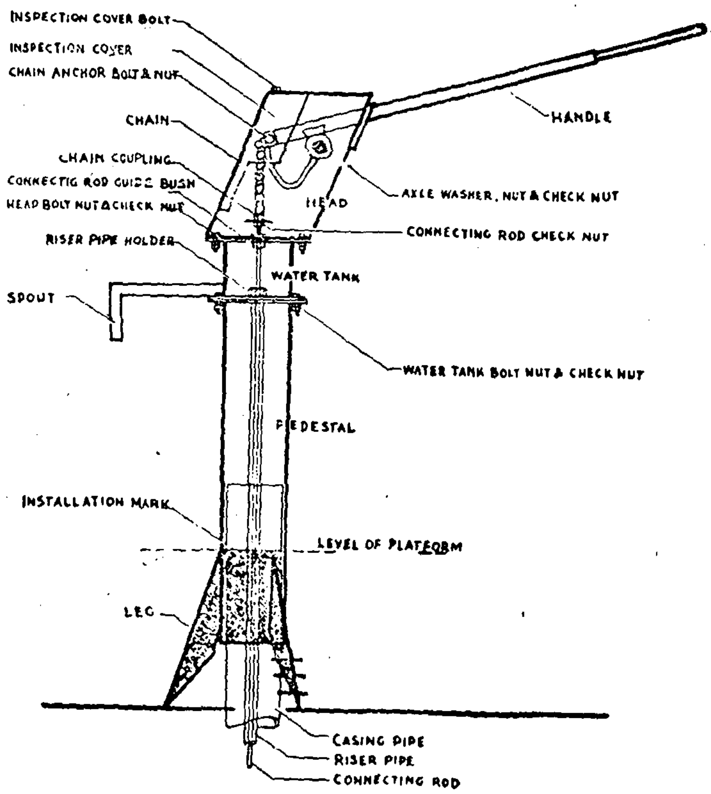
(b) Construction of platforms and drains

(c) Occasional replacement of other components, such as cylinders, pistons and washers

Price : (1) Approximate cost of conversion is as follows :

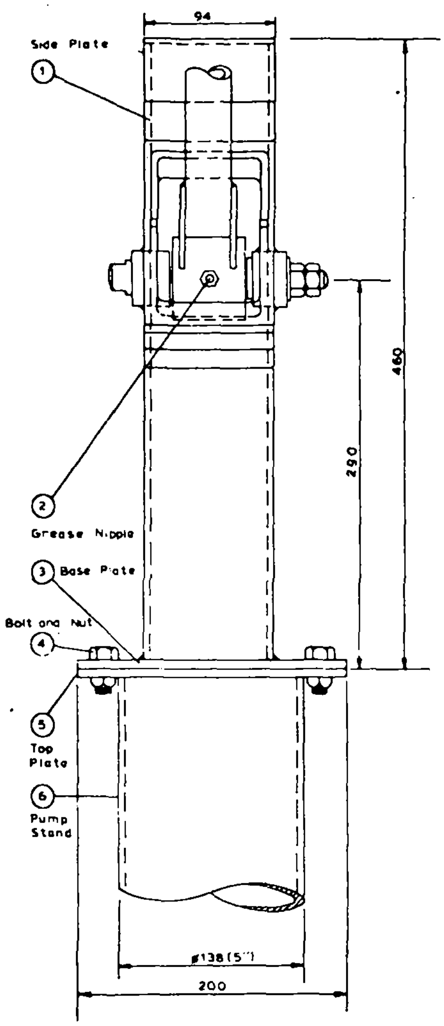
		Rs.
Cost of conversion head	..	300
Cost of new platform and drain	..	250
Cost of new cylinder, if needed	..	250
Total	..	800

(2) Installing a complete Sholapur-type pump will cost Rs. 1,500/- in addition to the cost of boring.

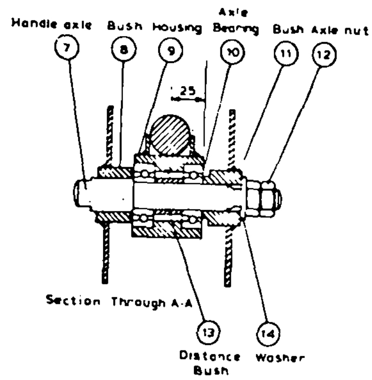


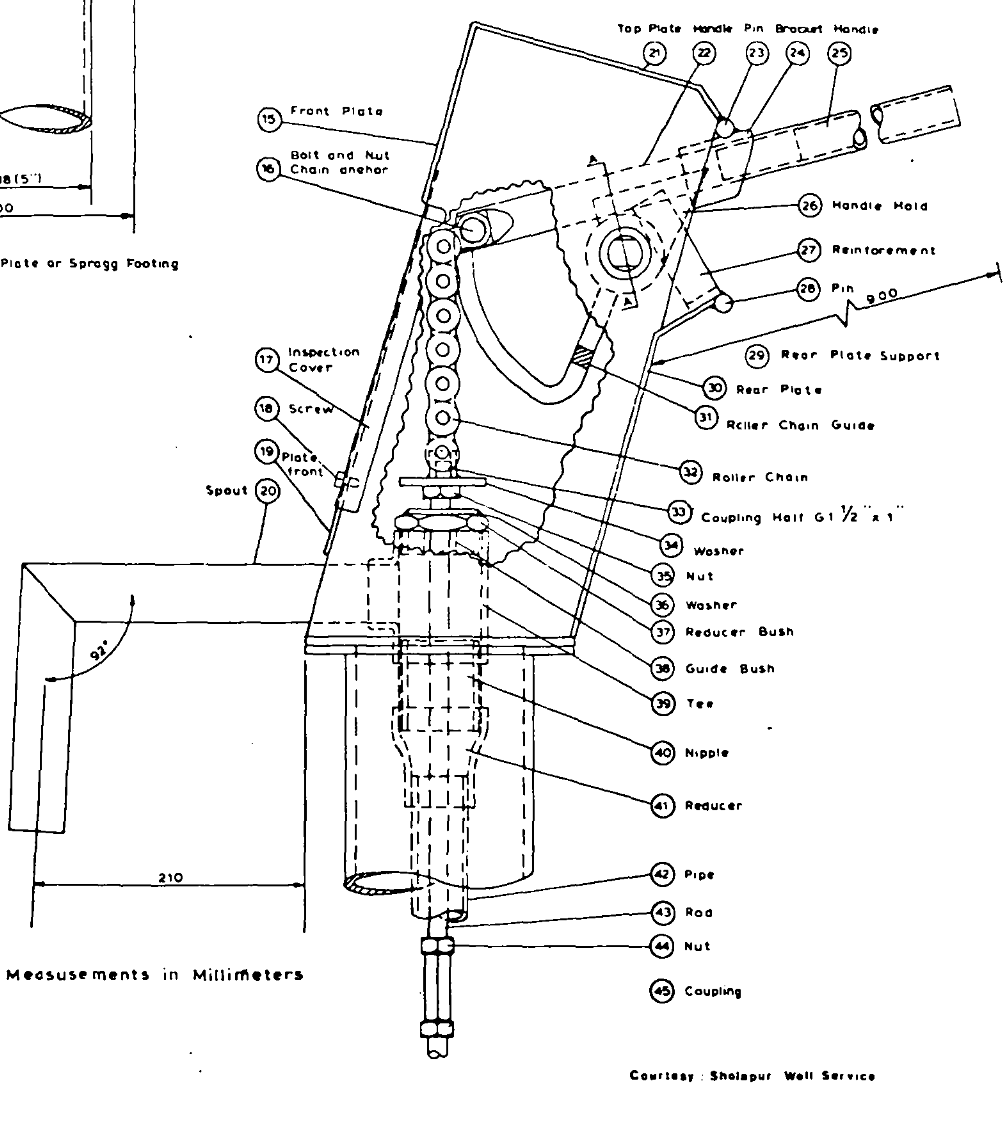
INDIA MARK II HAND PUMP

SHOLAPUR DEEP WELL HAND PUMP
TOP END MECHANISM



Complete with Base Plate or Spragg Footing





Note: Measusements in Millimeters

Courtesy : Sholapur Well Service

COMITE INTER-AFRICAIN D'ETUDES HYDRAULIQUES (CIEH) STUDIES IN UPPER VOLTA INCLUDING THE HYDRO-POMPE VERGNET

The Inter-African Committee on Hydraulic Studies (CIEH), an international organization headquartered in Ouagadougou, under a 1973 agreement with WHO and with assistance from UNICEF, is studying the use of small hand pumps for water supply in West Africa. The study comprises inventory and testing of pumps manufactured in Africa, including "ABI", Bodin "Majestic", Briau "Africa", and Craelius "Uganda", and imported pumps including Dempster "23F Ex" (US), Briau "Royale" (France), and Godwin "WIH 51" and "54" (UK).

An important part of these studies is the field testing of a newly developed pump, the French-made (by Mengin) "Hydro-Pompe Vergnet". Several prototypes of these pumps, provided by WHO and UNICEF, are being tested in Ouagadougou and in the village of Koupela, about 140 kms east.

1. The "Hydro-Pompe Vergnet" (Description)

This pump has a novel operating mode. A flexible diaphragmatic hose (cylinder) is located inside a rigid cylinder immersed in the well. Using a hydraulic pilot system operated by a foot pedal, at ground level, the flexible hose is alternatively stretched, and left to contract, thereby pumping water from the rigid cylinder to the surface. Its operation is best explained stepwise in conjunction with the fig. Beginning with the pump primed* and the foot pedal in the high position:

(1) The operator steps on the pedal, forcing the piston down into the cylinder.

(2) The water in the piston cylinder is forced from the cylinder, through the pilot pipe or hose, and into the diaphragmatic hose with flexible, springlike walls.

(3) The increasing water pressure in the flexible hose stretches its walls, thereby expanding its volume.

(4) The increased volume of the smaller cylinder increases the pressure of the water within the larger, rigid cylinder surrounding the smaller cylinder.

(5) The rising pressure within the rigid cylinder closes the suction valve and opens the delivery (discharge) valve.

(6) The water within the rigid cylinder is forced to the surface through the discharge valve and discharge pipe or hose as the smaller cylinder expands.

(7) The operator lifts his foot, relieving pressure within the pilot system.

(8) The flexible, springlike cylinder contracts to its initial position, forcing water up the pilot hose and pushing the pedal back to its high position.

(9) The contraction of the flexible cylinder reduces the pressure of the water within the rigid cylinder.

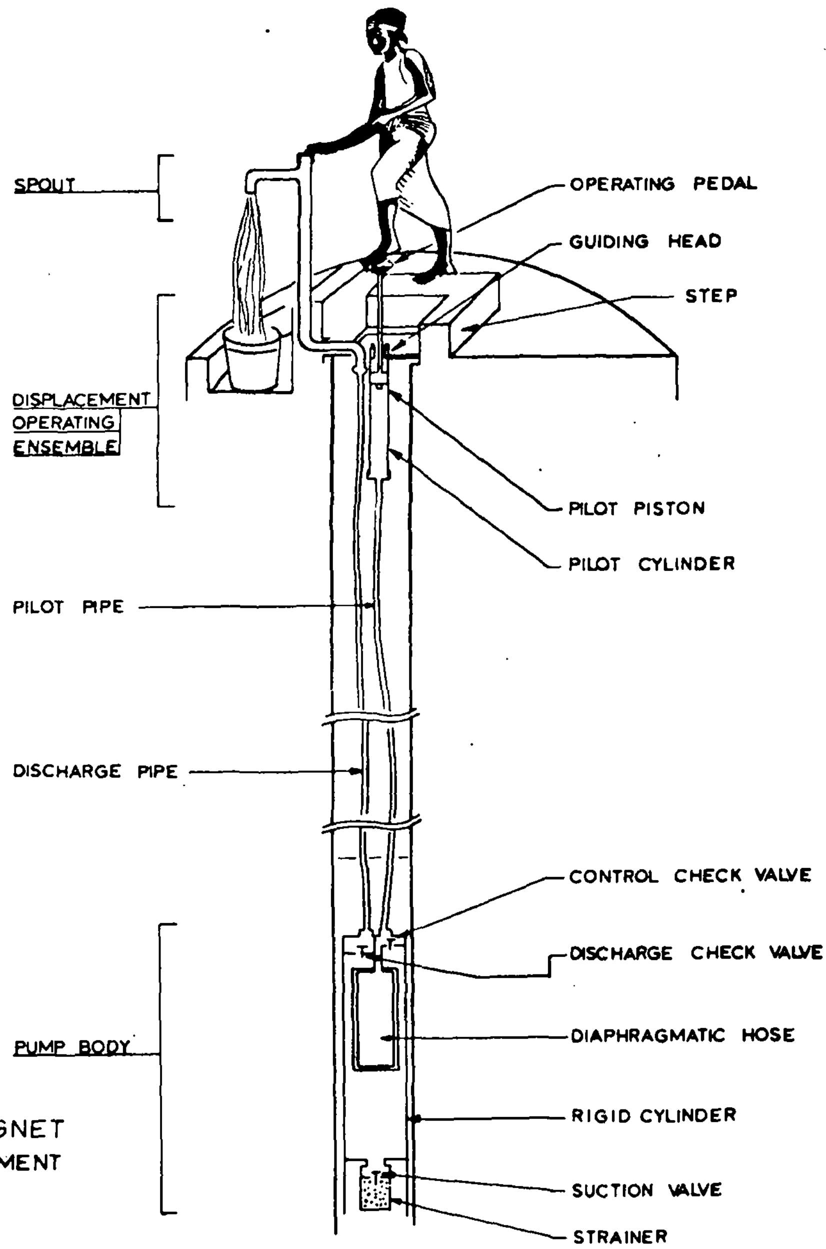
(10) The falling pressure within the rigid cylinder closes the delivery valve and opens the suction valve, refilling the rigid cylinder.

(11) The operator again steps on the pedal and the cycle begins anew.

---

* Rigid cylinder around flexible hose primed; the pilot system is filled with water upon installation.

The diaphragmatic hose as well as the pilot cylinder and pipe are filled with water from the surface upon installation in the well. The pilot system being completely closed, apart from a refilling valve, there should be no potential for contamination of the pumped water.



HYDRO - POMPE VERGNET
SCHEMATIC ARRANGEMENT

2. Observations

In spite of careful development work and many laboratory tests (including testing of the flexible diaphragmatic hose for over 2 million cycles, without failure), some modifications of the "Vergnet" pump's original design proved necessary in view of difficulties experienced under field conditions. The PVC used for the rigid cylinder was found to develop cracks due to the continuous pressure variations, and was replaced by stainless steel. Leather cup seals used in the pilot cylinder did wear very quickly; a marked improvement was achieved by the introduction of piston rings with leather or urethane seals.

In wells less than 30 meters deep, light-weight flexible piping can be employed in the "Vergnet" pump assembly facilitating its installation and maintenance. Pipes and pumping unit are readily pulled from the well. Normally, two men should be able to do this by hand so eliminating the need for tripods or scaffolding. The use of light-weight materials also should save on transport costs.

In reciprocating hand pumps the short life of cup seals is a major maintenance problem, especially for deep well pumps where the pump rod, discharge pipe and cylinder have to be pulled up in order to replace the seals. In the "Vergnet" pump all rubbing parts are readily accessible at the surface.

Another group of maintenance problems in conventional hand pumps is associated with handles, pump rods, and handle/pump rod linkages - components which are non-existent in the "Vergnet" pump.

Because the "Vergnet" pump is foot-operated, it can be pumped with more power and less fatigue than the conventional lever operated pumps. The linear movement of the foot pedal eliminates all rotating components.

The "Vergnet" pump requires a well casing of 4-inch (100 mm) or more. It can be used as a lift pump or lift-and-force pump, but not as a suction pump; its pumping cylinder must be immersed.

According to the manufacturer (Mengin), of the 2000 "Vergnet" pumps installed sofar (June 1977), about 70% operates at pump depths between 20 m (70 ft) and 60 m (200 ft). In most African countries "Vergnet" pumps have been installed, with the largest number (500) in Ivory Coast where a first government programme has just been completed (June 1977). Outside Africa, the pump has not yet found wide-spread use.

Factors likely to influence wider acceptance of the "Vergnet" pump are:

(1) It is relatively high priced at U.S. $ 600 (October 1976 price list) for pump Type A or C complete with one set of service parts and tools. (A set of maintenance parts including one pedal guide and four leather piston rings, is quoted at U.S. $ 4).

(2) The need to import the unique parts, i.e. the flexible diaphragmatic hose, the stainless steel cylinder and foot pedal, and piping.

3. CIEH Report

The report of this study is scheduled for some time in 1977. An earlier CIEH study (circa 1964) is a descriptive account of the man and animal powered pumping methods then in use in West Africa including many of ancient origin. (Also see papers by Benamour, CIEH, Gagara, and Vergnet and manufacturer's literature from Mengin).

Enclosures to No. 6

III INERTIA PUMP

The inertia pump, perhaps the simplest pumping device so far designed, was originally conceived from the mud-lifting tube that is used for digging shallow tube wells in many parts of the world. The main pump body (riser) consists of a long pipe with a check valve and a discharge spout located near the top end. The name of the pump derives from the belief that part of the function of water lifting by this device is due to the inertia of the mass of water held in the riser. The design of an inertia pump for use in irrigation has been reported earlier by DAWSON in 1969 [1/]. In the present study the basic pump design was modified to incorporate a prime mover assembly consisting of a bicycle-type drive and a flywheel with a view to achieve more efficient pump performance, as shown in Fig. 3.1.

3.1 Pump Description

In this study, the initial design for an inertia pump, designated here as IP-1, consisted of a riser made of 8 cm diameter cast iron (CI) pipe. The upper end of the riser pipe was plugged and fitted with a bracket to which the pump handle was attached using a 7 mm bolt. Near the top end of the riser at an angle of 30 degrees another short CI tube, also 8 cm in diameter, was welded on to serve as the pump outlet. At the mouth of this tube was attached a 6.4 cm flapper valve seated in a flange followed by another short length of 8 cm CI piping. The design details of the pump are given in Fig. 3.2.

During operational testing some difficulties (to be discussed subsequently) were encountered with the above design necessitating some modifications. In the modified version the flapper valve was located in the riser instead of in the spout as in the previous design. Two pumps were constructed, one with a 5 cm diameter riser and the other with a 7.6 cm diameter riser, both of cast iron piping. Another short CI piping welded at right angle onto the riser near the upper end, 2.5 cm above the valve seating formed the spout. The pumps were designated as IP-2 (5 cm riser) and IP-3 (7.6 cm riser). A 5 cm diameter flapper valve was used in each of these designs. A third unit of the modified inertia pump designated as IP-4, was also constructed using a 7.6 cm riser and a 6.4 cm flapper valve. Design specifications for the three inertia pumps are shown in Fig. 3.3 and 3.4 while Fig. 3.5 shows a dismantled unit.

1/ DAWSON, R.W. (1969) Inertia Hand Pump, Paper presented at a Workshop on Rural Water Supply, University College, Dar es Salaam.

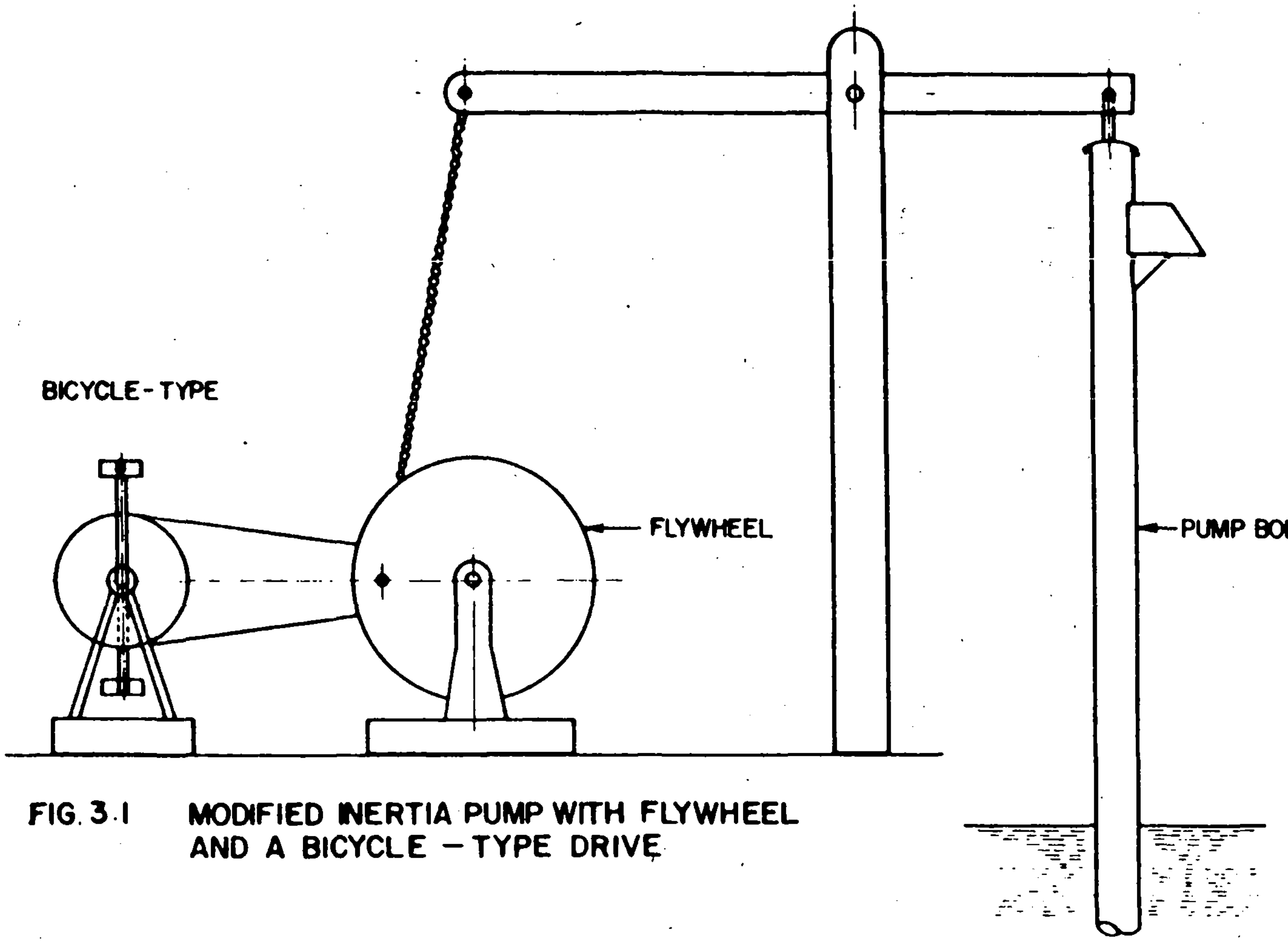


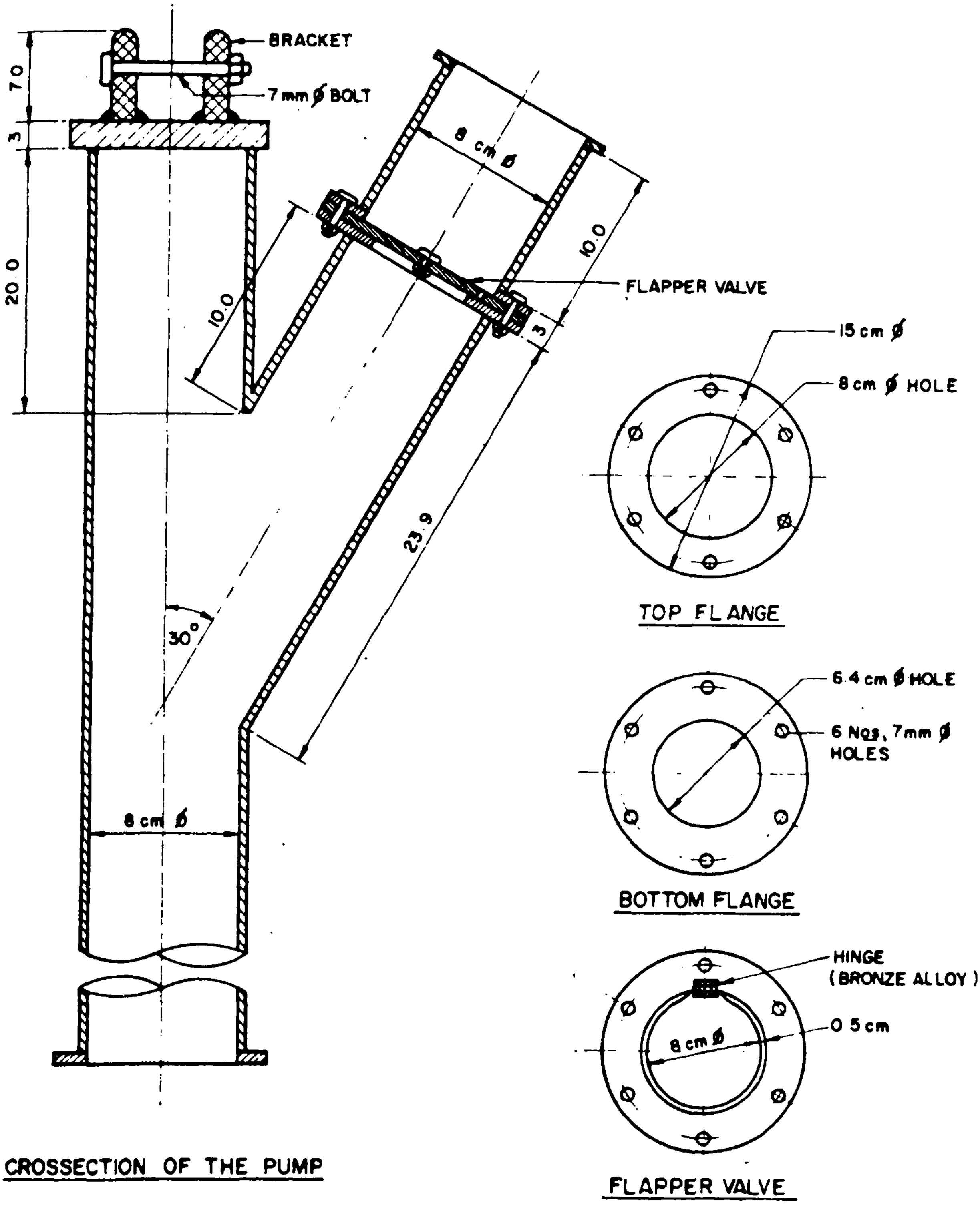
FIG. 3.1 MODIFIED INERTIA PUMP WITH FLYWHEEL AND A BICYCLE – TYPE DRIVE

3.2 Prime Mover Assembly

The prime mover assembly consisted of a triangular wooden supporting frame on which was mounted a bicycle-type drive mechanism including pedals, chain and a sprocket as shown in Fig. 3.6. A seat for the operator as well as a handle-bar were also provided so that the operator would assume a position approximating that on a bicycle. At one end of the driving shaft on which the sprocket was mounted was a flywheel with a disc crank. The pump handle was connected to the disc crank through a wooden connecting rod.

3.3 Pump Operation

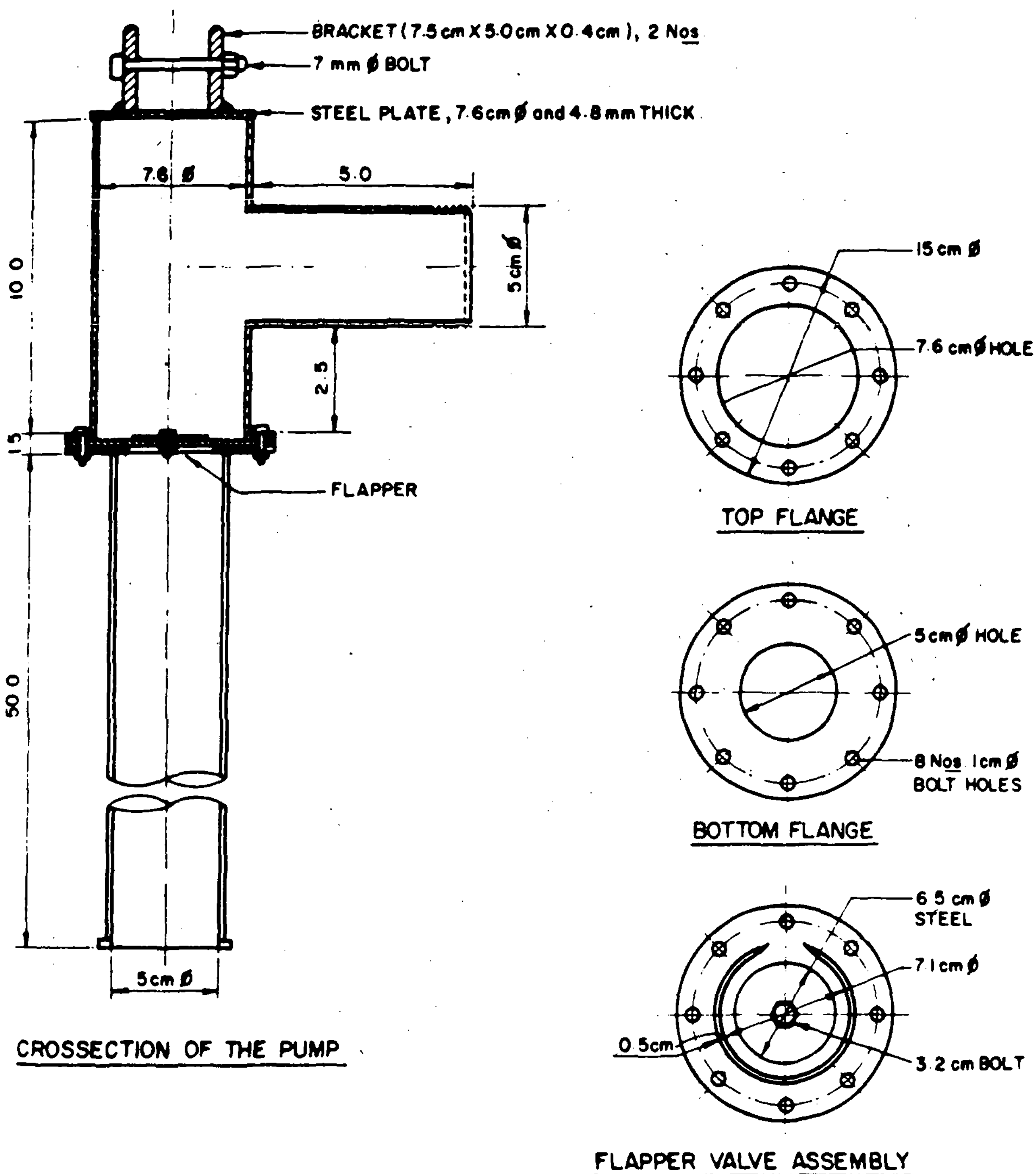
Operation of the inertia pump consists of causing a steady up and down motion of the pump body with the lower end of the riser immersed in water. In the present designs the rotary motion of the prime mover is converted into reciprocating motion by the disc crank and transmitted to the pump handle and to the pump through the connected rod. In the downward stroke the pump returns to its lowest position under the force of gravity. The function of the flywheel is to help recover some of the otherwise lost energy when the pump is on the down stroke.



NOTES:

1. All dimensions are in centimeters
2. Flanges are made of 5.0 mm thick cast iron.
3. Flapper valve is made of rubber

FIG. 3.2 DESIGN OF INERTIA PUMP IP-1



NOTES:

1. All dimensions are in cms.
2. Flanges are made of 5.0 thick Cast Iron.
3. Flapper valve is made of rubber and strength and with 6.5 mm. ø steel sheet.

FIG. 3.3 DESIGN OF INERTIA PUMP IP-2

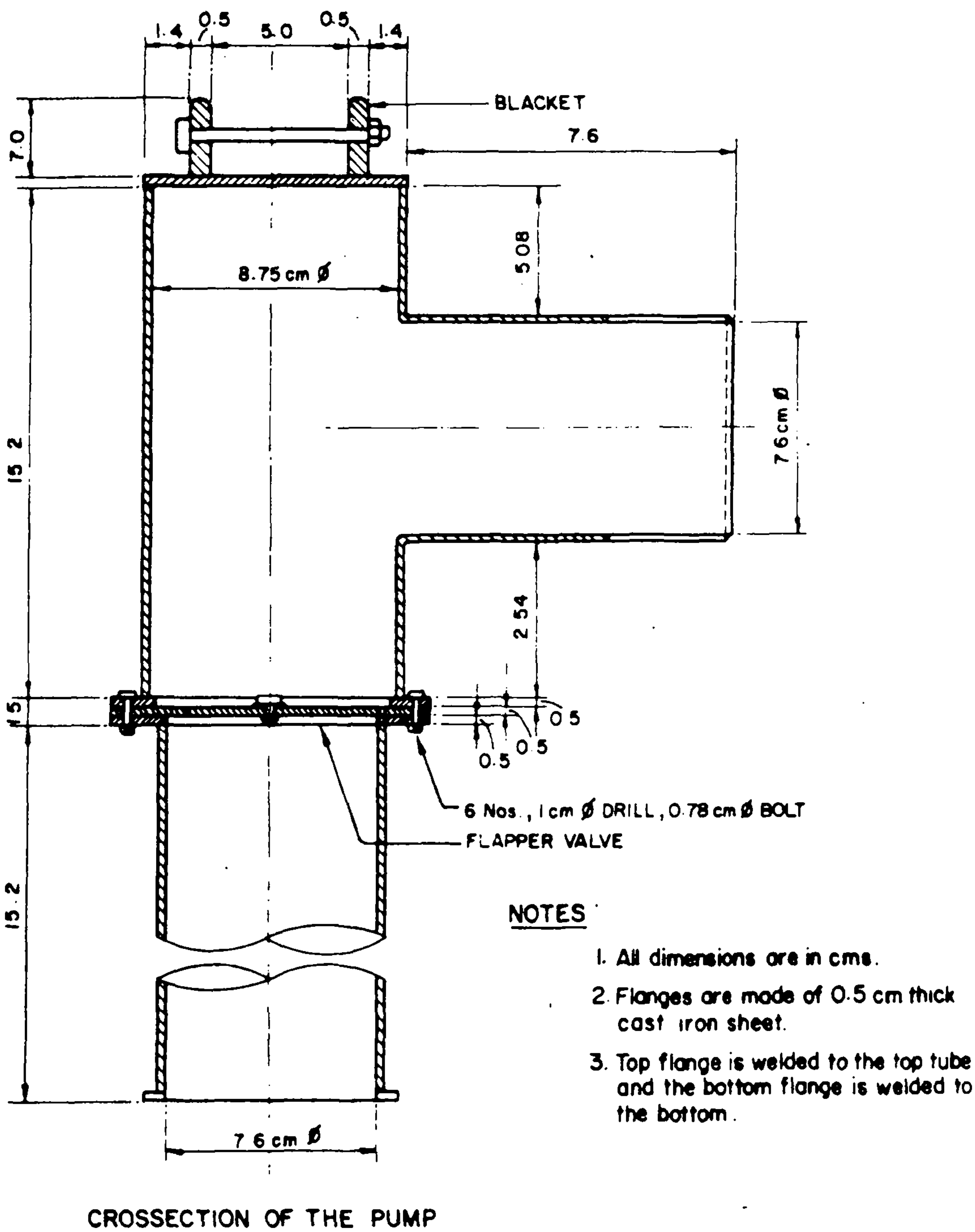


FIG. 3.4 DESIGN OF INERTIA PUMP IP-3 & IP-4

Two fundamental forces are believed to exist during pump operation. When the pump body moves down a portion of air or water leaves through the flapper valve. During the upward stroke the flapper valve is closed under atmospheric pressure, creating a suction inside the riser which forces water up into it from the source. In the downward stroke water is apparently pushed up in the riser due to the inertia of the mass of water held in the river. It is this force that helps open the flapper valve and force water out through the spout.

Fig. 3.7 shows the inertia pump in operation.

3.4 Experimental Testing

Experimental testing of inertia pump performance was carried out at the Regional Engineering Experimental Centre of the Asian Institute of Technology. The testing procedure was primarily aimed at determining the relationship between the operating head and output of the pump as well as to examine the best stroke length and operational speed for working the pump over extended periods. As in the case of the bellow pump a labourer was asked to operate the pump.

3.4.1 Testing of Inertia Pump IP-1

A few preliminary test runs using IP-1 pump were carried out to determine the best stroke length and speed of operation at three levels of operating head, namely, 1.0, 1.5 and 2.0 meters. A riser of appropriate length was used for operation at a particular head. Segments of CI piping were joined together by welding to yield a riser of required length. Several operational difficulties were encountered during these trial runs leading to abandoning of the design and development of modified designs as noted earlier. Further detailed evaluation of pump performance was not therefore undertaken for this unit.

3.4.2 Testing of Inertia Pumps IP-2, IP-3 and IP-4

Pumps IP-2, IP-3 and IP-4, based on a modification of pump IP-1, were evaluated with respect to stroke length in the range of 10 to 20 cm and operating speed in the range of 140 to 200 strokes per minute at three levels of operating head of 1.5 m, 2.0 m and 2.5 m. The stroke length was varied by using different diameters of disc crank. In these test runs a constant operational speed was maintained for long periods of operation by using a variable speed DC motor to drive the pump. For a given run at specified values of stroke length, operating speed and head, the pump output was recorded by cumulating the discharge over fifteen minute periods and computing the mean discharge rate from several samples. Subsequently the pumps were manually operated to determine the most favourable stroke length and operating speed for various values of operating head. The maximum value of operating head investigated here was 2.5 m since a pump body longer than this created excessive weight problem.

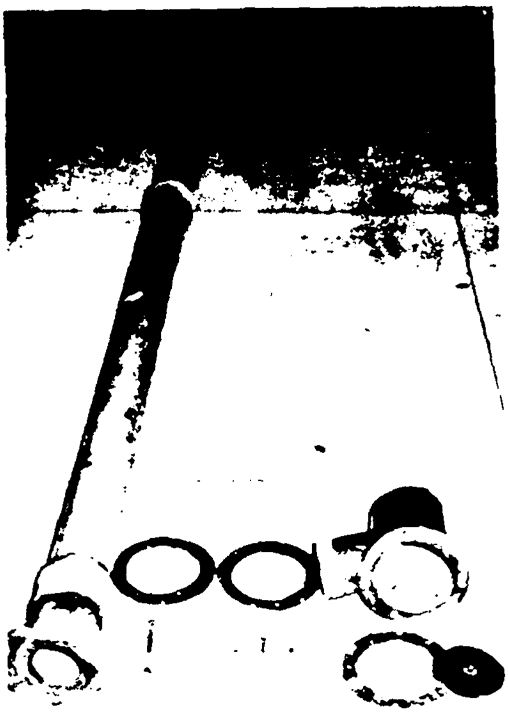


Fig. 3.5 - Inertia Pump IP-[illegible] Disassembled.

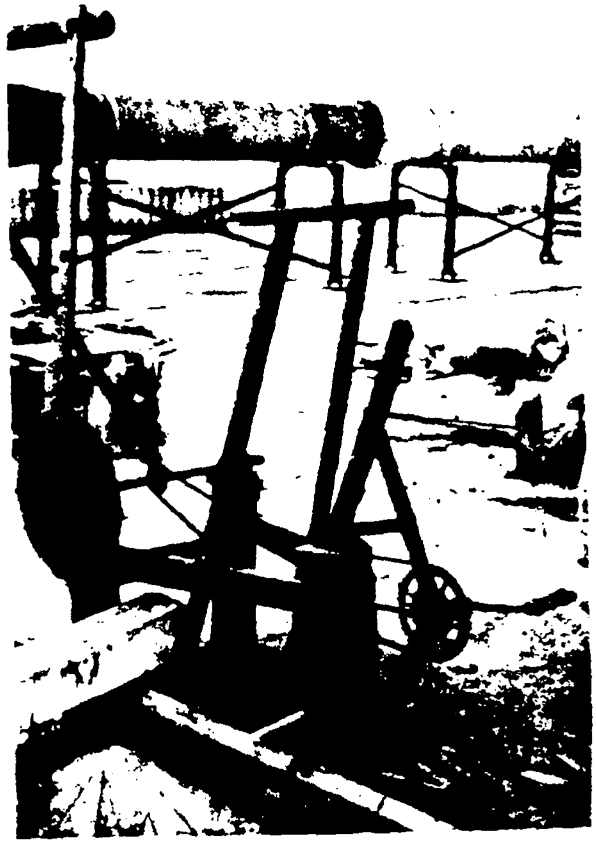


Fig [illegible] - [illegible] Inertia Pump

3.6 Conclusions

The initial design of an inertia pump IP-1, with the valve assembly located in an inclined side arm, is not only inferior to the bellow pump in performance but is also difficult to operate because of a tendency to swing. The later designs IP-2, IP-3 and IP-4, in which the valve is housed in the riser, are free from the shortcomings of the earlier model. The construction and maintenance of the inertia pump is much simpler than that of the bellow pump. In addition, each of the three designs studied is in general superior to the bellow pump in performance. The inertia pump therefore appears to be a superior alternative to the bellow pump for incorporation into small rural water supply systems. It may be necessary to use two or more pumps in series if the total lift required is greater than about 2.5 m. The output of pump IP-2 is sufficient for the daily requirement of about 500 people with the pump operated 3 to 4 hours daily. Pumps IP-3 and IP-4 are capable of serving a larger population.

Volumetric output of inertia pump increases with increased riser diameter and size of valve opening. Other operating conditions being maintained constant, increasing the speed of operation of the pump linearly increases pump discharge. The discharge also increases monotonically with increased stroke length. At constant stroke length and operating speed the discharge decreases with increasing head on the pump.

For manual operation, a pumping speed of 140 to 160 strokes per minute is most suitable for extended periods of operation with a bicycle type drive assembly. A stroke length of pump IP-2 may be operated at 20 cm stroke length while a 15 cm stroke was found to be optimal for IP-3 and IP-4.

Table B1 - Mean Volumetric Discharge Rates (ℓ/min) of Inertia Pump IP-2 under Various Operating Conditions

Head	1.5 m				2.0 m				2.5 m			
Operating Speed Strokes/min / Stroke Length, cm	140	160	180	200	140	160	180	200	140	160	180	200
20	108	125	138	152	81	95	106	116	68	83	100	116
15	56	79	88	102	56	68	79.5	101	47	62	78	100
10	-	41	56	78	25	36	53	68	23	35	58	66

Table B2 - Mean Volumetric Discharge Rates (ℓ/min) of Inertia Pump IP-3 under Various Operating Conditions

Head	1.5 m				2.0 m				2.5 m			
Operating Speed Strokes/min / Stroke Length, cm	140	160	180	200	140	160	180	200	140	160	180	200
20	146	156	184	212	120	146	162	187	119	133	156	171
15	119	121	131	152	104	116	131	159	89	111	135	158
10	75	84	105	121	73	82	100	119	50	89	103	108

Table B3 - Mean Volumetric Discharge Rates (ℓ/min) of Inertia Pump IP-4 under Various Operating Conditions

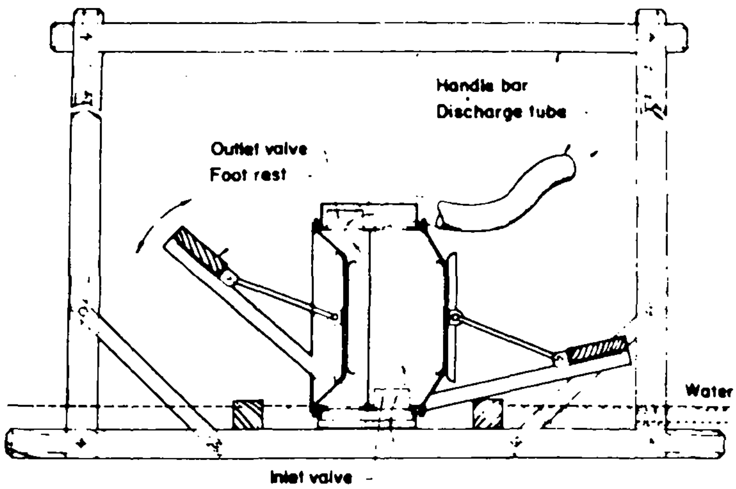
Head	1.5 m				2.0 m				2.5 m			
Operating Speed Strokes/min / Stroke Length, cm	140	160	180	200	140	160	180	200	140	160	180	200
20	172	192	232	298	142	181	208	222	156	178	199	209
15	104	141	185	209	113	135	165	169	106	129	151	167
10	69	86	90	106	61	73	67	71	37	47	61	59

From: "Design of Simple and Inexpensive Pumps for Village Water Supply Systems" AIT-WHO Research, Bangkok, 1977

'he pump

he foot operated diaphragm pump is ouble-chambered and performs well in ow-lift irrigation applications. The ump casing consists of a light shee'-etal cylinder with a central partition o provide two chambers. Rubber flap alves are used on the intake and ex-aust ports. The two rubber diaphragms re made from automotive inner tube and re mounted so that they can be easily eplaced.

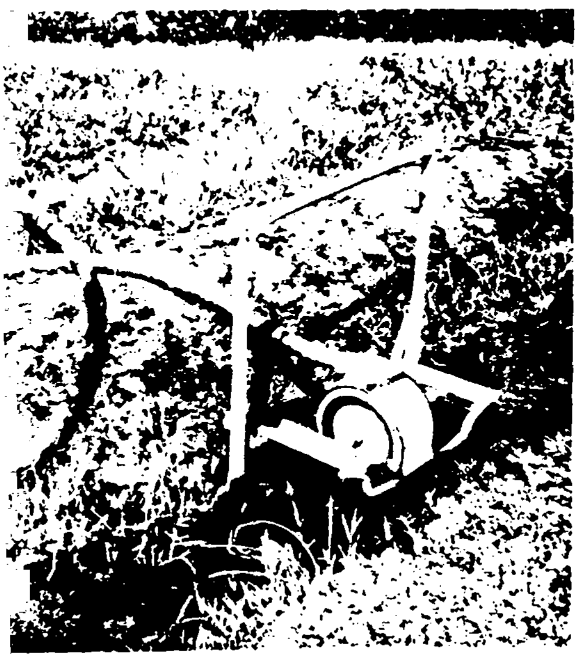
he entire unit, equipped with a handle or convenient carrying, weighs 28 kg. t was designed for long service and asy repair yet simple enough to be anufactured by small machine shops.



Schematic drawing of the Diaphragm pump

ow it works

e operator stands on the two foot ests and shifts his weight from one oot to the other. This compresses a hamber, forcing water from the outlet alve. By alternately shifting his eight in a rhytmic manner, the operator umps a continuous flow of water.



What it does

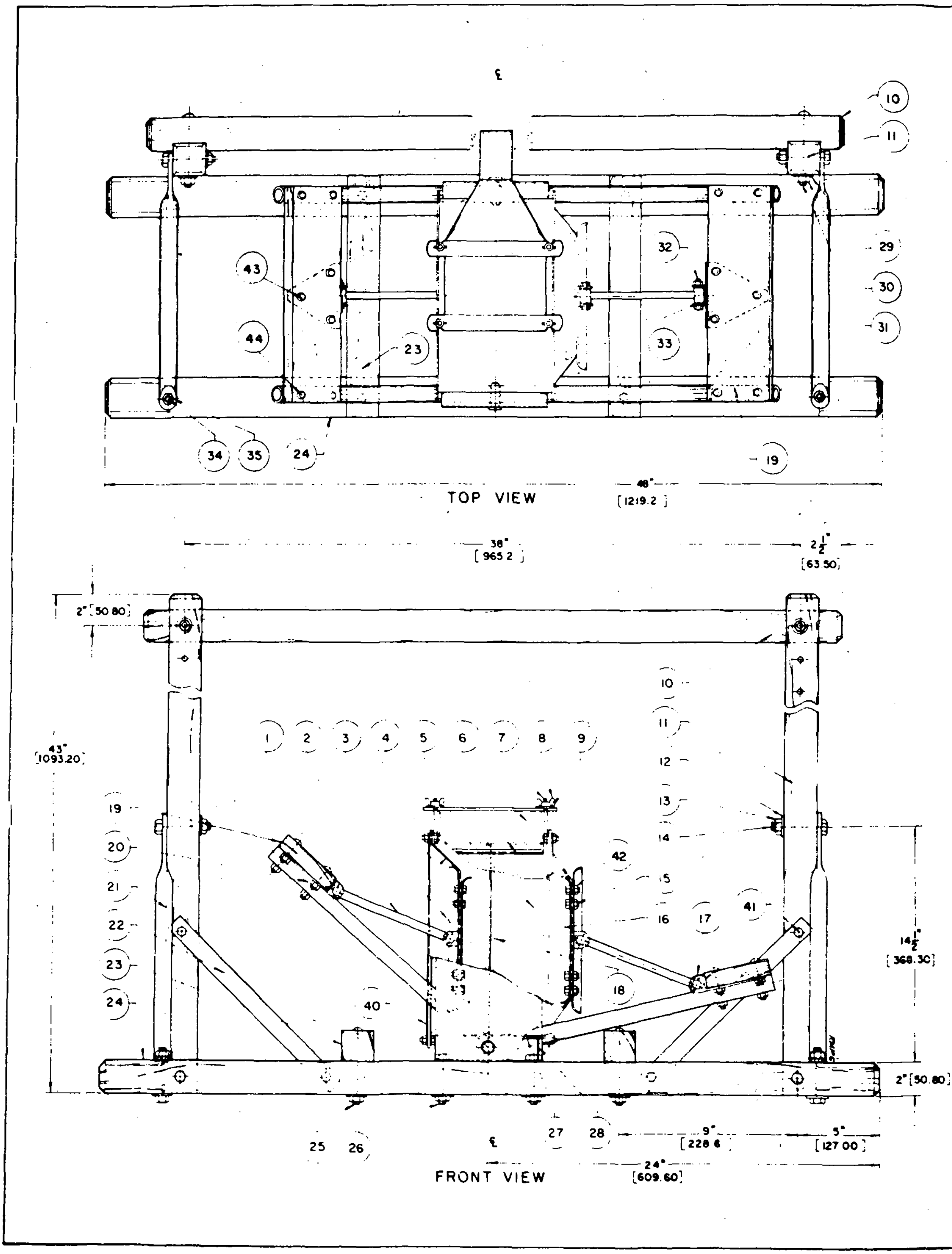
This low-cost pump can lift 190 to 120 liters of water per minute to a height of 1 to 2 meters.

The IRRI diaphragm pump is well suited for pumping water from irrigation ditches, open channels, river banks, and shallow wells. Unlike most pumps, it can handle water with mud or other small impurities.

Machine specifications

POWER:	1 man
WEIGHT:	28 kg
LENGTH:	122 cm
WIDTH:	45 cm
HEIGHT:	109 cm
CAPACITY:	190 liters/min at 1.0 m head 120 liters/min at 2.0 m head
CONSTRUCTION:	Wood and steel frame, rubber diaphragms

Drawings can be obtained from the International Rice Research Institute, P O Box 933, Manila, Philippines
Cable RICEFOUND, MANILA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TOP VIEW
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2 1/2"
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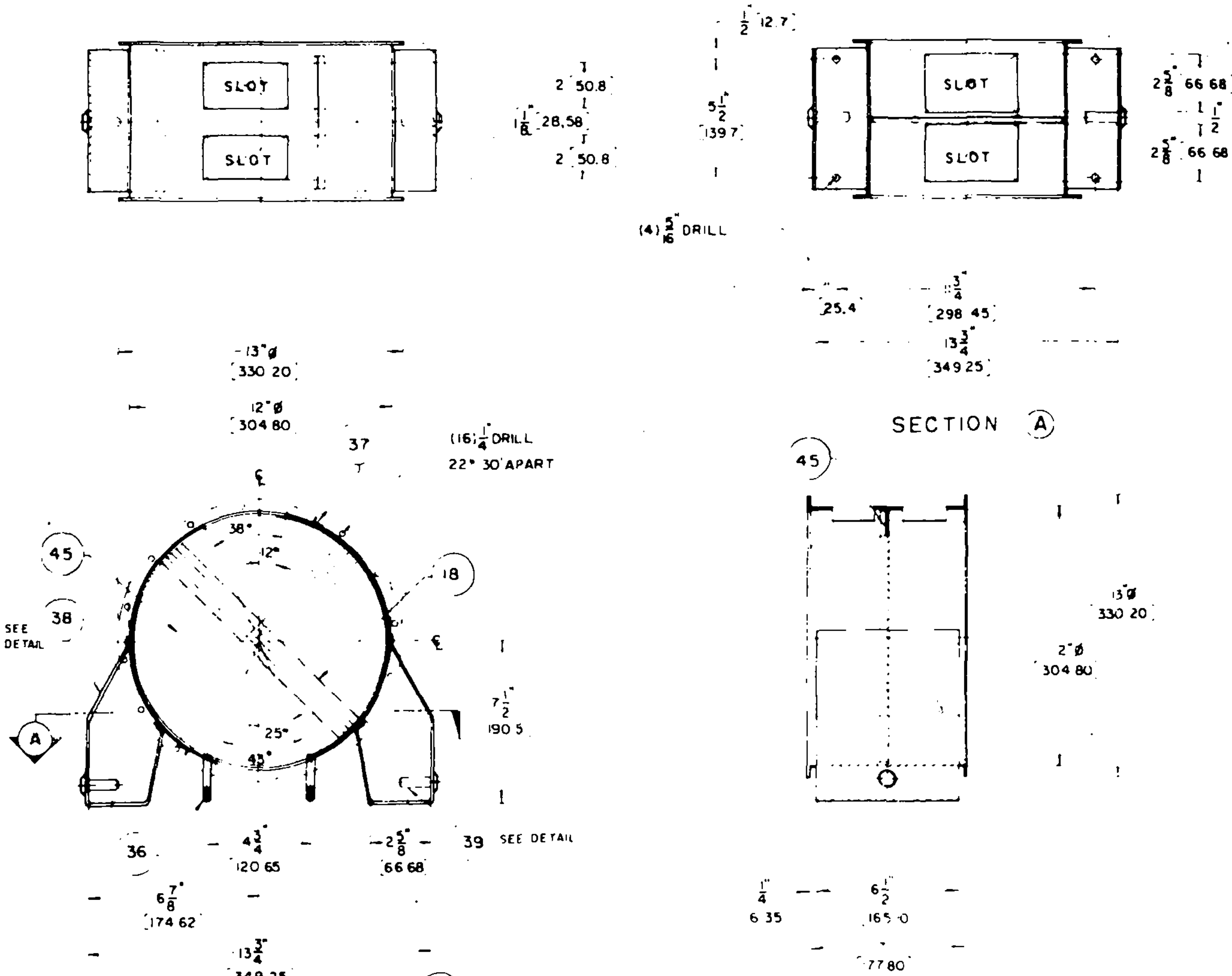
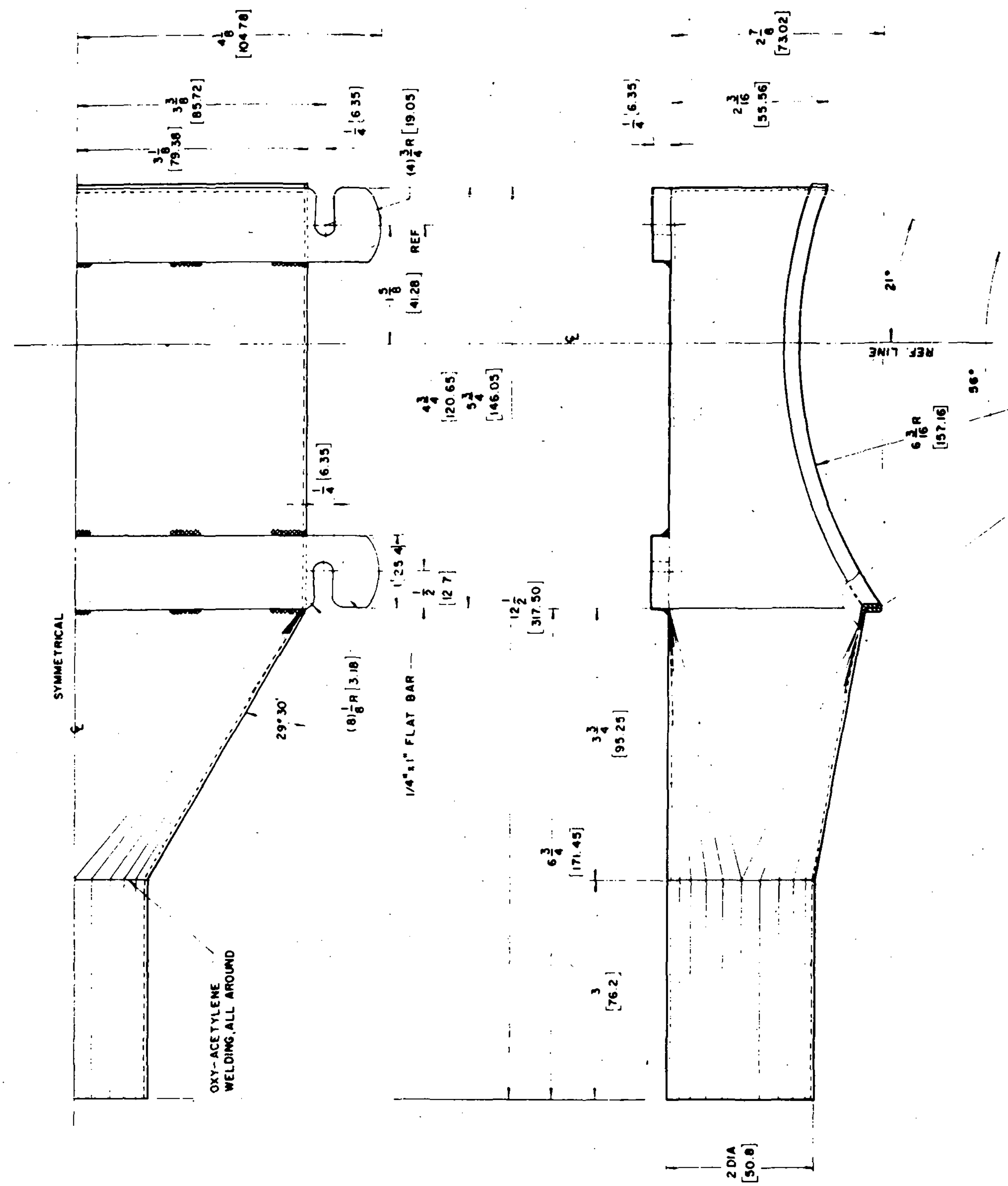
FRONT VIEW

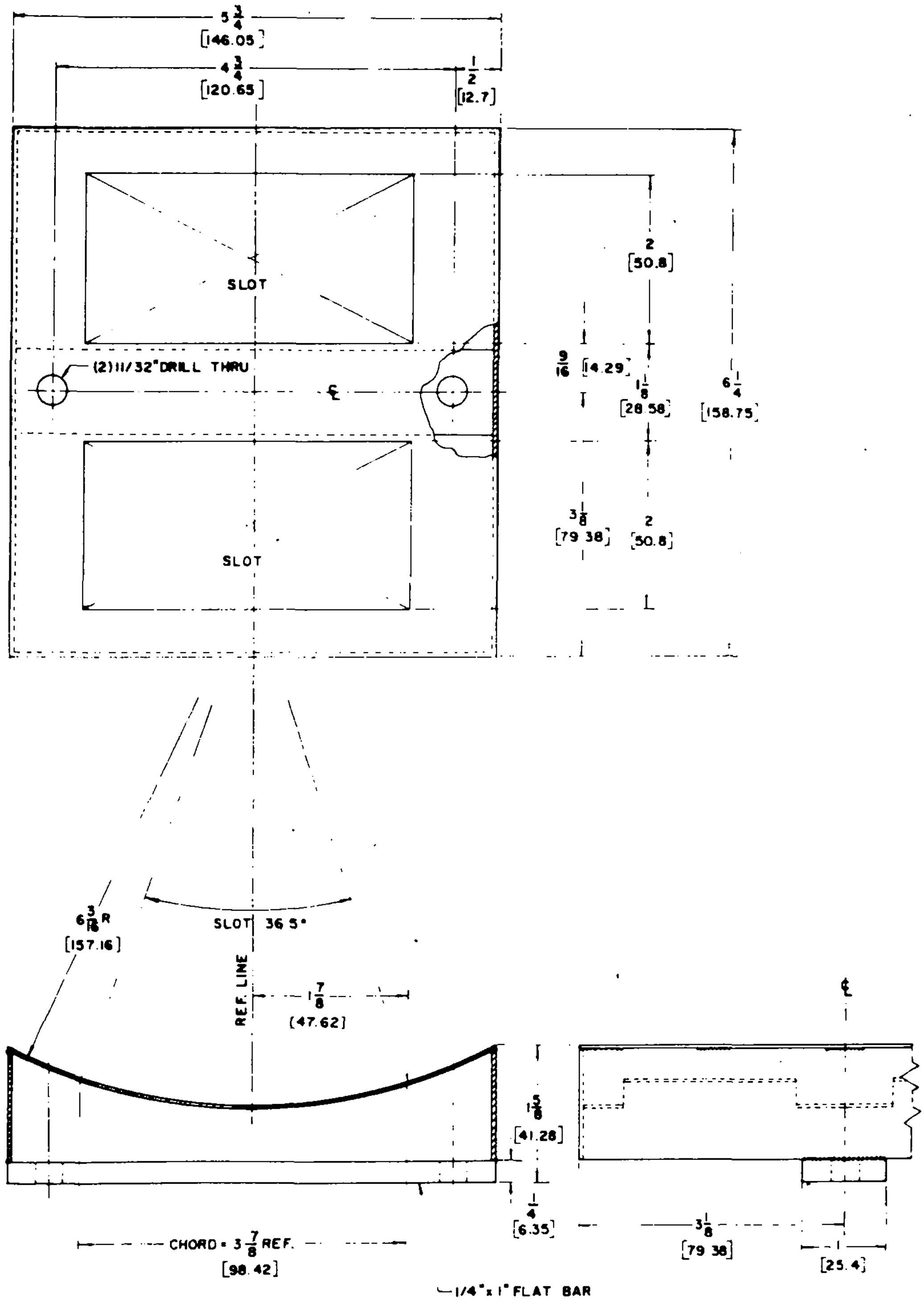


4 DETAIL OF CYLINDER

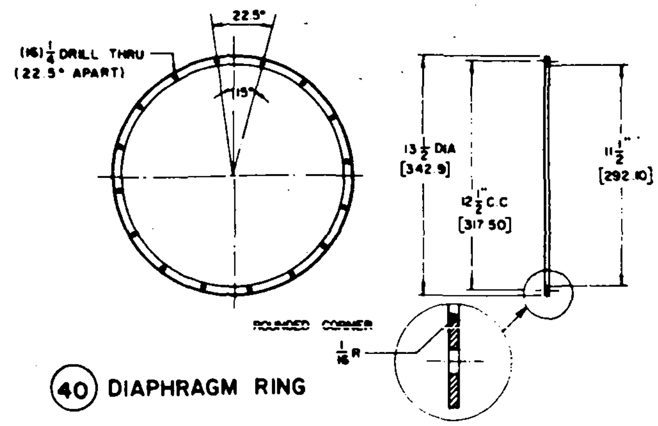
REF	NAME	REQD	MATERIAL	REF	NAME	REQD	MATERIAL
23	STOPPER BLOCK	2	2" x 2" x 15" HARD WOOD	46			
22	STAND BRACE	2	1/8" x 1" FLAT BAR	45	CENTER PLATE	1	14 GA B.I. SHEET
21	STAND BRACE	2	1/2" B.I. PIPE SCH 40	44	CARRIAGE BOLT 5/16" x 2 1/2"	8	STANDARD
20	FOOT PEDAL ARM	2	3/4" B.I. PIPE SCH 40, OD=1.05	43	CARRIAGE BOLT 1/4" x 1 1/2"	6	STANDARD
19	FOOT REST BOARD	2	HARD WOOD, 1" x 4" x 13 7/16"	42	NUT, HEXAGON 1/4" - 20 NC	62	STANDARD
18	STIFFENER	2	16 GA B.I. SHEET	41	BOLT, HEX HEAD 5/16" - 18 NC	4	STANDARD
17	PLUNGER BRACKET	2	14 GA. B.I. SHEET	40	DIAPHRAGM RING	2	1/8" THK M.S. PLATE
16	INNER CENTER PLATE	2	16 GA B.I. SHEET	39	PIVOT FOOT PEDAL	2	3/4" DIA C.R.S.
15	BOLT, HEX HEAD, 1/4" - 20 NC	44	STANDARD	38	LEG CYLINDER	2	14 GA B.I. SHEET
14	BOLT, HEX HEAD, 5/16 - 18 NC	8	STANDARD	37	VALVE GUIDE	2	16 GA B.I. SHEET
13	NUT, HEXAGON, 5/16" - 18 NC	12	STANDARD	36	CLAMP BOLT	2	5/16"-18 NC 2 1/4" BOLT HEX
12	PLAIN WASHER 5/16" I.D.	30	STANDARD	35	BOLT HEX HEAD, 5/16 - 18 NC	4	STANDARD
11	VERTICAL STAND	2	HARD WOOD, 2" x 2" x 43"	34	NUT, HEXAGON, 5/16 18 NC	4	STANDARD
10	HANDLE	1	HARD WOOD, 2" x 2" x 43"	33	PLUNGER BUSHING	4	1/4" B.I. PIPE SCH 40, OD=.54
9	PLAIN WASHER 1/4" I.D.	4	STANDARD	32	BOLT HEX HEAD, 5/16" - 18 NC	4	STANDARD
8	WING NUT, 5/16" Ø	4	STANDARD	31	CARRIAGE BOLT 5/16" x 4	2	STANDARD
7	DISCHARGE CHAMBER BOLT	4	STANDARD	30	NUT, HEXAGON, 5/16" - 18 NC	4	STANDARD
6	DISCHARGE CHAMBER	1	16 GA B.I. SHEET	29	PLAIN WASHER 5/16" I.D.	4	STANDARD
5	VALVE	1	RUBBER 3/16" THK	28	INTAKE VALVE SEAT & CLAMP	1	16 GA B.I. SHEET
4	CYLINDER	1	16 GA B.I. SHEET	27	VALVE	1	RUBBER, 3/16" THK
3	INNER TIRE TUBE	2	TIRE TUBE (SIZE 9.00 x 20)	26	BOLT HEX HEAD 5/16" - 18 NC	4	STANDARD
2	OUTER CENTER PLATE	2	16 GA B.I. SHEET	25	CARRIAGE BOLT 5/16" x 4 1/2	6	STANDARD
1	PLUNGER	2	1/4" B.I. PIPE SCH 80, ID=.546	24	BASE	2	HARD WOOD, 2" x 2 1/2" x 48"



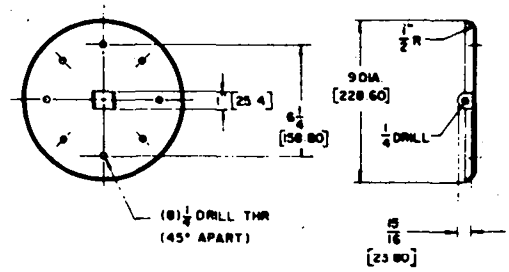
(6) DISCHARGE CHAMBER



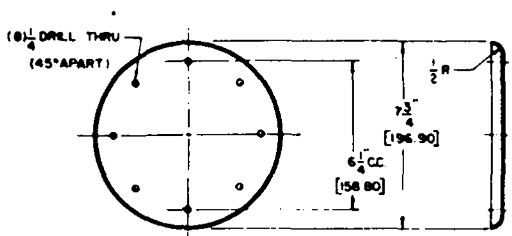
(28) INTAKE VALVE SEAT and CLAMP



(40) DIAPHRAGM RING



(2) OUTER CENTER PLATE



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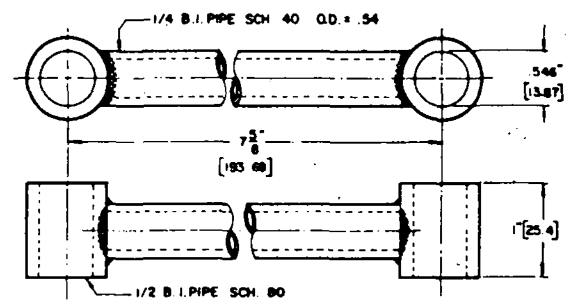
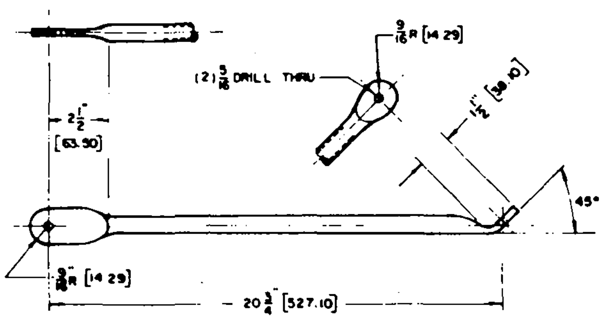
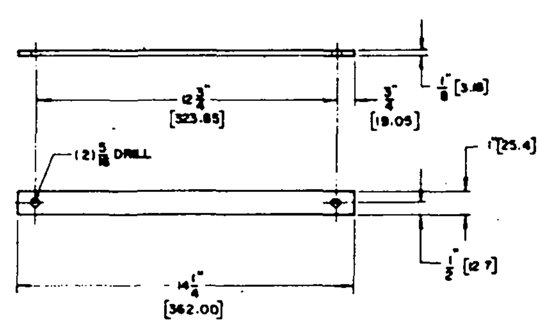


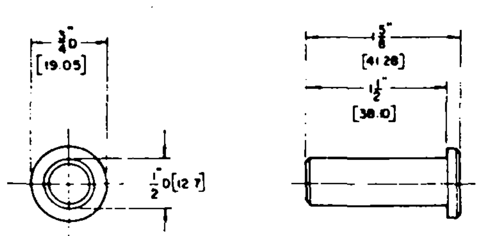
(1) PLUNGER



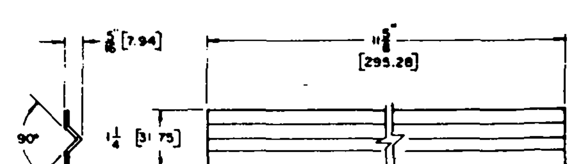
(21) STAND BRACE



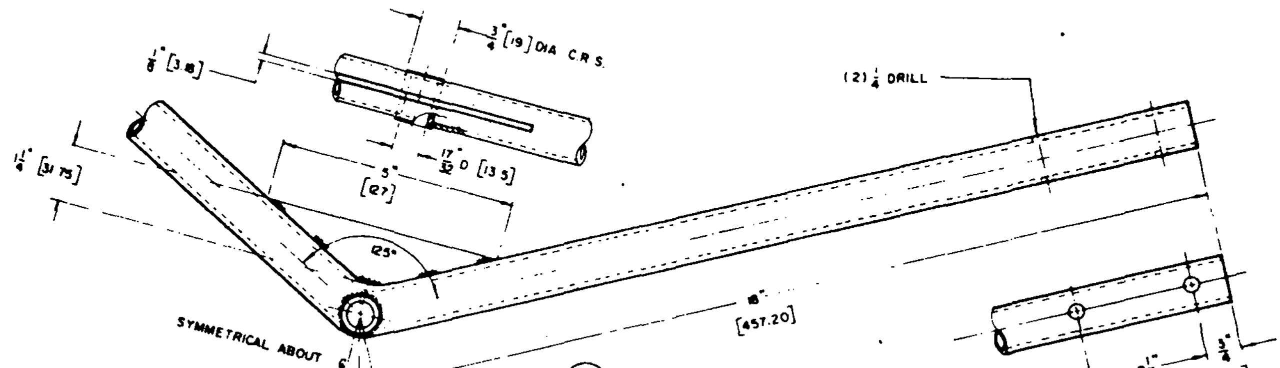
(22) STAND BRACE



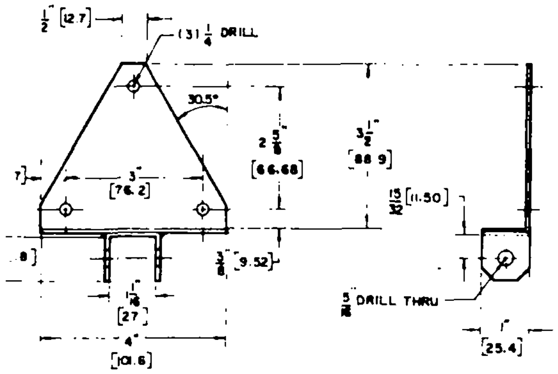
(39) PIVOT FOOT PEDAL



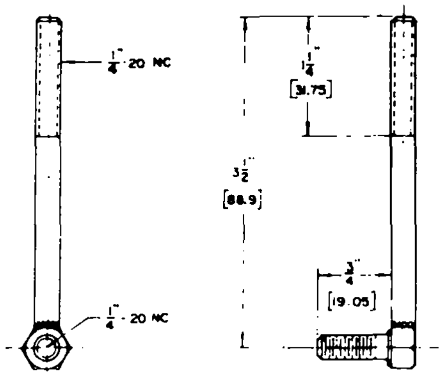
(18) STIFFENER



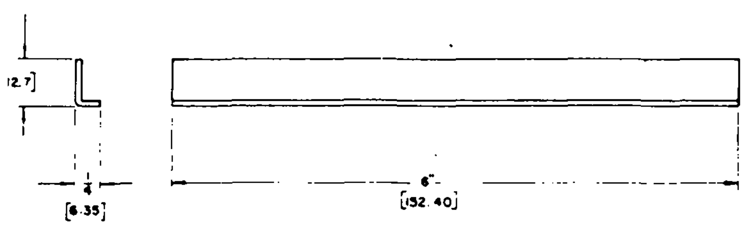
(20) FOOT PEDAL ARM

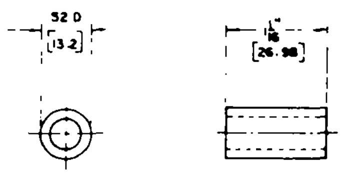


(17) PLUNGER BRACKET



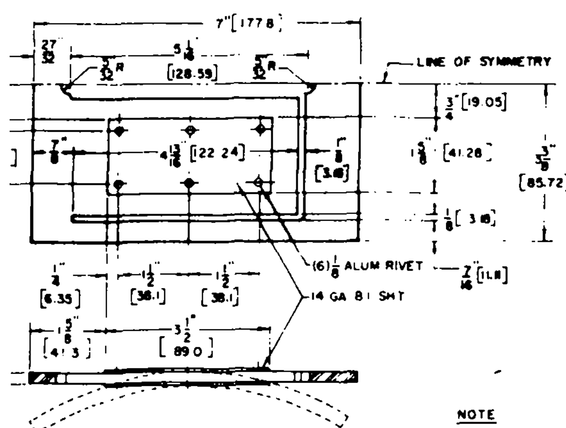
(7) DISCHARGE CHAMBER BOLT





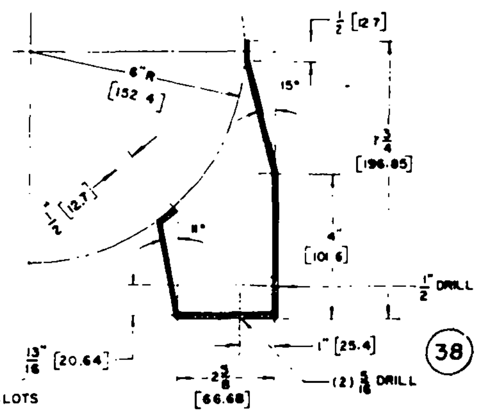
(33) PLUNGER BUSHING

(37) VALVE GUIDE



(27) VALVE (stretchout pattern)

NOTE
TO BE FORMED (SHOWN BY DASH LINE) TO FIT THE SLOTS ON THE CYLINDER



(38) LEG CYLINDER

II THE BELLOW PUMP

The idea of a very simple water lifting device utilizing a pair of flexible bellows as the pumping element was originally evolved at the International Rice Research Institute (IRRI), Philippines, where a prototype pump design was developed for use in irrigation 1/. The bellow pump investigated in this study was a modified version of the original design and was constructed at the Asian Institute of Technology.

2.1 Pump Description

The IRRI design was such that the pump body needed to be partially submerged during operation. Since this might not often be desirable for pumping from the usual sources of surface water supplies the design of the pump was modified by providing external suction lines to deliver water to the bellows. Foot-valves on suction lines were substituted for the flapper valves provided in the IRRI pump. Fig. 2.1 schematically illustrates the pump configuration adapted for the present work.

The basic components of the bellow pump consisted of:

- a supporting frame and a base plate
- a pair of metal-reinforced flexible canvas bellows
- a discharge box
- a pair of suction lines and foot-valves, and
- a pair of foot rests

The bellows constituted the basic pumping element and consisted of an outer layer of cotton canvas and an inner layer of rubber lining stuck together with rubber cement. The rubber lining served to render the bellows impermeable while the cotton canvas sheet was tough enough to withstand the pressures generated during pumping. The bellows were reinforced with galvanized-iron (GI) metal plate inserts between the inner and outer layers to prevent it from deforming during operation. The bellows were supported at the bottom by the base plate fixed to the wooden frame. The suction lines deliver water to the bellows and these discharge into the discharge box which in turn is connected to the delivery pipe.

The base plate as well as the discharge box having a volume of about 3 ℓ were made of GI sheets. Flow of water between the bellows and the discharge box was controlled by a pair of flapper values also made of GI sheets, lined with cotton canvas. During compression of the bellows the flapper valves open and allow water to flow up into the discharge box. The valves close during the suction stroke preventing water from flowing back into the bellows from the discharge box. The discharge box was provided with a 5 cm spout to which the delivery pipe was connected.

The foot-valves for the suction lines were 2.5 cm in diameter and were procured from the local markets. These being standard fittings for the conventional types of pumps, are easily available in most areas. The foot rests for the operator to stand on while pedalling the pump were made of wooden planks.

Detailed specifications for the component parts of a prototype pump model are shown in Fig. 2.2 to Fig. 2.9.

2.2 Pump Operation

The bellow pump is easy to operate. The operator stands on the foot-rests and merily shifts his weight from one foot to the other thus expanding one bellow while compressing the other. The expanding bellow sucks in water from the source while that in compression forces water out into the discharge box. By alternatively shifting his weight in a rythmic manner, the operator pumps a continuous flow of water. Fig. 2.10 shows the pump in operation.

1/ KHAN, A.M. and DUFF, B. (1975), Agricultural Mechanization Technology Development at the International Rice Institute, Special Report, The International Rice Research Institute, Los Banos, Laguna, Philippines.

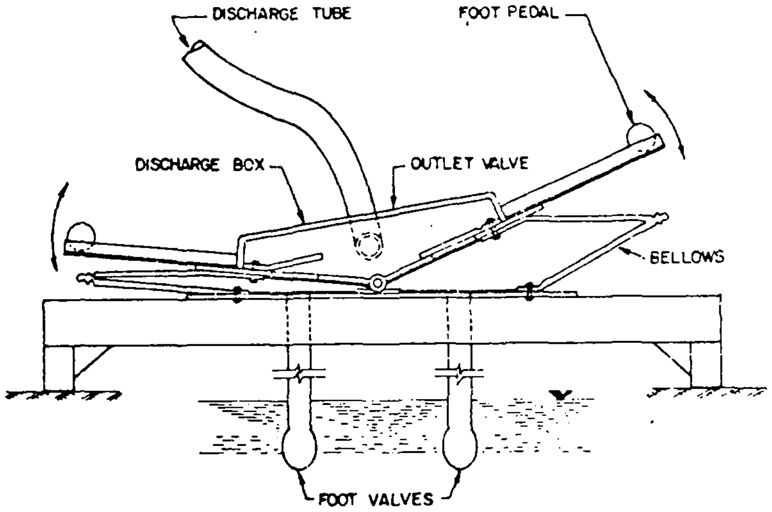
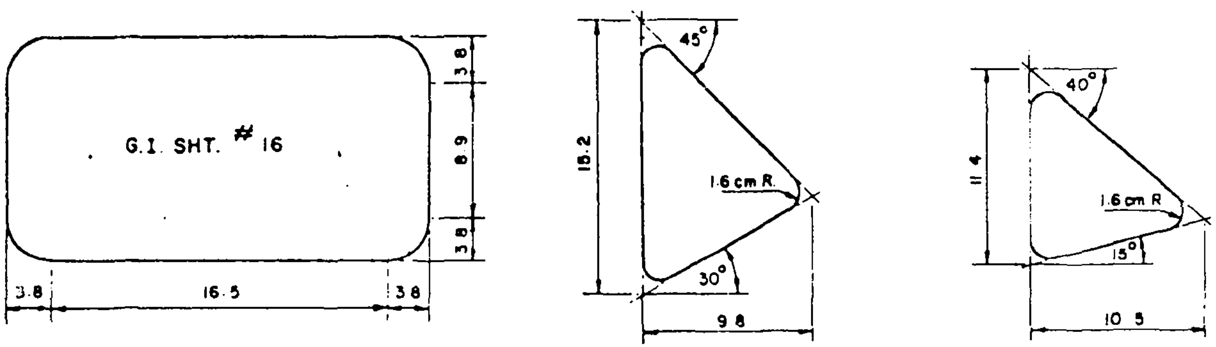
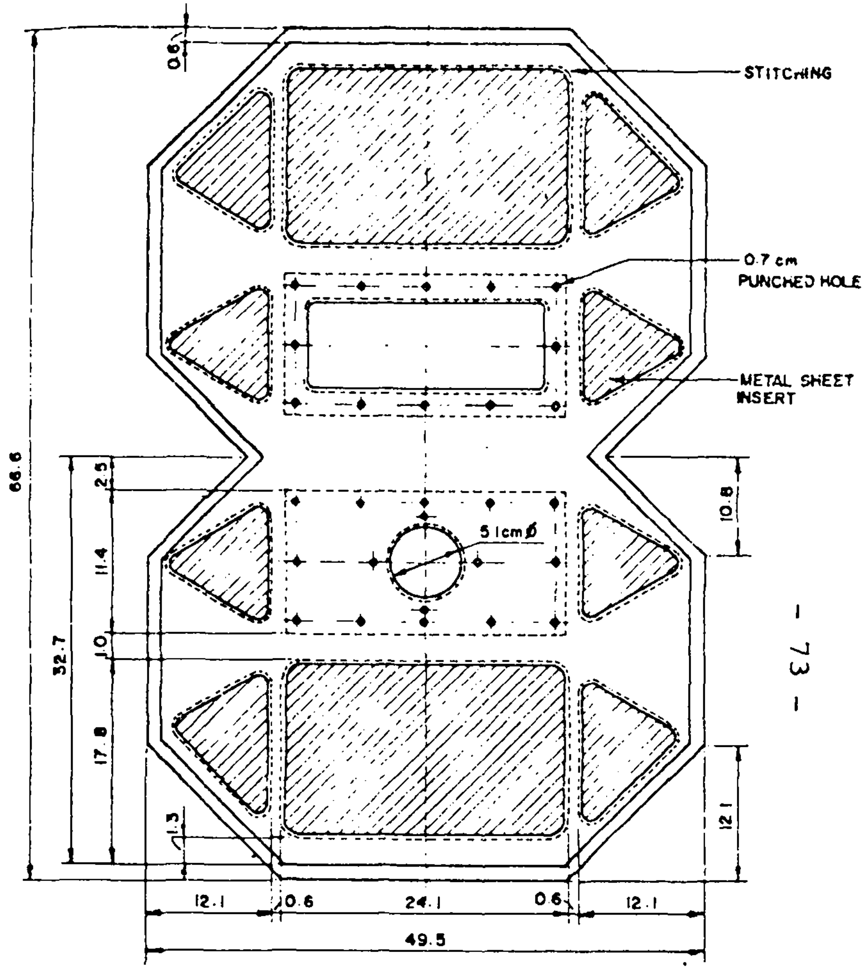


FIG. 2.1 MANUALLY OPERATED BELLOW PUMP
FOR RURAL COMMUNITY WATER SUPPLY



ALL DIMENSIONS ARE IN CENTIMETERS

FIG 2 3 METAL INSERTS FOR BELLOW REINFORCEMENT



ALL DIMENSIONS ARE IN CENTIMETERS

FIG. 2.2 SPECIFICATION OF A BELLOW

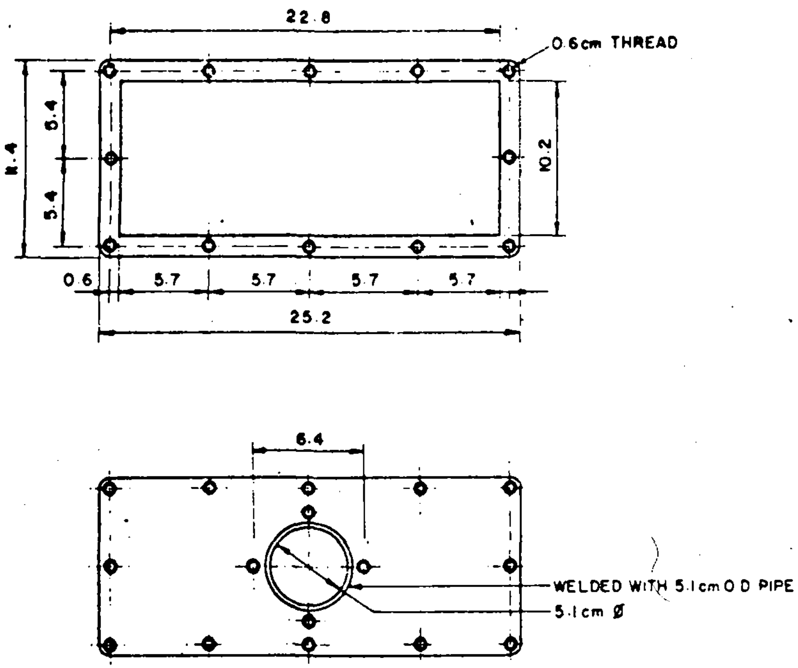


FIG. 2.4 BELOW CLAMPS

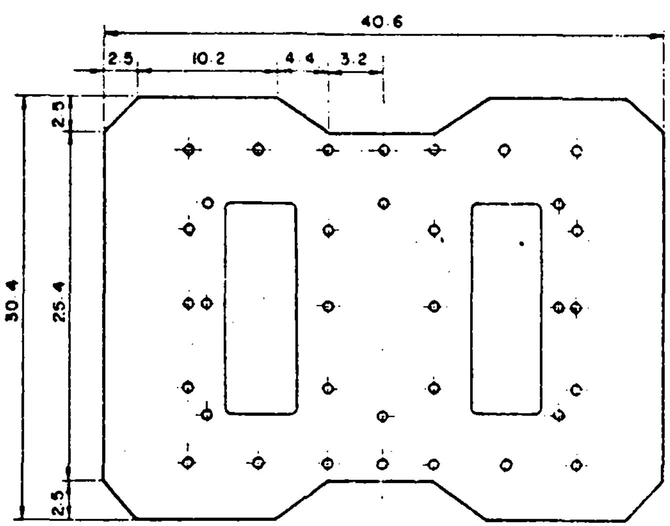


FIG. 2.7 BOTTOM OF DISCHARGE BOX

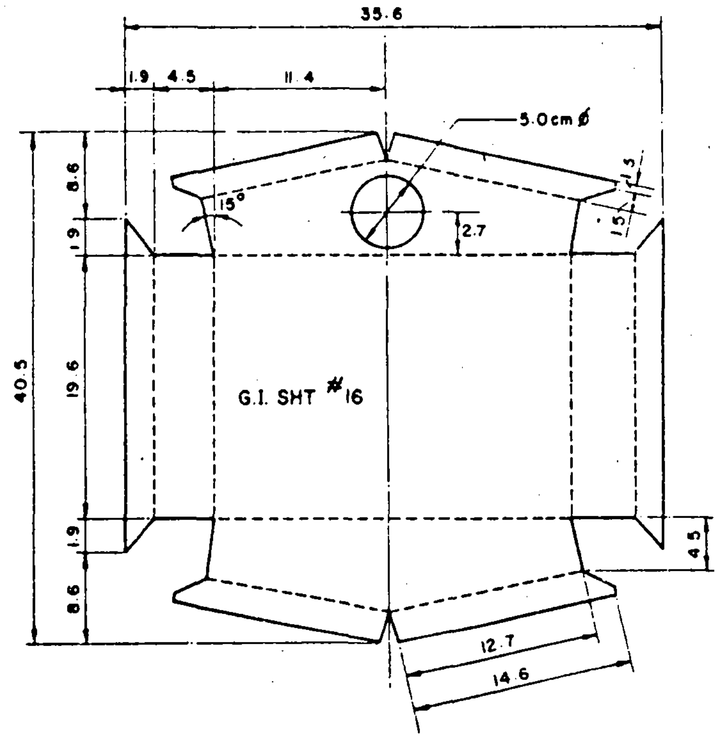


FIG. 2.6 DISCHARGE BOX

ALL DIMENSIONS ARE IN CENTIMETERS

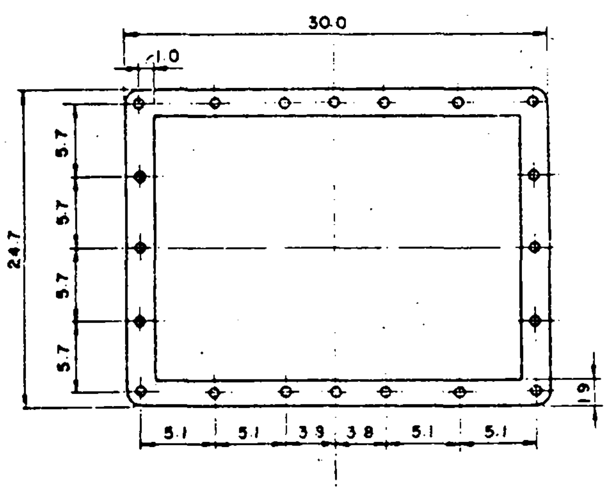


FIG.2.8 RUBBER TIE FOR DISCHARGE BOX

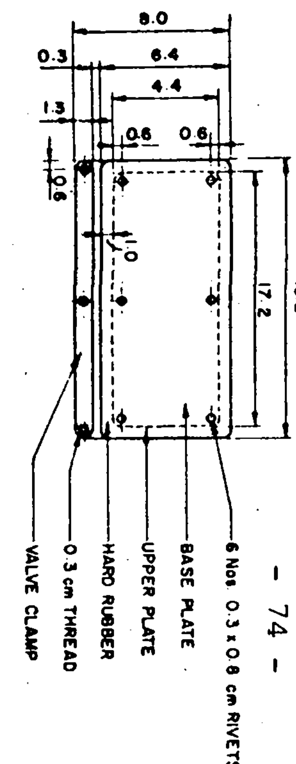


FIG. 2.5 FLAPPER VALVE

ALL DIMENSION ARE IN CENTIMETERS

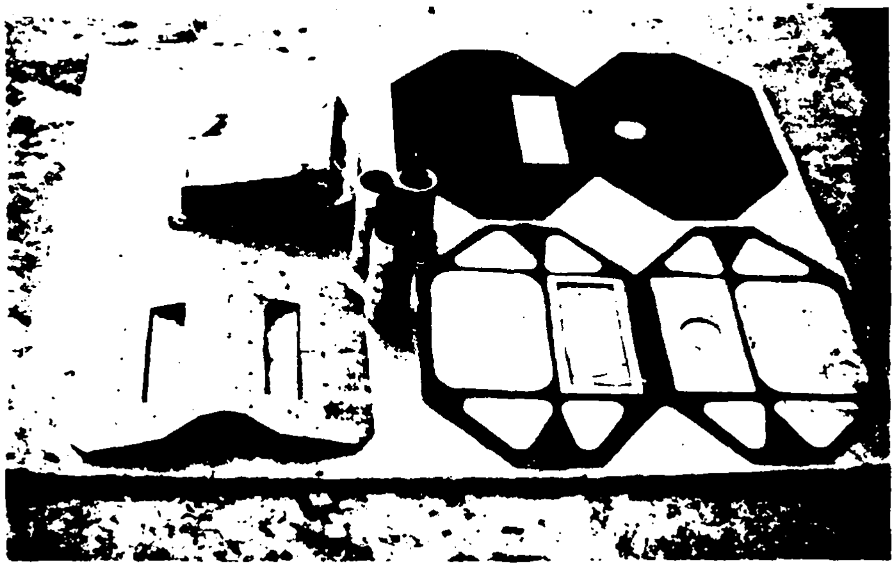


Fig. 2.9 - Anatomy of the Bellow Pump

Fig. 2.10 - Operation of the Bellow Pump

Tests for evaluating the performance of the bellow pump were carried out at the drainage canal of the Regional Engineering Experimental Centre of the Asian Institute of Technology, Bangkok. A labourer was asked to operate the pump and the volumetric discharge capacity of the pump was noted as a function of total static head through which water was lifted. The pump was operated at three levels of static head - 1.5, 2.5 and 3.5 m. Different operators were asked to work the pump, each of them weighing between 50 to 53 kg. Normally a single operator pedalled the pump during each test run, but the increase in pump output when two operators simultaneously worked the pump was also recorded. Initially it took about five minutes for the operator to develop a stroke rythm. Once the operator established the stroke rythm, the pump output was recorded by cumulating the discharge over fifteen minute periods and computing the mean discharge rate from several samples. Continuous operation of the pump for extended periods was tiresome for the operator, but with a five to ten minute rest after every half hour of operation, the pump could be worked over a period of several hours.

2.4 Results and Discussion

For each operating head several test runs were carried out and the mean volumetric discharge rate of the pump recorded when one and two operators pedalling the pump. These data are tabulated in the Appendix A. The results of the tests using a single operator are summarized in Table 2.1. Pump output at 1.5 m head ranged from 77 to 100 ℓ/min with a mean of about 89 ℓ/min. At 2.5 m static lift the range was 73.3 to 76.7 ℓ/min while at 3.5 m head the discharge obtained was between 37.1 and 40.3 ℓ/min. The observed decrease in pump output with increasing head was to be expected since the work done in raising a given quantity of water increases with head while the energy input remains more or less the same. The head-discharge relationship for the bellow pump is presented graphically in Fig. 2.11. It has been estimated that the energy output from sustained human labour is of the order of 0.1 hp This value was used for the average energy input in computing the values of overall efficiency of the pump at various operating heads, shown in Table 2.1 and plotted in Fig. 2.12. The pump efficiency was calculated as follows:

Table 2.1 - Bellow Pump Performance with One Operator*

Total Operating Head m	Mean Volumetric Discharge Rate ℓ/min	Overall Pump Efficiency %
1.5	88.9	29.2
2.5	75.0	41.1
3.5	38.7	29.7

* The operator weighed between 50 and 53 kg.

Table 2.2 - Bellow Pump Performance with Two Operators

Operating Head m	Mean Volumetric Discharge Rate ℓ/min	Increase in Discharge Over that with a Single Operator %
1.5	115	29.4
2.5	94.2	25.6
3.5	49.2	27.1

Useful work done W, in raising Q liters of water per second through a total head of h meters is given by:

$$W = Q \rho h \text{ kg-m/sec}$$

where, ρ = the density of water, kg/ℓ

If the average energy input is taken to be at a rate of 0.1 hp (7.604 kg-m/sec), the overall efficiency is given by:

$$= \frac{Q \rho h}{7.604}$$

It may be noted that the optimum utilization of input energy by the pump occurs when the operating head on the pump is about 2.5 meters. Thus from the point of view of energy economy it would appear best to operate the pump at this head.

Actual operating experience with the pump indicated that the best operating schedule should let the operator rest for five to ten minutes after about 30 minutes of continuous operation. In this way the operator was saved from undue fatigue and could produce a more or less uniform output over several hours of pump operation.

The foot rests of the pump was large enough for two operators to stand on it and simultaneously pedal the pump. The performance of the pump when operated in this manner is summarized in Table 2.2. It was found that operating the pump using two operators simultaneously resulted in only about 27 percent increase in the pump output. Although the operators tired less easily in this arrangement, especially at 3.5 m head, from the point of view of energy economy simultaneous operation by two workers appeared undesirable. Furthermore, the 30 minute operation followed by a 5 to 10 minute rest suggested earlier for a single operator appeared, on the whole, to be quite satisfactory for the optimal operating head of 2.5 m.

Recently THANH and PESCOD [1/] have reported on the development of low-cost series and dual-media filter units for small rural community water supply systems. Each of these units was estimated to serve a population of about 250 people and required the water to be lifted from a surface source through about 4 to 5 meters. Using a figure of 30 ℓpd for the per capita water consumption by rural population, it can be seen that two bellow pumps, considered in this study, arranged in series, each operating at the optimal head of 2.5 m, could deliver the daily water requirement of two filter units (or a population of 500) in 3 to 4 hours of daily operation.

Operational experience with the pump also throws some light on the problems to be expected with this device. Operation at a head exceeding 2.5 m, in addition to quickly exhausting the operator, also resulted in significant leakages along the sticking on the bellows. This could be due to poor sticking which can perhaps be improved with experience. Rusting of the mild steel rod forming the hinge between the bellows was also a problem causing excessive friction loss. This could be largely alleviated by frequently lubricating the hinge and smoother pedalling could be achieved.

2.5 Conclusions

On the basis of the results and discussions presented above it may be concluded that the modified bellow pump developed in this study can form an integral part of small rural community water supply systems in Southeast Asia. The essential characteristic of the pump is the relative simplicity of its construction and maintenance compared to conventional pumps. It is reasonably expected that any necessary repair work can be easily carried out by the village artisans, which would minimize disruption of water supply caused by pump failure. Even where conventional types of pumps are provided as regular equipment, the bellow pump may be used as a dependable and economical stand-by unit. Incorporation of the pump into typical village water treatment systems may require an arrangement of two or more pumps in series in order to achieve the desired lift. The optimal operating head for the pump is about 2.5 m. At this head the pump can deliver approximately 75 ℓ/min, sufficient to satisfy the daily requirement of about 500 people in 3 to 4 hours of operation.

The stitching of the bellows should be done with care in order to achieve water-tightness and minimize leakages. Frequent lubrication of the hinge can control nesting and ensure smoother operation.

1/ THANH, N.C. and PESCOD, M.B. (1976) Application of Slow Filtration for Surface Water Treatment in Tropical Developing Countries, Research Report No. 65, Asian Institute of Technology, Bangkok.

from: "Design of Simple and Inexpensive Pumps for Village Water Supply Systems"

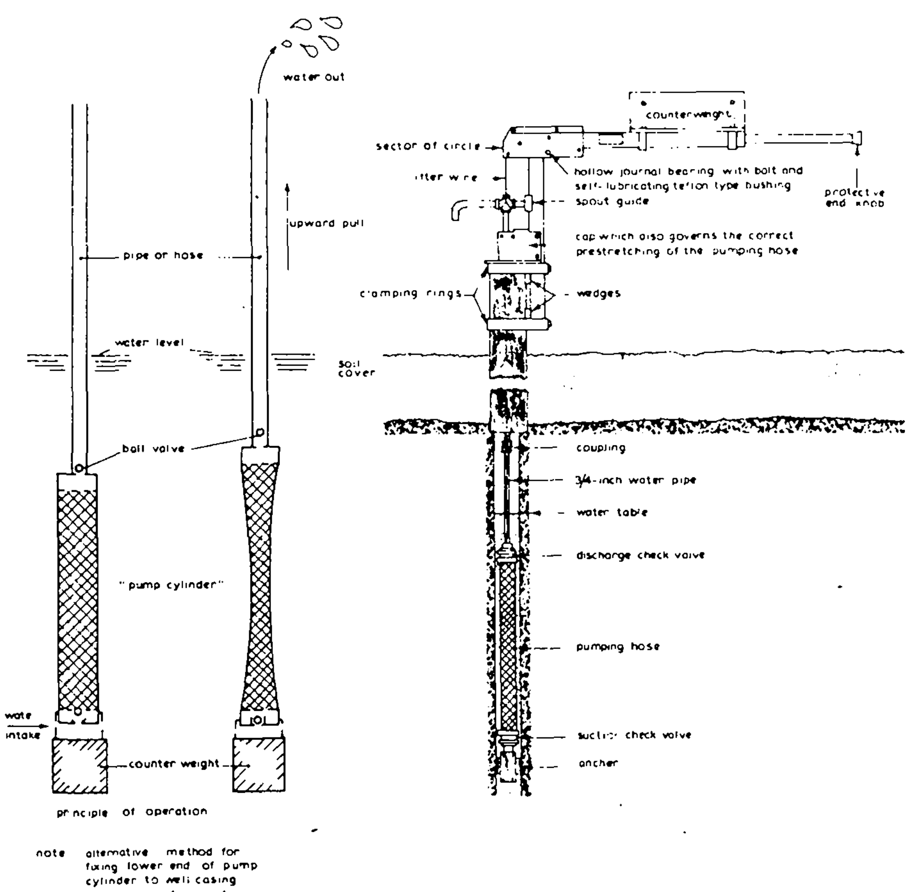
Enclosures to No. 9.

The Petro Pump (Sweden)

An interesting new variation of the diaphragm pump, suitable for use in deep wells, is the Petro pump. The pumping element or 'cylinder' consists of an elastic rubber hose, reinforced by two layers of spirally wound brass-coated steel and equipped with a stainless steel check valve of the poppet type at each end. The suction valve housing at the lower end of the hose is fixed within the well by expander jaws which are wedged against the well casing, and which can be disengaged by turning the pipe string a dozen turns clockwise. The discharge valve housing is attached to a string of ¾-inch (19 mm) galvanized pipe serving as both the pump connecting rod and the drop pipe. The upper end of the pipe string with the delivery spout is connected to the pumping head.

A new pumping head has been specially designed to work in correct conjunction with the elastic characteristics of the pumping hose, but a traditional pumping head may also be suitable.

The discharge capacity of the standard pumping element is approximately 0.5 liter per 10 cm (4-inch) stroke, and can be increased by using a longer hose. The 'Petro' pump can be made in small diameters.



note alternative method for fixing lower end of pump cylinder to well casing is by use of expanding wedges or jaws

The 'Petro' pump is operated as follows:

(1) Push down the handle, thereby lifting the pipe string and stretching the reinforced rubber hose approximately 10 cm (4 inches).

(2) Due to the effect of the spirally wound steel wires, the hose decreases in volume (displacement); the increased pressure within the hose opens the discharge valve, and water is forced through the pipe string to the surface.

(3) On the return stroke of the handle, the rubber hose retracts to its original, larger volume; the suction check valve opens, and fresh water is sucked in.

Obvious advantages of this new pumping concept are:

(1) The elimination of the usual cup seals or buckets. There is practically no mechanical friction during pumping, and water containing fine sand or silt may be pumped without appreciable wear to the pumping hose.

(2) The combining of pump rod and drop pipe results in considerable savings in piping. The relatively low weight of the required piping facilitates installation, inspection and maintenance. It is claimed that the pumping element together with the string of pipes can be readily installed by hand, so that no tripod, scaffolding or installation truck will be needed.

(3) No stuffing box is needed, when the pump is used as a force pump.

At present (June 1977), two types of the 'Petro' pump are commercially available:

- Type 95, with standard wedges, suitable for wells of 4 to 4½ inch (95 to 120 mm).
- Type 48, suitable for 2-inch wells (diameter 48 to 60 mm).

The latter type should be of particular interest for use in small-diameter wells with the water table deeper than 22 feet (6.7 meter), i.e. where suction pumping is not practicable.

The price for one complete pump (pumping element with anchor, and pumping head) is: Swedish Kronor 2.000 (U.S. $ 440).

Shipping weight of a complete pump is only 43 kg (95 lbs) which should save on transport costs.

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.

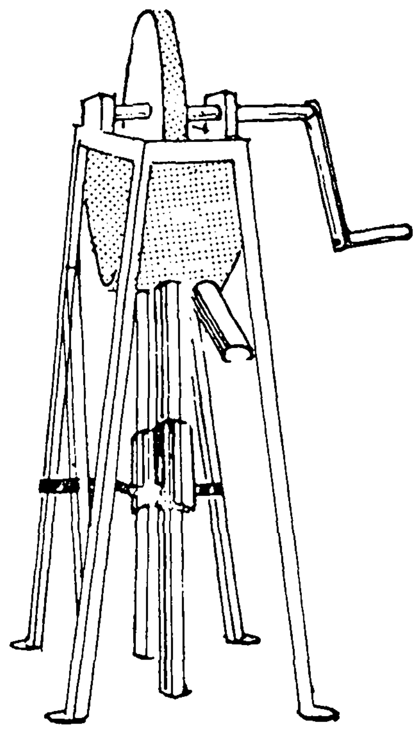


FIGURE 1

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.

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.

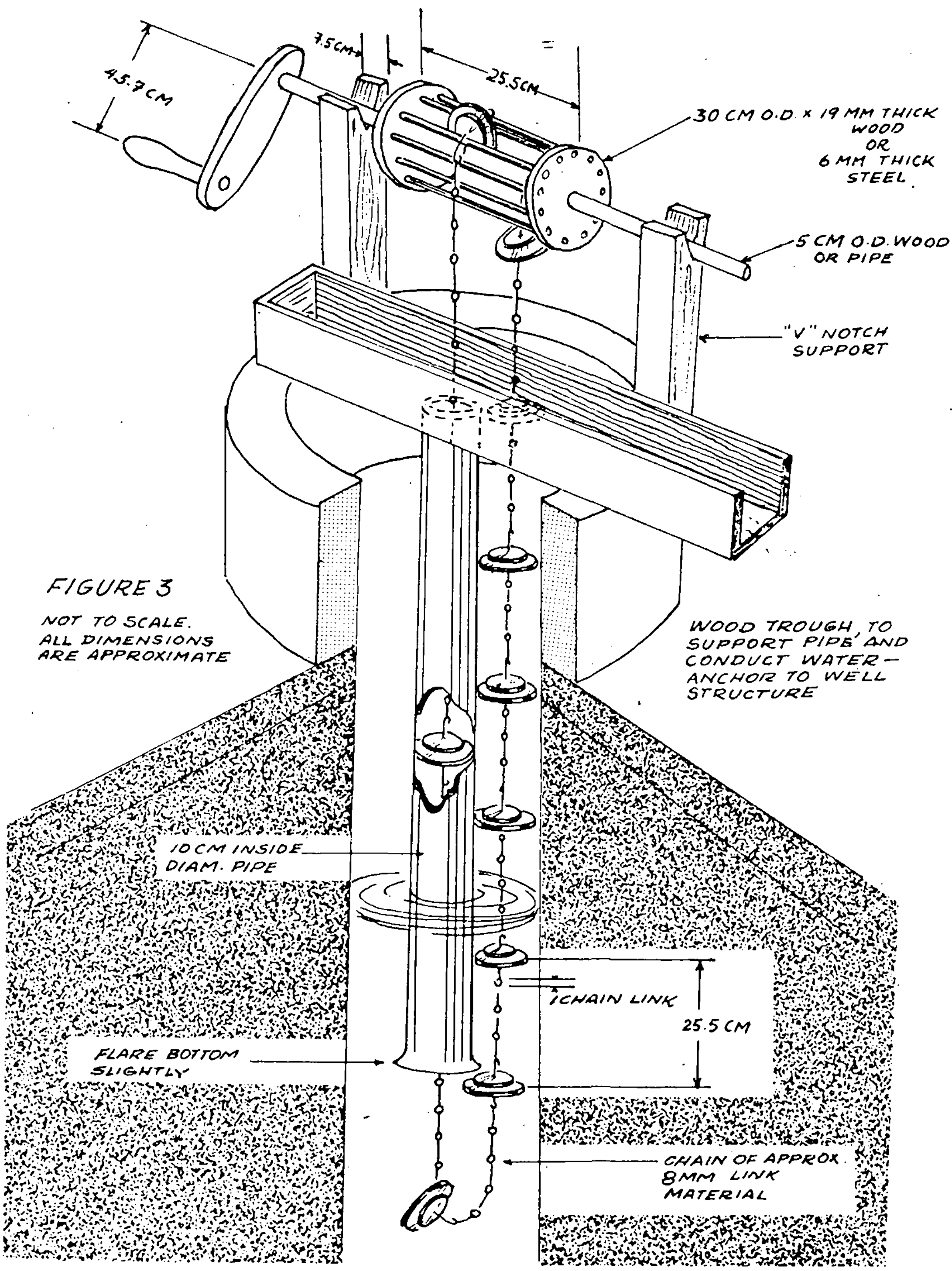


FIGURE 3

NOT TO SCALE. ALL DIMENSIONS ARE APPROXIMATE

FIGURE 4
LEATHER WASHER

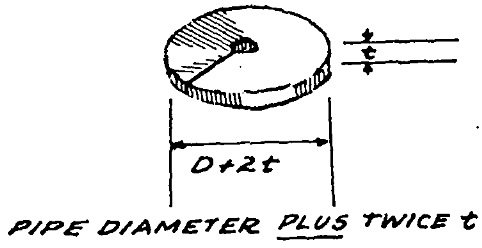


FIGURE 5

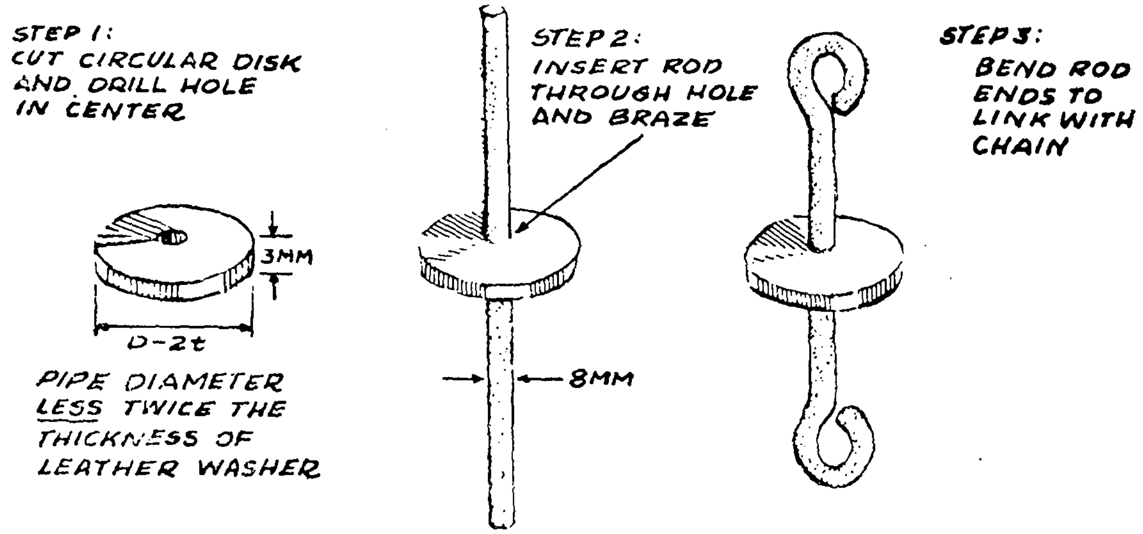


FIGURE 6
RETAINING PLATE

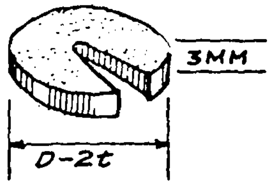


FIGURE 7
PISTON LINK
ASSEMBLED

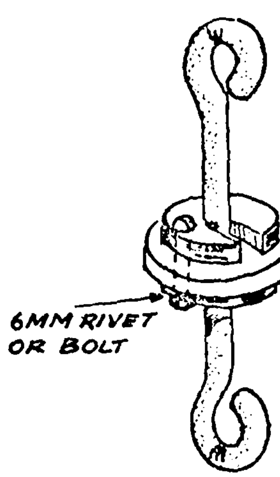
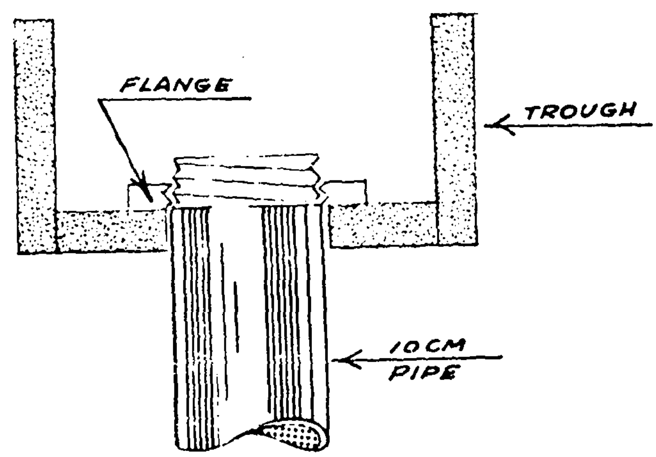
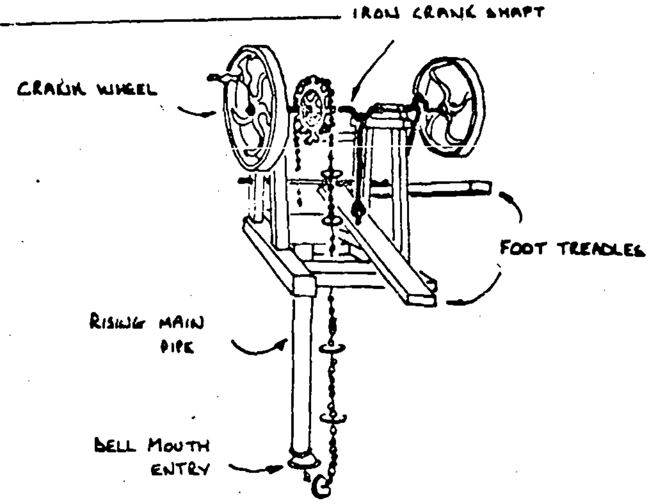


FIGURE 8 PIPE SUPPORT

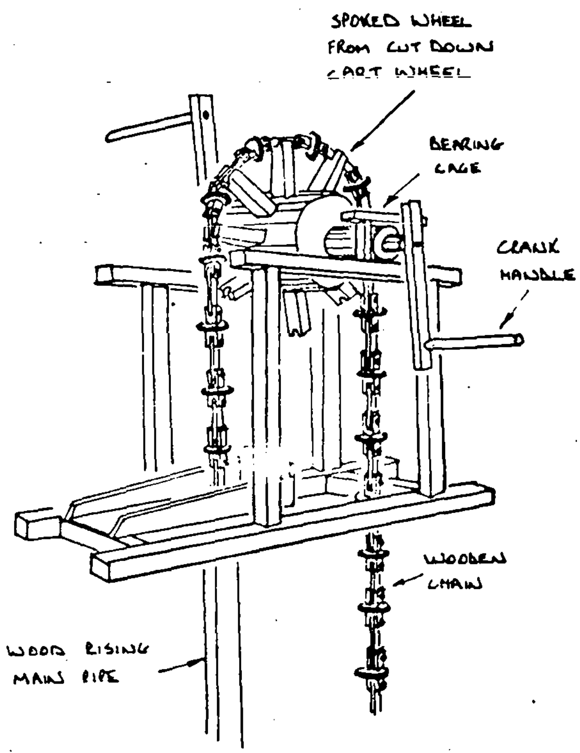


Examples of Chinese Chain Pumps

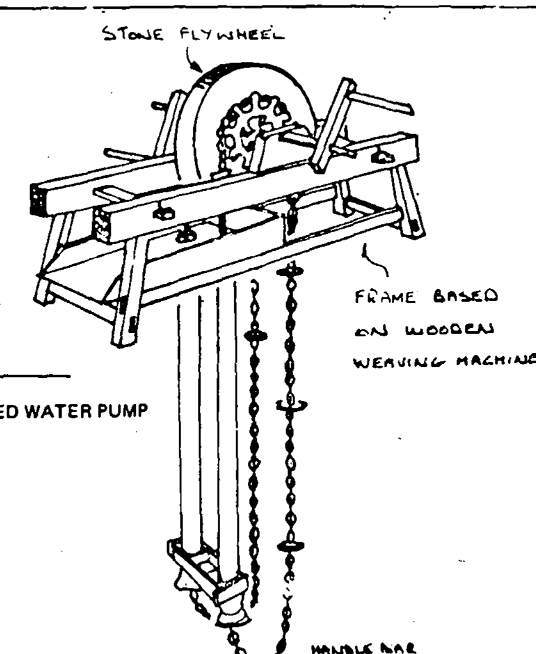
Ref.: "Chinese Chain and Water Pumps" by S. Watt,
ITDG, London, April 1976



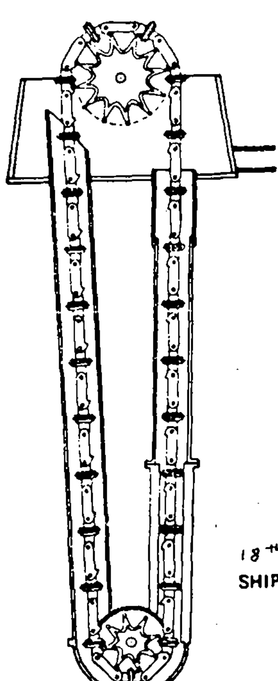
DUAL-DRIVE THREE WHEELS PUMP



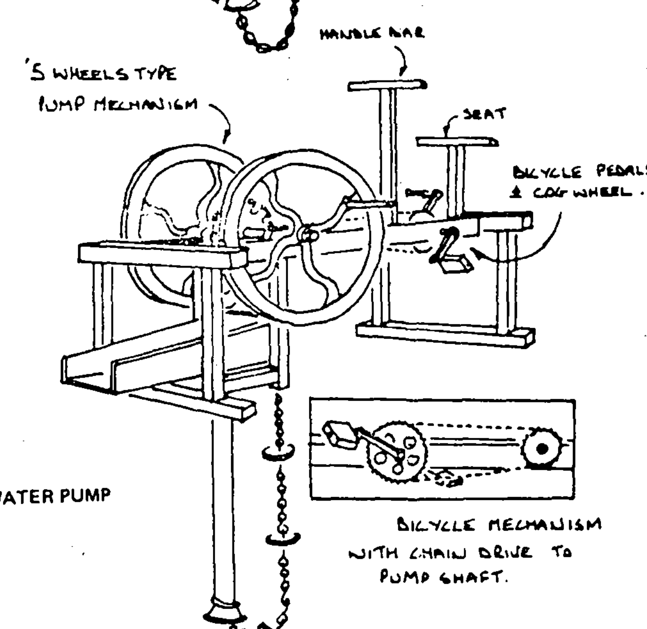
HAND OPERATED – SPOKED WHEEL WATER PUMP



DOUBLE PIPE HAND OPERATED WATER PUMP



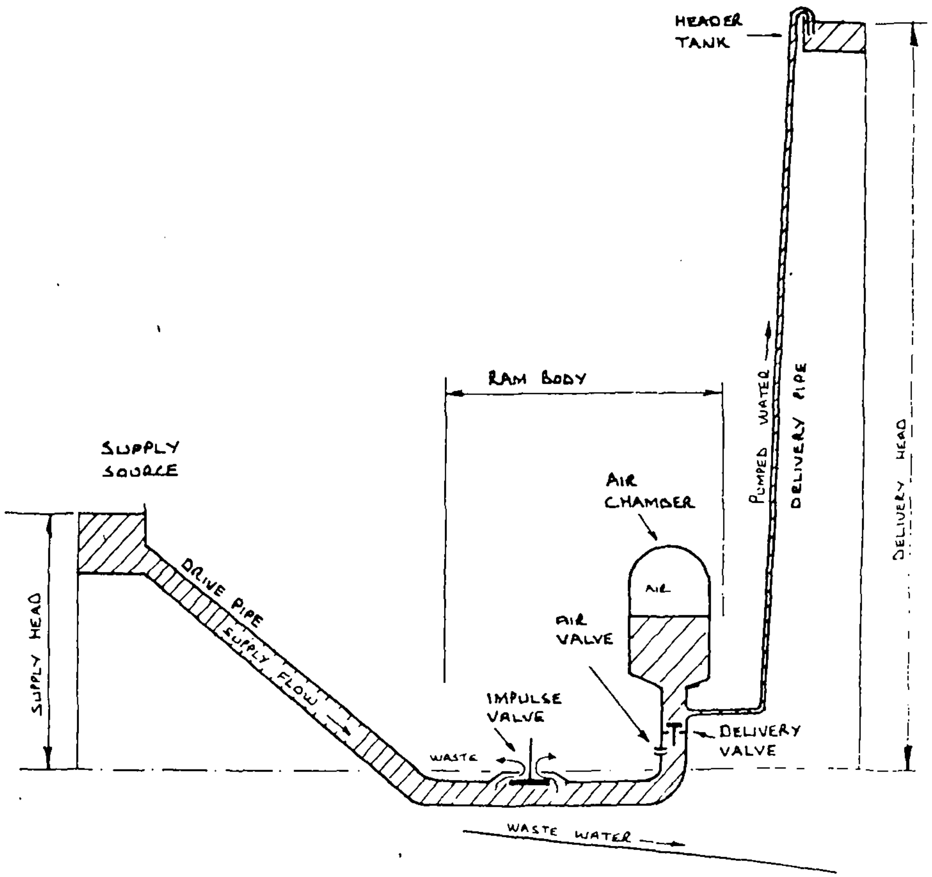
18th CENTURY
SHIP'S CHAIN PUMP



CYCLE TYPE WATER PUMP

HYDRAULIC RAM

FIG.1 THE ARRANGEMENT OF A TYPICAL RAM ASSEMBLY



The vertical distance between two water levels is known as the 'head' of water available and is a measure of the water pressure. For instance, the pressure in the ram body when it is full of water and not pumping, is known as the supply head: similarly the pressure in the air chamber with the delivery valve closed, is the delivery head.

1. A Description

The automatic hydraulic ram is used for pumping water. It works by pumping a small fraction of the water that flows through it from a supply source, to a level that can be much higher than the source. The ram can only be used in places where there is a steady and reliable supply of water, with a fall sufficient to operate the ram.

The ram described in this manual needs to have a fall of at least 1 metre from the source to the ram, and a flow at the source greater than 5 litres per minute. The amount of water that it can pump to different heights is given in Table 1. (Page 7)

In places where this ram can be used, it has many advantages over other pumps powered by hand, animal, wind, or motors, despite the fact that it wastes a lot of water:-

a) it does not need an additional power source and there are no running costs,

b) it has only two moving parts, and these are very simple and cheap to maintain,

c) it works efficiently over a wide range of flows, provided it is tuned in correctly,

d) it can be made using simple work shop equipment.

2. How it works

A labelled diagram o a typical working ram installation is shown in Fig. 1.

Water flows down the drive pipe from the source and escapes out through the impulse valve. When the flow of water past the impulse valve is fast enough, this flow and the upward force on the valve causes the valve to shut suddenly, halting the column of water in the drive pipe. The momentum of the stopped column of water produces a sudden pressure rise in the ram, which will, if it is large enough, overcome the pressure in the air chamber on the delivery valve, allowing water to flow into the air chamber and then up to the header tank.

The pressure surge or hammer in the ram is partly reduced by the escape of water into the air chamber, and the pressure pulse 'rebounds' back up the drive pipe producing a slight suction in the ram body. This causes the delivery valve to close, preventing the pumped water from flowing back into the ram. The impulse valve drops down, water begins to flow out again, and the cycle is repeated.

A small amount of air enters through the air valve during the suction part of the ram cycle, and passes into the air chamber with each surge of water up through the delivery valve. The air chamber is necessary to even out the drastic pressure changes in the ram, allowing a more steady flow of water to the header tank. The air in the chamber is always compressed, and needs to be constantly replaced as it becomes mixed with the water and lost to the header tank.

The ram is 'tuned' to pump the greatest amount of water possible, and this normally occurs when the ram cycle is repeated or 'beats' about 75 times each minute.

3. Is your site suitable for the ram?

You can install this ram at your site without doing any survey work to measure the flow of water at the source, or the supply and delivery heads at the site, and it will probably work perfectly well. However, it is often necessary to know if the ram is capable of pumping the amount of water you need, or whether you need a larger ram. Measuring for this information is not difficult, and is described below.

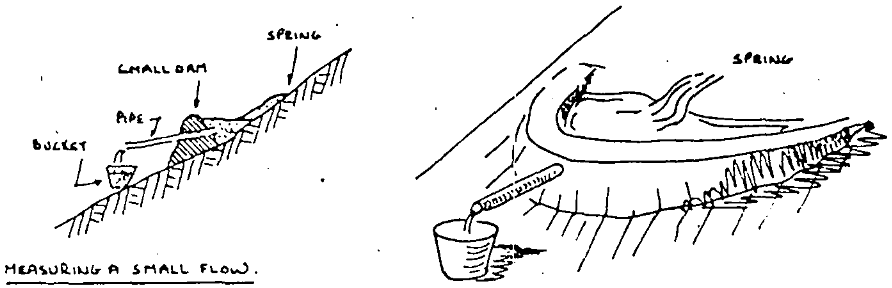
3.1 MEASURING THE FLOW OF WATER AT THE SOURCE.

The first thing you must measure, is the flow of water at the source, to see if it is enough to operate the ram; some people with experience can estimate this by eye.

Naturally occuring sources of water tend to dry up during the year, and you must make allowance for this if you use your measurement of water flow to calculate the pumping rate of the ram, otherwise your water supply may be less than you planned for.

a) Measuring a small flow, such as a spring.

When the flow is very small, you can measure it by constructing a temporary dam, and catching the water in a bucket. The amount of water (in litres) that flows into the bucket in one minute can then be measured. The dam may be made from any material, wood, metal sheet, planks etc., but you must make sure that there are no leaks:-

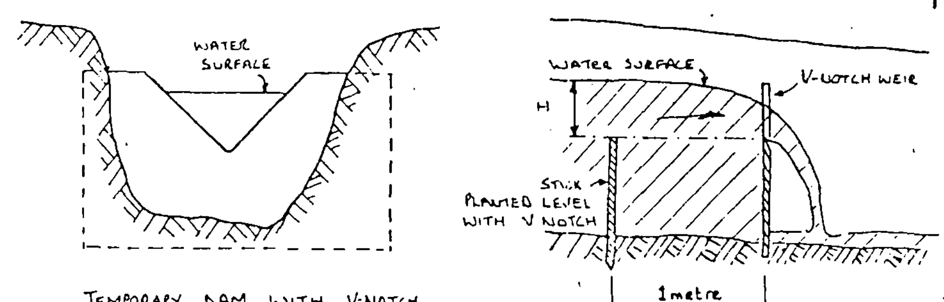


a) MEASURING A SMALL FLOW.

b) Measuring larger flows.

The ram described in this manual requires only a small amount of water to make it work, and often you can see by looking if the flow is large enough. However, if you are going to make or buy an expensive larger ram, it is essential to know how much water there is to be taken from the source.

Larger flows are measured using a timber plank or ply wood weir, with a 90° V-notch cut into the top:-



TEMPORARY DAM WITH V-NOTCH.

MEASUREMENT OF WATER DEPTH H ONE METER UPSTREAM FROM V-NOTCH WEIR.

b) MEASURING LARGER FLOWS

The depth of water flowing through the weir is measured about 1 metre upstream of the weir, and you can then use the graph in Figure 2 to read how much water is flowing

Example.

Depth of water measured 1 metre upstream = 10 cms.
From graph, the flow is then read as 275 litres/min.

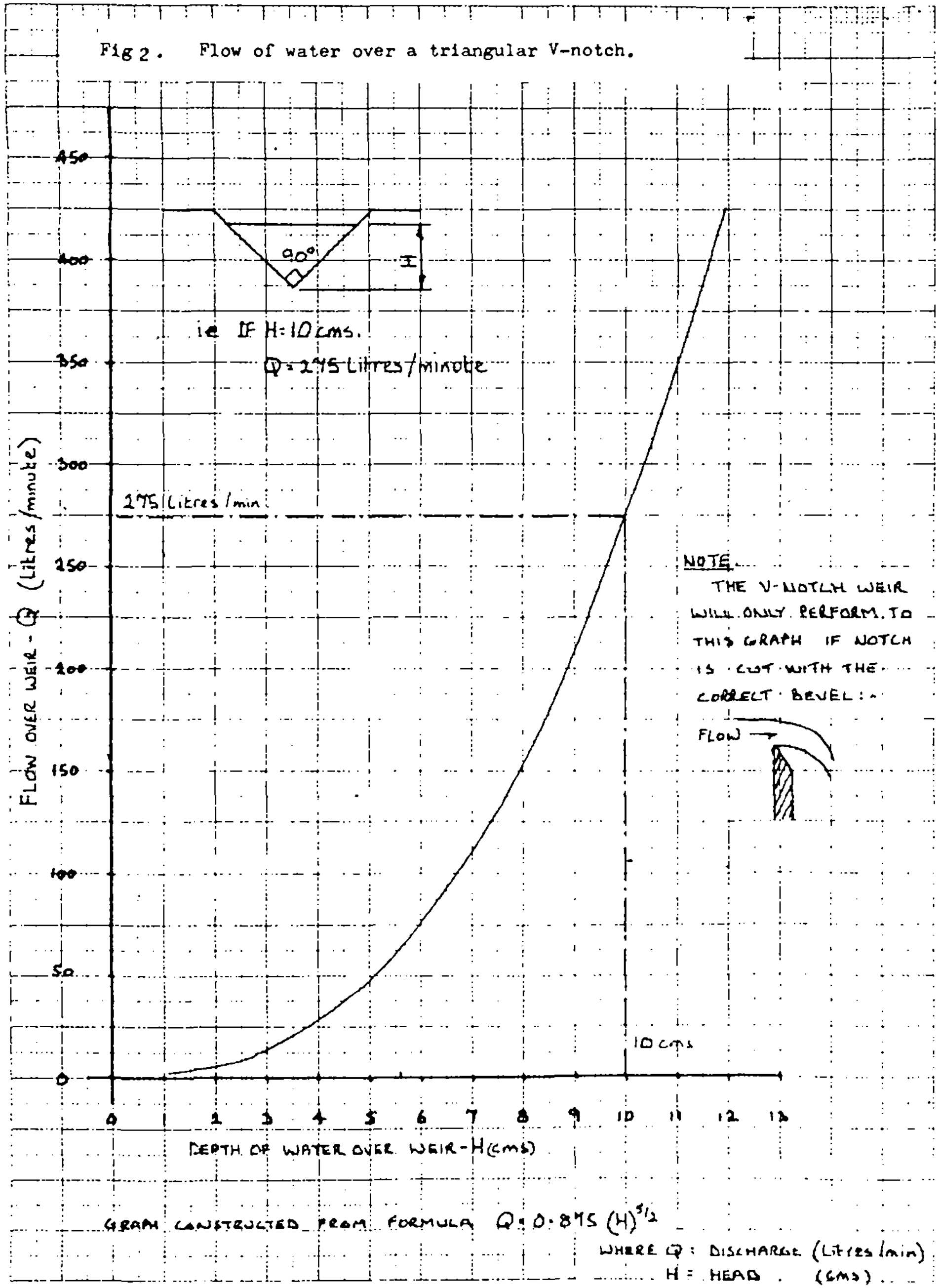
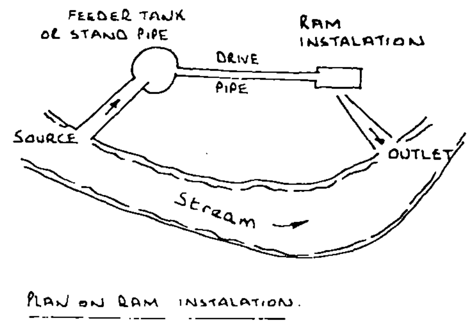


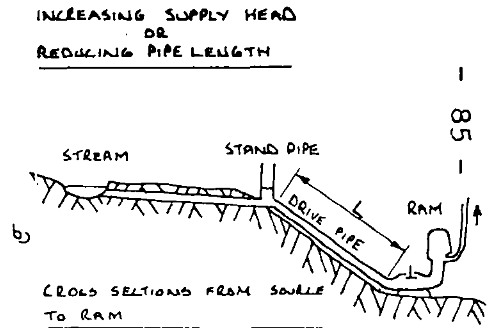
Fig 2. Flow of water over a triangular V-notch.

The weir must not leak around its sides, and the graph can only be used if all the water flow is contained within the notch.

3.2 MEASURING THE SUPPLY AND DELIVERY HEADS.

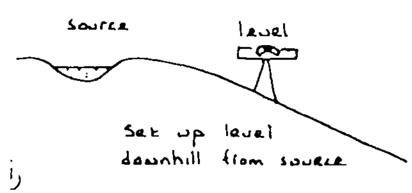
Most rams will work at their best efficiency if the supply head is about one third of the delivery head, but often the site will not allow this, and you must then try to make the supply head as large as possible; this will be necessary if the source is a slow moving stream or river which has a shallow slope. The supply head can be increased by leading the water from the supply source along a feeder canal or pipe to the drive pipe inlet:-

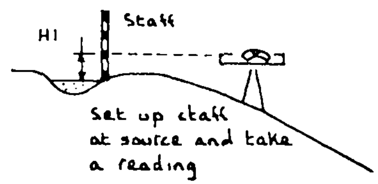




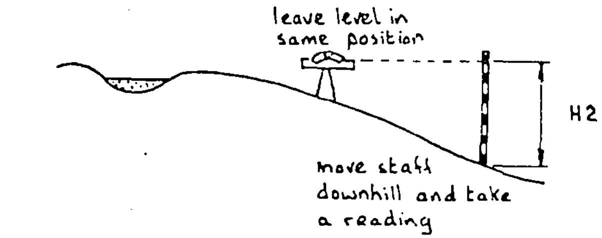
You will only need to measure the supply and delivery heads if you need to make sure that the ram will pump enough water, or if you have to buy a larger ram. The flow at the supply source, and the delivery and supply heads, can be used to calculate how much water this ram will pump. See Table 1. (Page 7)

The differences in level between the source and the ram, and the header tank and the ram, can be measured using a surveyors dumpy level, a clinometer, or even a carpenters spririt level attached to a stick. A method of measuring the supply head is described below:-

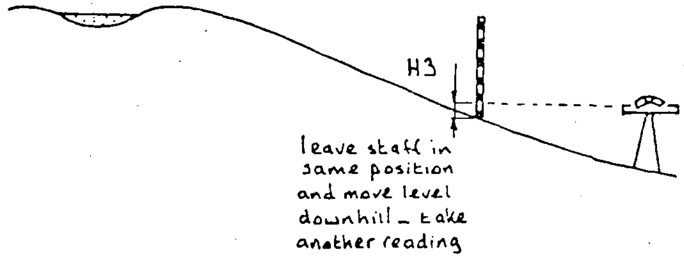




ii)



iii)



i. Set up the level near the source, and take a reading on a graduated measuring staff held by your assistant on the water surface of the source. Record this reading in a note book. (H1).

ii. Turn the level around on the same spot, and ask your assistant to carry the measuring staff down hill. The staff is held upright, and you take a second reading which you again record. (H2).

iii. Your assistant will stay on the same spot with the measuring staff whilst you carry the level down hill again to a position below your assistant. Set up the level again, and repeate stages i and ii above.

You repeat this process until the ram site is reached, and the supply head can be calculated as follows:-

$$\text{Supply Head} = H_2 - H_1 + H_4 - H_3 + \ \ldots\ldots \text{ etc.}$$

The delivery head is measured in a similar way.

4.1 HOW MUCH WATER CAN THE RAM PUMP

The simple ram pump made from commercial pipe fittings described in Section 5 of this manual, needs a supply flow of at least 5 litres each minute. Using this supply flow, the smallest amounts of water that this ram may be expected to pump each day for different supply and delivery heads, are given in Table 1.

TABLE 1 DAILY PUMPING RATES FOR RAM PUMP (litres of water)

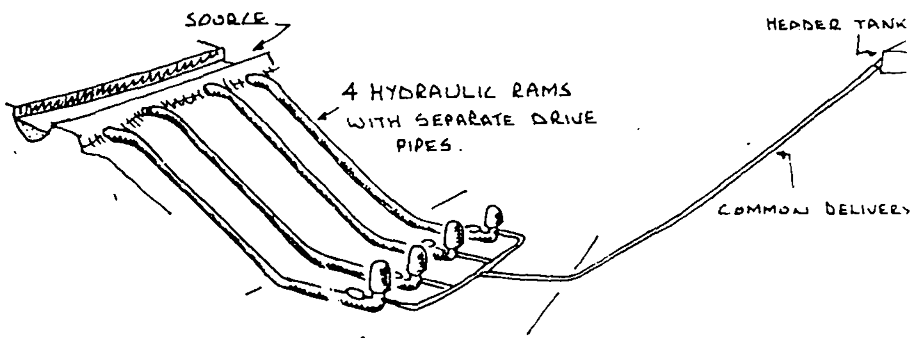
Supply Head (metres)	Delivery Head (metres)										
	5	7.5	10	15	20	30	40	50	60	80	100
1	400	200	150	80	70	50	30	20			
2		550	390	250	200	130	80	60	50	30	
3			650	450	320	220	150	130	100	70	40
4				650	430	300	200	150	130	90	60
5				750	550	370	300	250	200	120	90
6					700	450	350	300	250	150	120
7						550	410	320	270	200	150
8							450	370	300	250	150
10							600	450	400	300	230
12							750	550	470	350	280
14								650	550	400	330
16									620	470	370
18									700	520	420
20										600	450

We have not been able to test the ram pump over this wide range of supply and delivery heads. We have assumed that it will pump at only one half the rate of a comparable commercial ram manufactured by Blakes Hydrams Ltd. (see Table 2, page 30).

The ram will pump at a faster rate if the impulse valve is properly tuned, or if the supply flow is more than 5 litres per minute. If for example, your ram installation can be tuned to allow a flow of 15 litres per minute down the supply pipe, then the ram will pump three times the amount given in Table 1.

The greatest amount of water this ram can use from the source is governed by the size of the ram itself and if the ram installation is to use more water (and therefore be able to pump more water), then a larger ram should be chosen. How to choose the correct ram size is given in Part 11 of this manual.

If you find that your ram installation is not large enough to pump the amount of water you need, you can construct a duplicate ram alongside the original ram. The drive pipes should be separate, but you may use the same delivery pipe. Some installation have batteries of small rams, often 5 or more, next to each other.



A BATTERY OF SEVERAL RAMS

4.2 CHOOSING THE SIZE OF THE DRIVE PIPE.

The drive pipe is really the most important part of the ram installation - it carries the water from the source to the ram, and contains the pressure surge of the water hammer. It must be made from good quality steel or iron water pipe - plastic and concrete pipes are useless for drive pipes.

The diameter and length of the drive pipe is very important, although the ram will work satisfactorily if the ratios of pipe length (L) to diameter (D) are between the limits $\frac{L}{D}$ = 150 to 1000. These are very broad limits. We suggest that you try to install a drive pipe with an $\frac{L}{D}$ ratio of 500, or choose a length that is four (4) times the supply head, whichever is the smaller. The theory behind the drive pipe is described in greater detail in Part 11.

Example

Supply Head = 4.0 metres

Drive pipe diameter (D) = 25 mm.

a) Use $\frac{L}{D}$ = 500

L = 500 x 25 = 12500 mm or 12.5 metres.

b) Use L = 4 x Supply head

L = 4 x 4.0 = 16.0 metres.

The ram will work equally well if the drive pipe is cut from 25 mm pipe at either of these lengths, and you should choose the length which is most convenient for your site.

4.3 CHOOSING THE DELIVERY PIPE SIZE

Unlike the drive pipe, you can make the delivery pipe from any material, provided it can stand the pressure of water leading up to the delivery tank. The delivery pipe should have an internal bore of 20 mm; plastic hose pipe is quite satisfactory if it is strong enough.

The water from the ram can be pumped for great distances provided that the delivery head is small enough; in this case, the ram has to spend effort forcing water through the pipe, and you should try to keep the delivery pipe fairly short.

4.4 CHOOSING THE SIZE OF THE HEADER TANK.

One of the great advantages of a ram pump is that it works automatically and continuously, which means that it is always pumping water to the header tank.

If you think about the way that you use water in your household, you will see that during certain periods of the day, you will need a relatively large amount from the header tank. At other times, during the night, for instance, you will most likely use very little water.

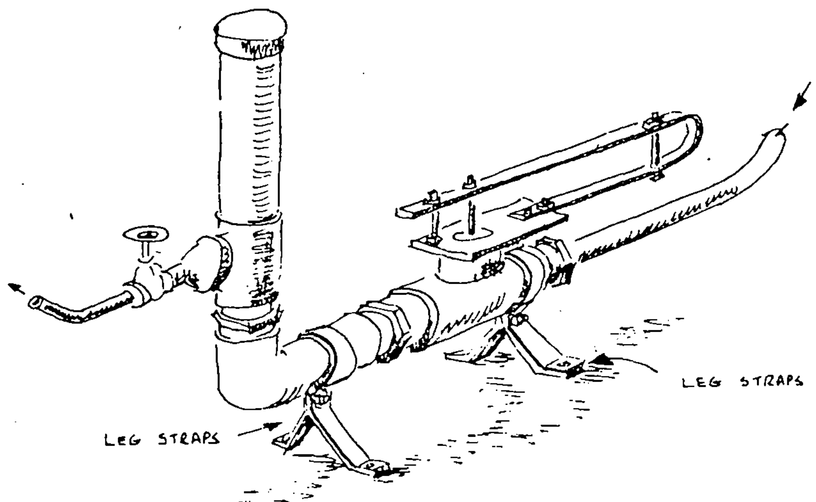
The header tank must therefore be large enough to hold enough water in reserve to supply your needs during periods of peak demand.

Even when you choose a header tank of correct size, there will be times when it overflows. You should therefore fit an overflow pipe to the tank, and lead the waste water to your garden or fish tank.

The way to choose the tank size is to estimate your daily water requirements, and make your tank to contain half this amount. If you find the tank is too small, you can easily add a second tank.

5. Building the ram.

You can build a ram from any size of pipe fittings that you have available, and the way that these will work is described in Part 11. The ram described here has a drive pipe bore of 30 mm. The ram body is made from pipe fittings of 50 mm internal bore, so that the impulse and delivery valves can have large openings: the relatively small sizes of commercial pipe fittings are a major disadvantage for ram construction, and effectively limit the maximum ram size that can be made. The finished ram is shown below and in Fig.3



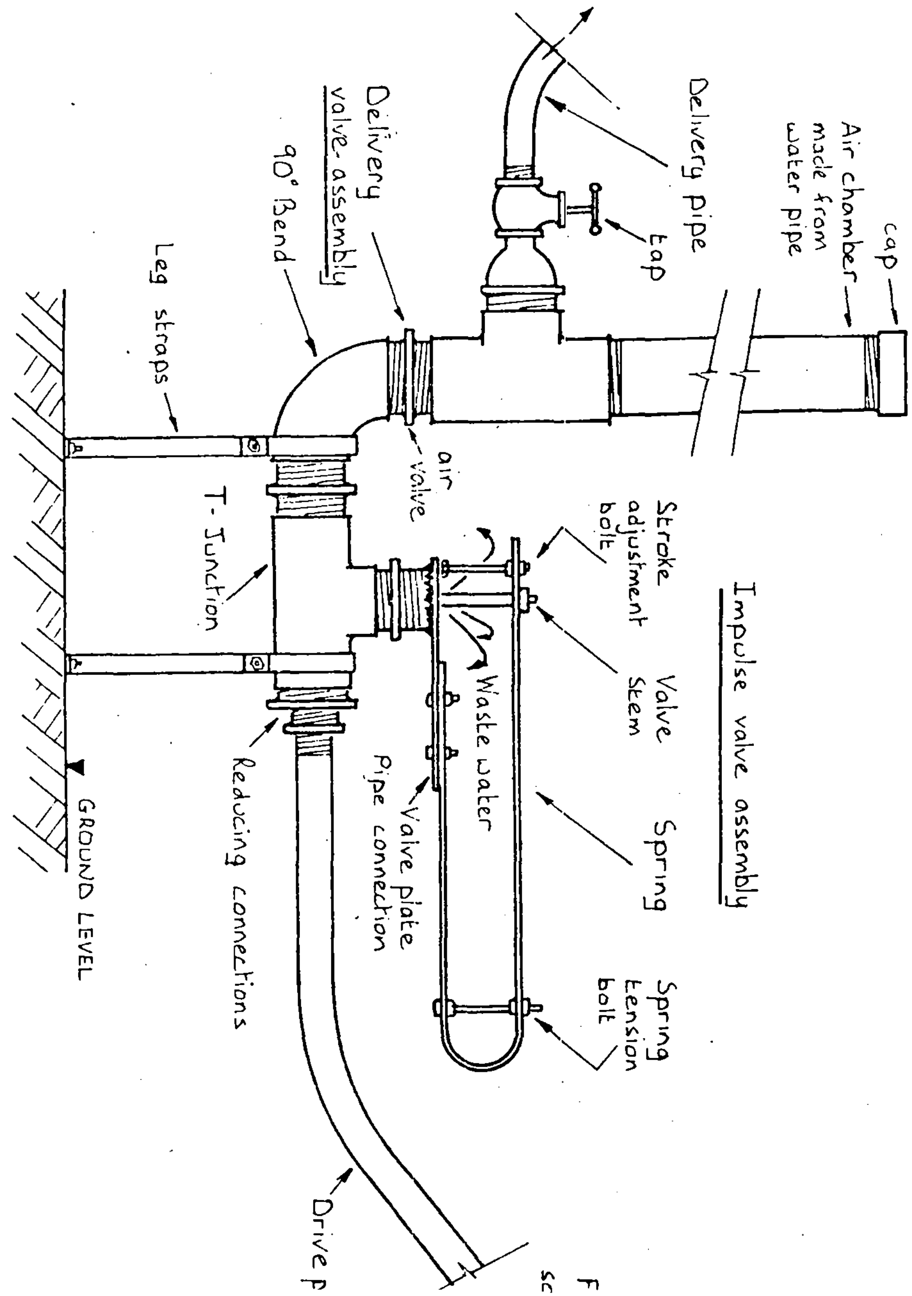
The main points you should note when you intend to build this ram are:-

a) the capacity of the ram depends on the size of the impulse valve which allows the water to discharge. The pipe fittings are therefore several sizes larger than the drive pipe.

b) the flow of water through the ram should not be restricted by sharp changes of direction of water flow or by the sudden junction of different sized pipes.

c) the ram experiences savage pounding during its working life and all the parts, connections and valves must be strong enough to stand the stresses.

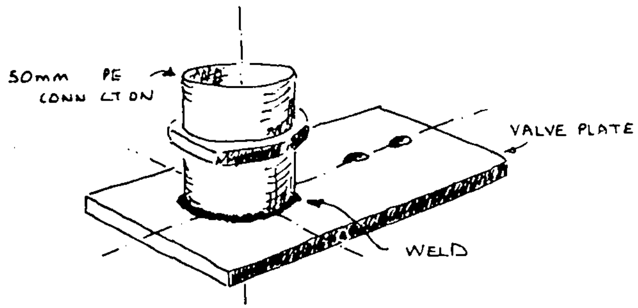
FIG 3 GENERAL ARRANGEMENT OF RAM CONSTRUCTED FROM PIPE FITTINGS



d) there are obviously any number of combinations of pipe fittings which can make up a ram body, and the one described below can be modified to suit available fittings.

5 1 MAKING THE IMPULSE VALVE.

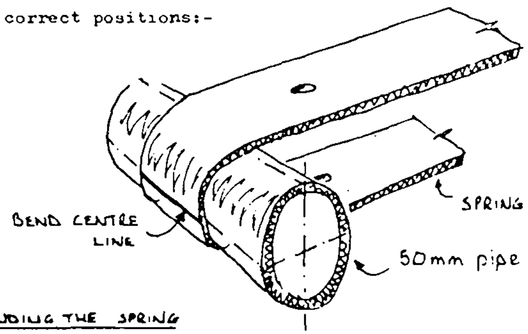
Weld or braze a 50 mm threaded pipe junction onto the valve plate shown in Fig.4.1 centrally over the 30 mm diameter hole:-



WELDING CONNECTOR TO PLATE

This will leave a lip inside the pipe connection about 10 mm wide all round, which will act as a seating for the impulse valve washer. File or rub and smooth the valve plate over the valve seating area to prevent wear on the valve washer. The two elongated holes, each 6 mm diameter on the valve plate, are to hold the valve spring.

The valve spring is made from a strip of mild steel, 650 mm. long, 30 x 2 mm in cross section, marked out and drilled as shown in Fig.4.3. Bend the spring to shape around a 50 mm pipe, with the bend centre line on the strip in the position as shown below, this will set the spring with the drilled holes in the correct positions:-

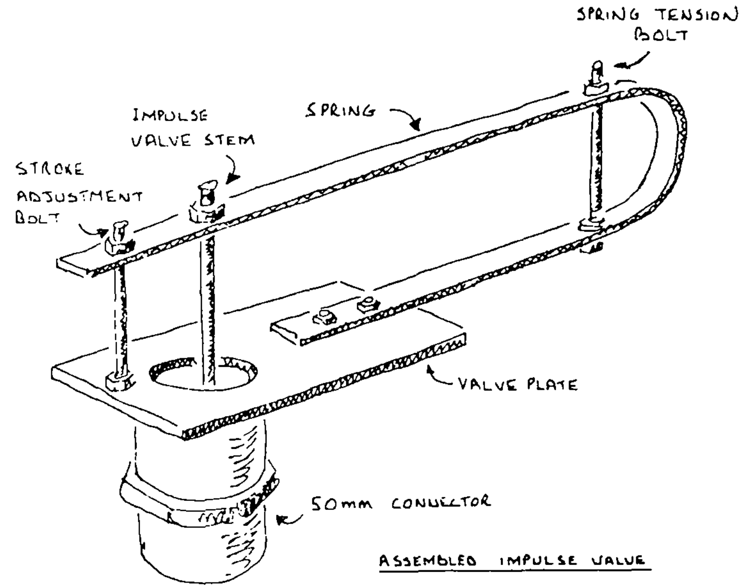


BENDING THE SPRING

Bolt the spring onto the valve plate, which has elongated holes to allow the impulse valve stem to be adjusted for correct seating.

The impulse valve itself is made up from a 6 mm diameter bolt, tube and washers which you assemble through the valve plate to the valve spring, Fig. 4.4

Finally, add spring tension and the valve stroke adjusting bolts. These allow the ram to be tuned for maximum efficiency. You can see that the impulse valve assembly can be removed from the ram for maintenance by just unbolting the spring, then unscrewing the pipe connector and valve plate:-



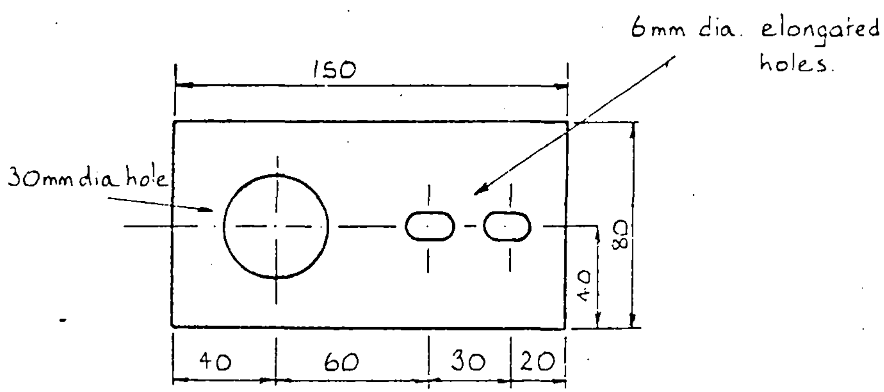
ASSEMBLED IMPULSE VALVE

We have chosen this system of impulse valve assembly because it has no wearing parts except for the valve rubber. It is possible that with time, the valve spring will work harden and break; it is also possible that the spring assembly will be damaged during floods if the ram is installed on the side of a stream. An alternative more robust design for the impulse valve assembly is described below.

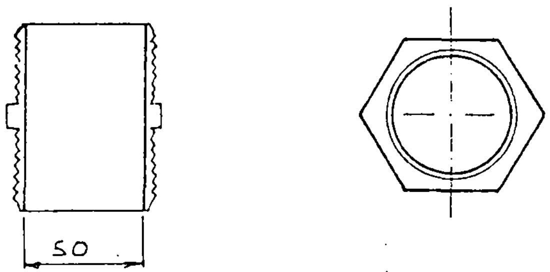
5.1 B AN ALTERNATIVE IMPULSE VALVE.

The impulse valve assembly described above has been taken from a design by VITA, and as far as we know, it works quite satisfactorily.

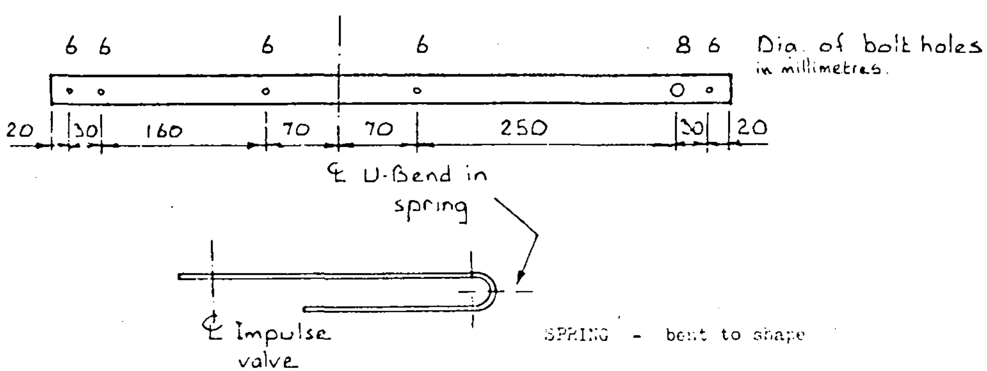
4.1. VALVE PLATE, 150 x 80 x 3 mm Mild steel plate



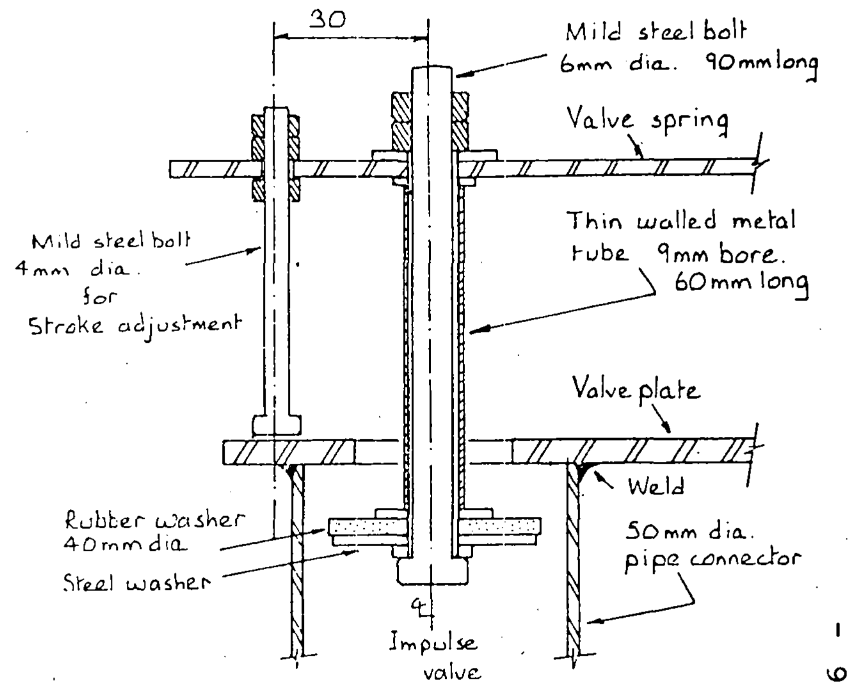
4.2. PIPE CONNECTION. 50 mm diameter, mole threaded



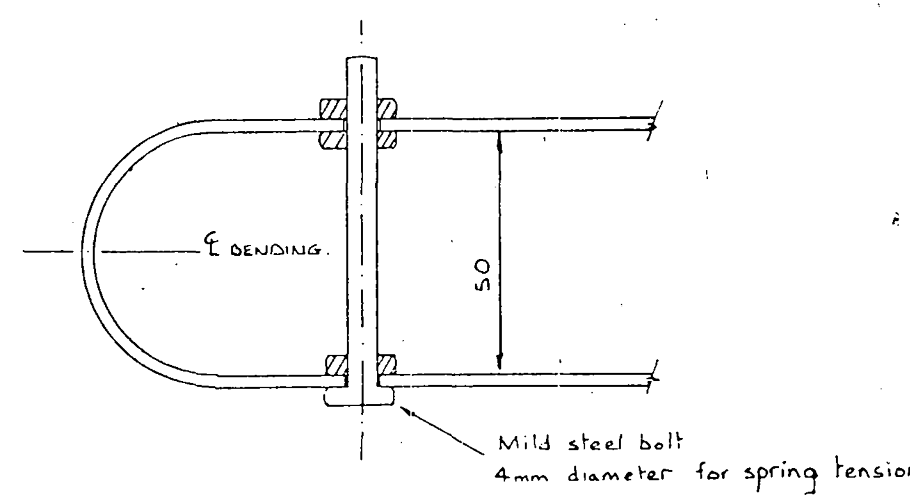
4.3. SPRING, 650 x 30 x 2 mm Mild steel strip



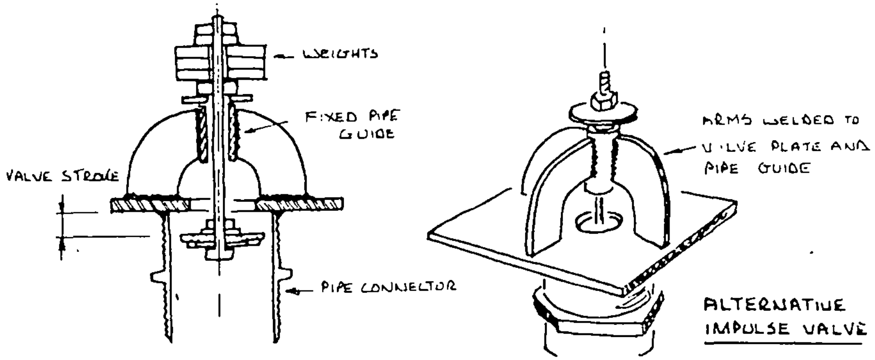
SPRING - bent to shape



4.5. SPRING TENSION BOLT



We include in this section a more robust impulse valve with a sliding valve which will wear in time. The impulse valve in this case works by falling under its own weight at the finish of each ram cycle:-



The valve stem is fitted through a fixed pipe guide supported above the valve plate by arms welded both to the pipe and valve plate. The pipe connector is welded as before over the centre of the 30 mm diameter hole in the valve plate.

Choose the pipe guide and the valve stem bolt so that they have a close but easy fit. Alternatively, the pipe guide can be chosen to hold a replaceable brass or plastic sleeve which will take the wear from the moving valve stem bolt.

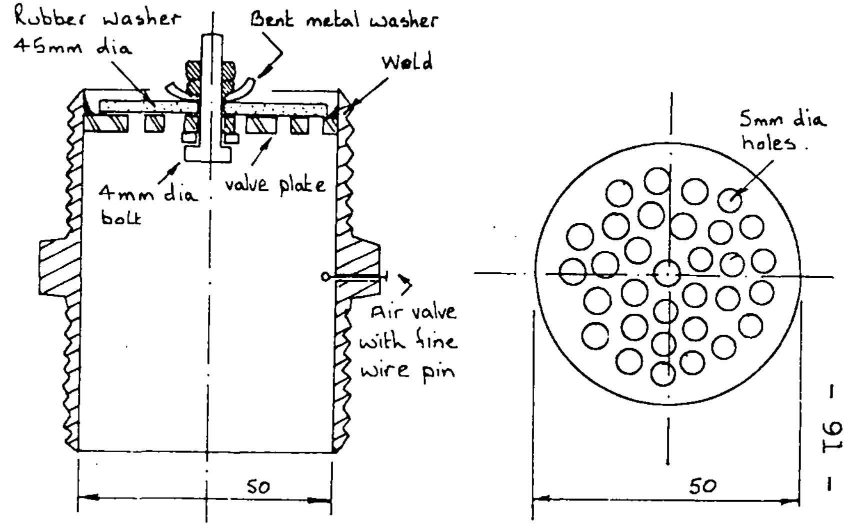
The valve stroke is set by adjusting the nuts on the top of the valve stem bolt, and the weight of the valve can be altered by adding weights onto the bolt.

We have not built or tried this impulse valve assembly, but there is no reason why it should not work. Tuning the ram will be a similar process to that described in Section 7.

5.2 MAKING THE DELIVERY VALVE.

The delivery valve prevents the pumped water from flowing back into the ram after the pressure pulse has been dissipated. It is therefore a non return valve, and you can make it very simply by welding or brazing a cut and drilled piece of 3 mm steel plate into the top of a 50 mm pipe connector:-

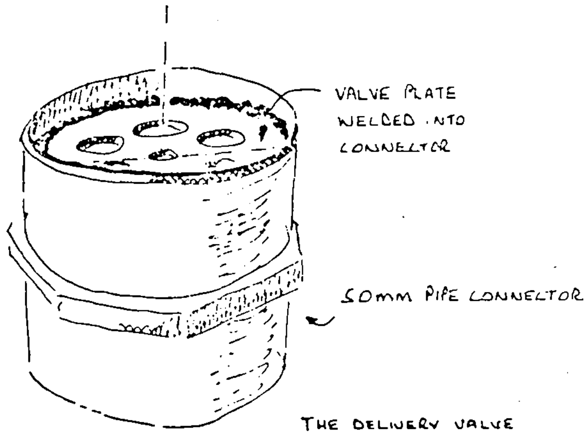
FIG.5 CONSTRUCTION OF DELIVERY VALVE.



Take care when the valve plate is welded or brazed into the pipe connector that the plate remains clean, otherwise the valve rubber will not seat correctly and the valve will leak.

Non Return valve from 3mm steel plate -

drilled with 5mm dia holes and polished smooth. Larger holes may cause the valve rubber to distort and leak.



THE DELIVERY VALVE

Cut the plate to shape and file smooth to fit exactly into the end of the pipe connector, and weld or braze it into place. Attach a rubber washer to the plate and bolt it into position; the washer must be flexible enough to allow water to pass easily, but must be firm enough to support the water pressure from the air chamber. The cupped washer above the rubber valve holds the valve in place.

The air valve is made simply by drilling a small hole 1.0 mm in diameter in the side of the pipe connector and below the delivery valve. This is partially blocked by a fine wire split pin which moves with pressure changes in the ram, keeping the hole open and allowing air to enter. Fig.5.

Make sure on assembly that the air valve is placed on the opposite side to the delivery pipe outlet, otherwise the air entering the air chamber is likely to escape into the delivery pipe; it is, of course, essential that the air feeder valve is located below the delivery valve.

5.3 MAKING THE AIR CHAMBER.

Cut a 1 metre length of 50 mm diameter water pipe, and thread each end. Screw one end into the delivery pipe T-junction pipe fitting, and seal the top with a cap.

5.4 MAKING THE MOUNTING LEGS.

Make the mounting legs from any available scrap strip iron, and drill, bend, and bolt these around the ram body. The legs can be bolted to the ground when the ram is assembled at the site if you want the ram to be a permanent fixture.

6. Assembling the ram at the site.

a) Assemble the pipe fittings using plenty of pipe joint compound. Screw these firmly together and adjust them for the correct position in the ram assembly. They must be completely free from leaks.

b) The impulse and delivery valves must move freely and when closed seat evenly on the valve plates.

c) Set the ram level on the mounting legs at the required site, and attach the drive and delivery pipes. Flush these pipes with clean water before connection.

d) The drive pipe should be laid as straight as possible with no sharp bends, and it should have no upward kinks which will trap air.

e) The inlet to the drive pipe must always be submerged, or air will enter the pipe and prevent the ram from working.

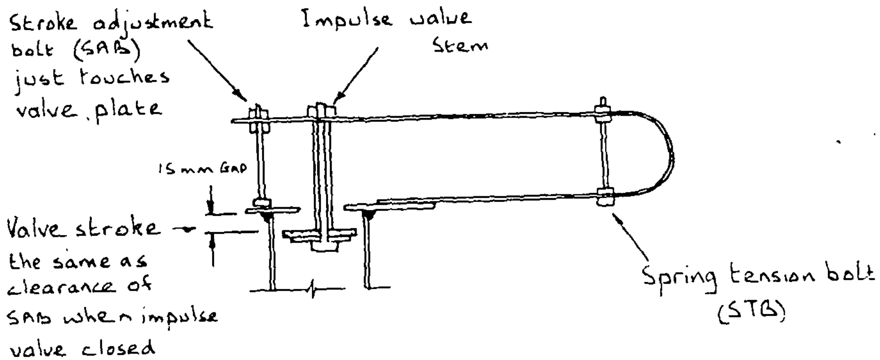
7. Tuning the ram.

The ram should be tuned to pump the greatest amount of water to the delivery tank. Tuning is not difficult, and you will find that the ram will pump some water at most settings of the impulse valve assembly.

The amount of water that the ram will pump, and the number of valve beats each minute, are measured for different valve settings, and the results compared to find the best setting for the ram. You can do this quite easily:-

a) Hold the impulse valve closed, and adjust the 'stroke adjustment bolt' (SAB) until there is a gap of about 15 mm between this bolt and the valve plate. This can most simply be done by slipping a measured pile of steel washers under the bolt and screwing the bolt down onto them.

b) Remove the washers, release the impulse valve, and adjust the 'spring tension bolt' (STB) until the SAB just touches the valve plate. Shortening the STB will bend the spring down.



c) Nip tight the STB and SAB nuts, and allow water to enter the drive pipe. Hold the impulse valve closed until the drive pipe is full of water, then release the valve, moving it up and down by hand several times. The ram should now work by itself.

d) If the valve stays open allowing water to flow out, the spring is too tight, and you should stop the flow of water, and reset the SAB and STB in the way described in a, b, and c, above to give a stroke of 13 mm.

e) When the valve works correctly, repeat a, b, and c, above for valve stroke settings of 13, 11, 9, 7, 5, 3, millimetres, measuring for each setting the amount of water that is pumped and the valve beats each minute.

f) Compare the pumping rates, and reset the STB and SAB as described in a, b, and c, to the stroke setting that gave the best pumping rate. If the pumping rates for several of the valve settings are similar, choose the setting with the smallest stroke - this will mean a smaller spring tension and therefore less wear.

g) The results of our experiments on one of these rams are given in Part 11 of this manual. We obtained the best pumping rate from an initial valve stroke setting giving a valve beat of 100 cycles per minute, by tightening the spring tension bolt until the valve beat was 75 cycles per minute. The ram you make will work in a different way to ours, and you will have to fiddle with the impulse valve to find the best setting.

8. What to do if the ram doesn't work.

There are only two moving parts in an automatic hydraulic ram, and there is very little that can go wrong. However, possible causes of failure are listed below:-

a) Impulse valve does not work.
Check seating of valve washer on valve plate; the valve should not leak when held closed, and should not catch on the side of the pipe connector.
Check to see if there is any debris or obstruction in the drive pipe or ram body.

b) Delivery valve does not operate as a non-return valve.
This can be seen if the water level in the delivery pipe surges during operation, or falls when the ram is not working. The valve should be cleaned and checked for wear.

c) Ram pumps too much air.
Check air feeder valve; if it is too big it will allow large volumes of air to enter the ram, and a larger wire split pin should be used.
Check that air does not enter the ram through loose joints; the joints should be well sealed with pipe compound.
Check that inlet to drive pipe is submerged, otherwise air will enter drive pipe, spoiling the performance of the water hammer.

d) Ram pumps with a loud metallic sound.
Check that air feeder valve is working to allow enough air to enter below the non-return valve; a small spurt of water should come from this valve with each cycle. If there is not enough air entering the ram air chamber, fit a smaller split pin.
Check that air feeder valve is on the opposite side to the delivery pipe, or the air will be pumped with the water directly to the header tank.
Check that there are no air leaks from air chamber due to bad pipe fitting.

9. *Maintenance of the ram after installation.*

9.1 THE SUPPLY SOURCE

It is obviously essential to prevent dirt from entering the drive pipe or leaves from blocking its entry. So it may be necessary to provide a grating at the off-take from the river or stream supplying the water in order to keep back floating leaves, and a sump should be provided at the feeder tank to collect silt.

9.2 MAINTENANCE TASKS

Maintenance involves keeping gratings and filters clear, and cleaning the feeder tank and sump, as well as caring for the ram itself. The maintenance tasks which you must carry out are likely to be as follows:

- (a) dismantling the ram to remove dirt,
- (b) clearing air locks in the pipe system,
- (c) adjusting the tuning; tightening bolts which work loose,
- (d) changing the valve rubber; adjusting the seating of valves,
- (e) keeping the inflow to the drive pipe free of debris; clearing filters and gratings.

9.3 FREQUENCY OF MAINTENANCE

Rams have an exceptionally good reputation for trouble-free running, and maintenance will probably not need to be very frequent. The way in which the necessary maintenance is arranged, and the question of whether this type of ram is suitable for a particular application, depends very much on who is available to carry out the maintenance. Is there somebody living locally who can have a look at the ram at least once every week, or is there a technician from somewhere else who can come only at intervals of several weeks?

Tuning, and the adjustment of valves and bolts, may need to be done more frequently with this particular ram than with some commercial models made from purpose-designed alloys and components; and the need for maintenance may become greater as the delivery head becomes greater. On the other hand, specialised tools and spare parts may be needed for the maintenance of a commercially-built pump. So in general, this ram is best suited to a situation where the person responsible for maintenance lives nearby, and where the delivery head is not too great. A commercial pump may be the best choice when maintenance is done [illegible] by somebody with access to a wide range of tools and comp-

from: "A Manual on the Hydraulic Ram for Pumping Water"
by S.B. Watt, ITDG, 9, King Street, London WC2E 8HN, England

further Ref.: "A Hydraulic Ram for Village Use", by E.W. Kindel, VITA, 3706 Rhode Island Avenue, Mt. Rainier, Maryland, USA 20822

The Cretan Sail Windwheel as a Power Source

S.B. Watt, ITDG Projects Officer

ackground

The Cretan sail windwheel is still widely used in many countries around the Mediterranean for water pumping and corn grinding. It is used even in areas which have been supplied with electric power lines, and this indicates its present economic value. A typical installation for water pumping is shown in Fig. 1.

The origins of the sail windwheel are obscure, most probably the device evolved from intimate knowledge of and close contact with sailing ships. It achieves its power in an exactly similar way to the modern sailing yacht, the triangular canvas sails rigged on the wooden spars are set to provide the maximum turning force on the axle. The spars, which can number from six to twelve, radiate out from a hub which turns on a horizontal axis. The sails are set according to the strength of the wind, and are reefed by hand around the spars if the wind speed increases. In the areas of Crete where the device has been widely used, the characteristic wind conditions during the irrigation season are very gentle breezes, which will not threaten the device.

The sail windwheel is thus beautifully simple, using the minimum of skills and materials in its construction and operation. Before it is described in detail, it is useful to state the major characteristics of the wind as a source of power.

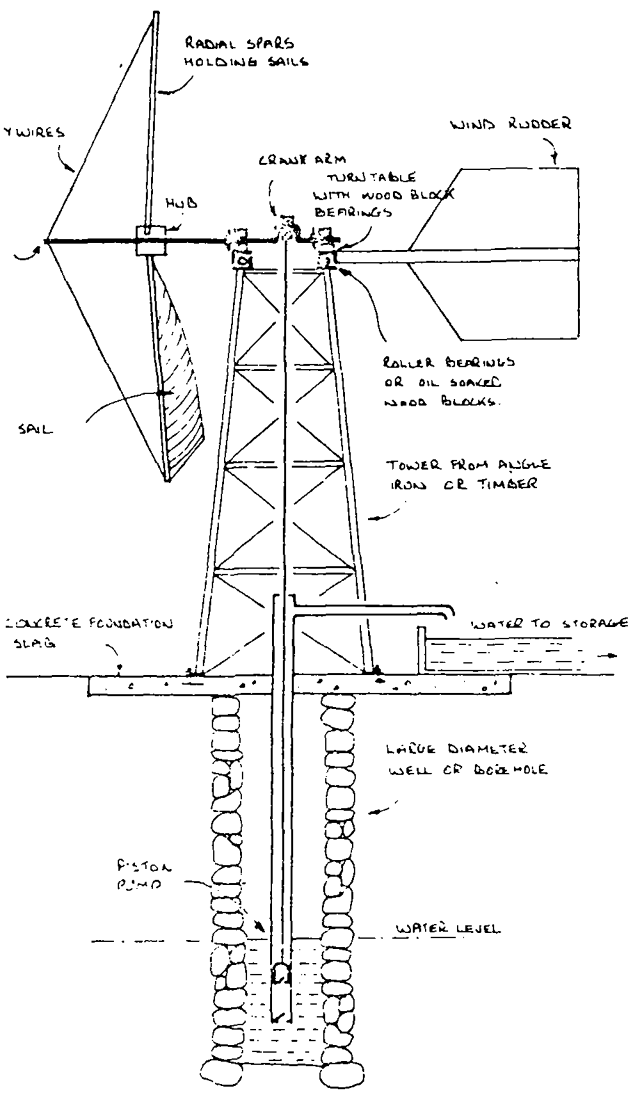


Fig. 1. Cross Section through typical Cretan Wind Pump

The wind as a source of power

The variation in wind speed: The most noticeable thing about the wind is its variability: changing from periods of calm and slight breeze, to howling gales. Each region, each area, and even each locality, will experience a unique pattern of wind movement over the year, known as the 'wind régime'. The use to which wind power can be put depends on the local confidence that the wind will blow when it is needed. This variation can be overcome during water pumping by storing the water in tanks for use during calm spells.

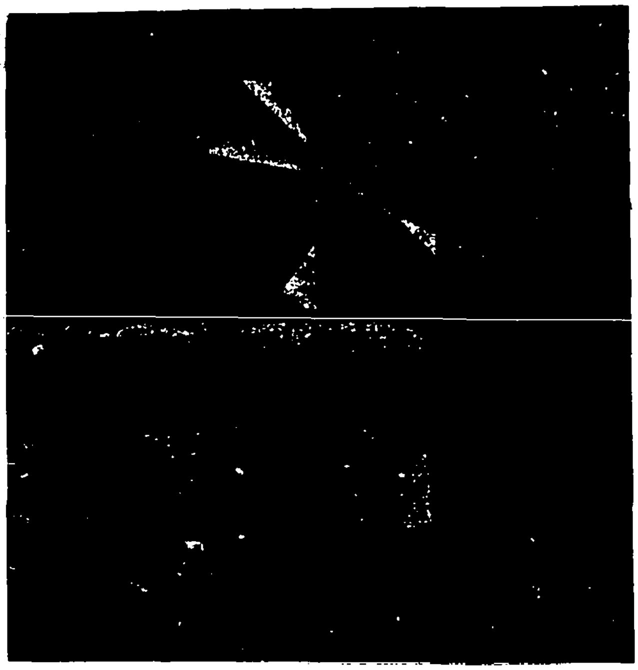
The power of the wind: the power of the wind varies as the cube of the wind speed. This means that if wind speed doubles, the power of the wind increases by a factor of eight. A windwheel therefore has to work very efficiently at low wind speeds, and either be strong enough to withstand gales, or have an efficient shut off device built into it to prevent catastrophic failure in gales. In addition, a wind wheel can only extract a proportion of the power of the wind passing through its swept area and if a reasonable amount of power is to be obtained in light winds, the size of the device must be large. These difficulties probably explain why wind power has been left in relative obscurity over the last 30 years.

The characteristics of the sail windwheel

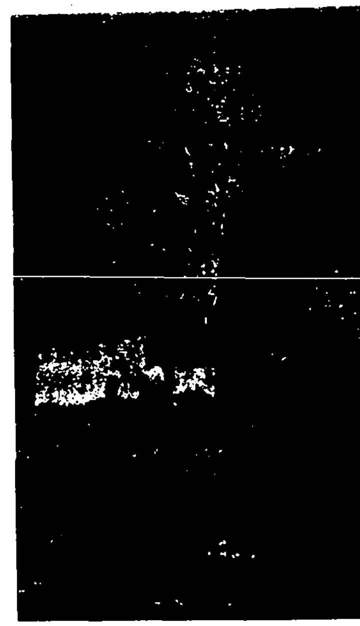
The obvious advantage of the sail windwheel is the ability of the sails to shape themselves to the wind. The device can therefore start itself and work in very low wind speeds of less than 2.75 metres per sec (6 m.p.h.).

It operates at a slow speed, high torque device -- that is, it rotates slowly at less than 25 r.p.m. with a powerful turning force, and can therefore be coupled directly to a simple piston or chain and washer pump with no expensive gearing. There are few of the dynamic problems associated with modern high speed wind turbines.

A second major advantage which is proved by the experience of centuries, is its built in safety against overspeeding. If the



Partly rigged Cretan sail windwheel pumping water to greenhouses growing cash crops.



Corn grinding sail windwheel in fixed direction on stone tower

device overspeeds in high winds, the canvas sail 'luffs' or changes shape, causing a rapid reduction in power and speed of revolution. The device is therefore self governing.

A comparison with the multiblade windwheel

The multiblade windwheel is a comparable low speed, high torque, device that has been proved over the last 100 years, and many thousands are still working efficiently and safely in all parts of the world. It consists of a series of sheet metal blades arranged radially around a hub which rotates on an horizontal axis, and is, in effect, like a sail windwheel machine with rigid sails. They are made commercially with engineering precision, and are designed to operate under even extreme climatic conditions with the minimum of attention. They are designed to turn automatically out of the wind in high winds, and are self controlling.

The sail windwheel works, of course, in an exactly similar manner to the multiblade device, but it is made with the simplest materials, wood, canvas, etc., and can be made locally with the minimum of equipment and skills. Its main limitation is that it needs constant attention to trim and reef the sails around the spars when strong winds start to blow.

Power output from the sail windwheel

There have been only limited attempts to investigate the sail windwheel in a scientific way, but the device appears to be able to extract over 30% of the power of the wind that passes through its swept area; this compares very favourably with the multiblade machines. Modern, high performance airscrew type turbines, on the other hand, achieve efficiencies greater than 45%.

Measurements of a sail windwheel built with nylon sails and ball bearings (Ref. 1) indicate that a 4m diameter machine set within a wind speed of 3.5 metres/sec (about 8 m.p.h.), a light breeze, can develop a power of 100 watts (0.13 h.p.) or equivalent to the rate of work of a man. In stronger wind or with larger diameter, more power will be generated.

Typical construction

The Cretan sail windwheel has been built in several ways, in fixed position on a stone tower, or on a steel angle iron tow with a turning carriage. The fixed direction devices were usu used for corn grinding, and were set to face the prevailing winds. The multi-directional device has a rudder down wind keep the sails pointing into the wind.

The water pumping machines in Crete take the power from the rotating shaft through a crank mechanism, to a vertical rod which is connected directly to a piston pump in the wel directly below. The radius arm of the crank is about 5 - 7 cn

The windwheel axle is carried on a rotating carriage which may be built either of metal or wood. The bearings are mad of oil soaked wood blocks, which run steadily for long peri without attention, and can be cheaply re-placed.

The correct rigging and setting of the sails has not been rec ded in any of the literature, and trial and error methods mu be used. Further information on the Cretan sail windwheel can be found from the references and contacts given below.

REFERENCES AND CONTACTS

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2. *Wind Workshop.* B. Hitchings. Alternative Sources of Energy No. 14, May 1974, Route 2, Box 90-A, Milaca, MN 56353 USA. (A full description and working drawings of a sail windwheel.)
3. *Windworks,* Box 329, Route 3, Mukwanago, WISCONSIN 53149 USA. (This group have carried out considerable development work on the sail windwheel. They also publish an excellent biblio raphy.