THE ROPE-WASHER PUMP

A Manual

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CONTENTS

SECTION 1.

INTRODUCTION.

Garden cultivation in Zimbabwe, as in many other parts of Africa, provides a substantial amount of food to the rural population and is particularly valuable for vegetable production in the dry season.

In many areas, such as dambos or vleis, water is found at depths of less than two metres below ground throughout the dry season. Irrigation of vegetables is carried out by the laborious method of drawing and carrying water from shallow open wells (Shona = matsime) in buckets or watering cans.

A simple method of raising water to ground level and distributing it to the crops could make the job of vegetable production much easier. Perhaps the simplest method is to fill a 200 litre drum by buckets at the well site and distribute the water by siphoning through a hose. This cuts out the necessity of carrying heavy buckets of water from the well to the vegetable plots.

To further reduce effort a water lifting device could be used to lift water from the well into the drum. To this end, the rope-washer pump has been designed. The design described in the following pages is intended for use (in gardens) with unlined shallow wells (less than 4m). The rope-washer or chain-washer principle may be used in deeper, lined wells, but some modifications in design are needed and are not discussed here.

The cost of materials for the rope-washer pump is not much more than that of a watering can. The materials are widely available in Zimbabwe. The skills required to make the pump are simple, operation of the pump is straightforward and maintenance and repair can be done on the spot. The output of the pump and the effort required to operate it compare favourably with other low-lift hand-pumps costing much more.

What follows is a detailed description of the materials required and processes involved in making the pump. The materials and processes are those that I have found to be both cheap and simple. Many alternatives exist and may be more suitable in different circumstances.

2. PRINCIPLE OF OPERATION.

The rope-washer pump is a water lifting device capable of lifting relatively large volumes of water from a water-hole or well to its own height.

A rope is pulled up through a pipe by means of a pulley-wheel. On the rope are flexible washers which are slightly smaller than the pipe. When the bottom of the pipe is inserted in water the washers on the rope pull the water up through the pipe. The rope and washers return to the bottom of the pipe, completing the circuit.

There are two very important details in the design of the pump : the possibility of the rope slipping on the pulley and of the washers getting stuck as they enter the pipe.

To overcome the first problem a pulley-wheel made from rubber is used and the washers are also made from rubber and correctly spaced on the rope.

This rubber to rubber contact will ensure a good grip even with water splashing and dripping from the rope. The spacing of the washers is important and should be one-eighth the internal diameter of the pulley-wheel. This ensures that four washers are always in contact with the pulley. The washers take a lot of the strain of pulling the rope and should be tightly fixed to the rope.

A suitable pipe-stand and rope-guide is necessary to overcome the problem of the washers getting stuck on entry to the pipe. This can be very easily assembled from simple materials.

The pump has no valves and because of the circular action there are no changes of direction of major moving parts.

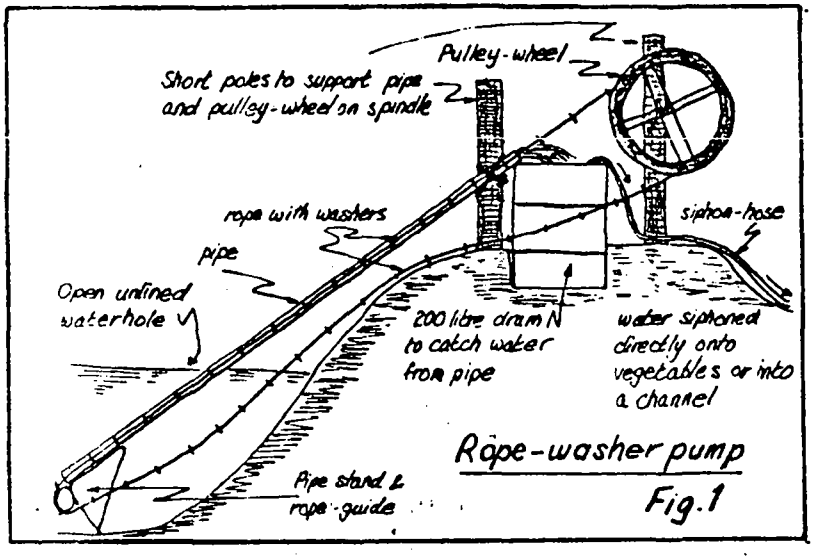
Mud and weeds do not prevent its operation.

A certain amount of water will leak between the moving washers and the pipe wall resulting in some loss. However, it is unwise to try and compensate for this by making the washers fit the pipe too closely, as the pump becomes difficult to operate.

A little loss of water is preferable to a lot of effort in pumping.

Other losses occur as the rope enters the pipe and as the rope returns down the bank of the water-hole. Correct design of the rope-guide will minimise the first loss, and keeping the path of the rope smooth, will minimise the second.

The details are shown on the accompanying diagram Fig. 1.



Rope-washer pump

Fig. 1

SECTION 3.

MATERIALS.

3. A wide variety of materials may be used in the manufacture of this pump. The materials described here have been used with success, are cheap, widely available, require basic skills, and are durable.

3.1 Materials Summary.

(i) Pipe : 1 pipe (length suited to well) 50mm Class 6 rigid PVC.

(ii) Rope : length depends on pipe, minimum 10m x 8mm diameter.

(iii) Old Tyre : 1 Old tyre, recommended 500mm internal diameter.

(iv) Round Bar : 1 round bar, 8,0 metres, 10mm diameter (as available).

(v) Timber : Axle 1,5m (75 x 50). Bearings 1,0m (75 x 50). Treated Poles 3 x 2m x 100mm.

(vi) Rubber Straps : 5m of old inner-tube strips.

(vii) Wire : about 5 metres.

(viii) Miscellaneous : Rope-guide - pipe, log, or sheet metal. Nails - 20 x 50mm.

3.2 Materials Description.

3.2.1 Pipe.

Almost any rigid pipe is suitable. The cheapest widely available pipes are made from PVC. It is recommended that a rigid PVC pipe be chosen with the minimum strength being Class 6.

A PVC pipe 50mm in diameter is recommended. A larger pipe e.g. 63 or 75mm, may be used but I have not had very much experience with larger diameters.

The length depends on the depth of the water-hole and the angle of the pipe leaving the water. It is important to remember that this pump will cause the level of the water to fall fairly quickly, so allow for this in estimating the length of pipe.

Pipes are sold in lengths of 6 metres. One of these lengths is often suitable for two pumps if they are to be used in gardens where the water is near the surface.

3.2.2. Rope.

In Zimbabwe 8mm nylon-braid rope is widely available at a reasonable cost and is ideal for this pump. Thinner rope will suffice but be more susceptible to breakage and wear and tear.

Other materials may be used, provided they are water resistant and do not slip on the rubber pulley-wheel.

For a pipe length of 3 metres, about 10 metres of rope is needed, twice the length of the pipe, plus 4 metres.

3.2.3 Old Tyre.

An old tyre provides the raw material for the pulley-wheel, the washers and perhaps the rope. A large tyre is desirable with the diameter of the inner rim being about 500mm, or 20 inches.

If the tyre is too small the pump output will be reduced. If the tyre is too big then it may be difficult for one person to operate the pump alone, but the output will be high.

3.2.4 Round Bar.

Round steel bar sold as reinforcing rod, is used to make the pipe-stand and the pulley-wheel, and may also be used for the handles. The recommended diameter is 10mm although 8mm or 12mm may be used as available.

Eight lengths of bar are needed for the pulley-wheel. The length of the bars depends on the size of tyre used. For a tyre with an inner diameter of 500mm, a rod length of 540mm is needed.

Each handle requires one bar of length 1600mm and two handles are needed.

The pipe-stand also requires two bars, each 1600mm long and one bar 400mm long.

3.2.5 Timber.

Timber is used for the axle and the bearings holding the axle to the posts. Three wooden posts are needed to support the pump at the well site. All timber should be treated with a wood preservative. The timber for the axle should be free of knots as these cause weakness.

The wooden axle should be 1500mm long and the cross-section 75 x 50mm minimum. The same size can be used for the two bearings, each being 500mm long.

3.2.6 Rubber Straps.

Rubber straps cut in strips from the old inner tubes are cheap and invaluable in making this pump. Each pump will need about 5 metres.

3.2.7 Wire.

The wire is required for joining the steel bar, about 5 metres will be sufficient.

3.2.8 Miscellaneous.

Two short lengths of pipe, plastic or steel, each 150mm long can be fitted to the handles to reduce wear on the hands.

For the rope-guide a smooth cylindrically shaped object is required. A piece of plastic pipe 400mm long and 100mm wide, is suitable. A piece of sheet metal 400mm x 400mm can be bent into a cylinder as required.

About twenty nails, 50mm long are needed for joining the two halves of the pulley-wheel.

SECTION 4.

MAKING THE PUMP.

4.1 Introduction.

Making the pump involves cutting and joining various pieces of car-tyre, cutting, bending, and joining steel bar, and a small amount of wood carving.

Some welding may be necessary.

The basic tools required are :-

- hacksaw to cut the steel bar and pipe.
- woodsaw for the timber.
- strong sharp knife capable of cutting car tyre; sandal makers who work with this material use a trimming knife which can be bought in most hardware shops.
- pliers for tying wire.
- hammer to drive the nails into tyre.
- vice to hold steel bar for bending.

If more tools are available then they may speed up the work but are not necessary to make the pump.

4.2 The Pipe.

Cut the pipe to the required length and make the ends smooth. It is better to have a pipe that is too long than too short.

4.3 The Rope and Washers.

The washers are cut from that part of an old tyre containing the reinforced ply. The thickness required is 7 or 8mm, or 7 or 8 ply. The ply is the inner part of the tyre tread.

First cut the tread part of the tyre into strips of length one or two metres and of width slightly greater than the pipe diameter.

The required thickness of ply may be separated as follows :-

- slit along each side of the strip at the required thickness.
- at one end slit the ply completely away from the tread to a length of about 150mm.
- the strip of ply may now be pulled by hand or with pliers from the tyre strip.

The details are shown on the accompanying diagram Fig. 2.

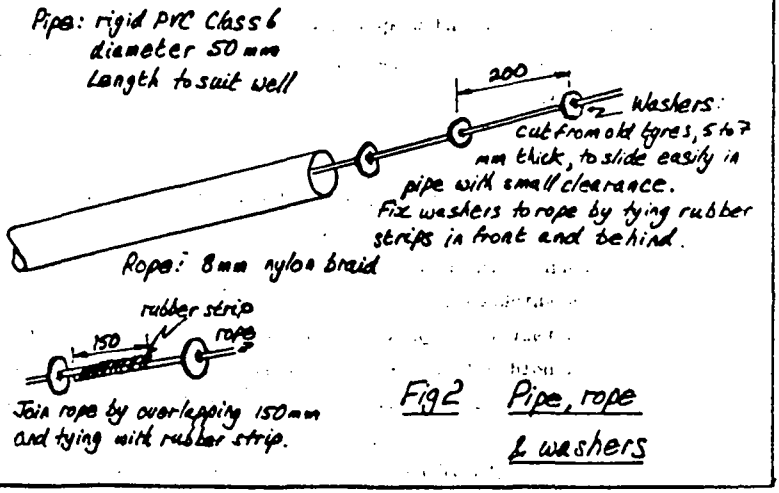


Fig2 Pipe, rope & washers

The washers are then cut from the strips of tyre containing the ply. They are cut to fit the pipe with a small clearance. A good method is to use a short section of pipe, say 50mm long, as a guide when cutting the washers. The pipe is used to mark a circle on the tyre strip and a disc cut. The disc is then trimmed to fit the pipe with the edges pared to round off the corners. The disc is inserted in the pipe and rotated to check the fit.

The holes are then cut in the centres of the washers to allow them to fit tightly onto the rope. They are spaced at 200mm intervals for a pulley-wheel of internal diameter 0,5 metres.

This spacing is one-eighth of the circumference of the pulley-wheel to ensure that any one time, at least four washers are in contact with the pulley. The washers are fixed in place on the rope by tightly wrapping thin strips of inner-tube rubber on the rope in each side of the washer. If the washer can be pulled on by hand over the rubber strips then they are not tight enough.

The ends of the rope must be joined together after it is passed through the pipe. The time to do this is at the well site as the length of the rope must be adjusted on site.

The best method of joining the rope ends is to overlap the ends by 150mm and wrap tightly with thin strips of inner tube. Knots, unless expertly done, are unwieldy and tend to open or slip with use.

As a cheaper alternative to nylon rope, rope may be cut from car tyre, as follows :-

- with a sharp knife cut out both side walls of the tyre.
- the rope may then be cut as a continuous strip from each of the side-walls. It should be about 10mm x 15mm in thickness.
- to test the rope for strength two people should be able to hold a 'tug-of-war' with the rope without breaking it.
- the rope's thickness should be the same along the whole length.
- the length of rope required depends on the length of the pipe used which in turn depends on the depth of the well. The rope should be twice the length of the pipe plus 4 metres to allow for the pulley and rope-guide.

Thus for a pipe three metres long the rope should be twice three metres, being six, plus an additional four metres making a total length of ten metres.

The techniques of rope-cutting is used for making door mats, which are sold all over Harare. The technique of stripping the ply from the tyre is used by sandal makers who make tyre-sandals.

In Harare, Zimbabwe, both techniques may be observed at the open market place near the railway bridge where Cameron Street joins Harare Road North. (Harare City Map Grid Ref. No. 927263). The artisans there may produce the washers, rope, etc, for suitable remuneration.

4.4 The Pulley-Wheel.

The pulley-wheel is made by clamping two pieces of cut-away tyre together with steel bars and nails. The cut-away tyre pieces can be cut from an old tyre. Alternatively they may be obtained at the market place where tyre-sandals and door mats are made.

The two cut-away tyres are joined together initially by hammering nails through the inner rim of the tyre. As the tyre is reinforced by steel wire the nails must be carefully placed to slide under the rubber, but outside the wire. This may seem difficult at first, but after a few attempts it will be easy.

Steel reinforcing bars are then used to tightly clamp the tyres together and form the hub of the wheel through which the axle passes. The steel bars should have a grip of about one centimetre on the tyre inner rim.

The bars are first assembled loosely and tied with strong tie wire. They are then adjusted so that the hub is centrally located and of the right size to allow the axle to be inserted freely, but with a minimum of play. Then the wire is tightened on the bars with pliers while the bars are tightly squeezed together by hand.

The details are shown on the accompanying diagrams Fig. 3. and Fig. 4.

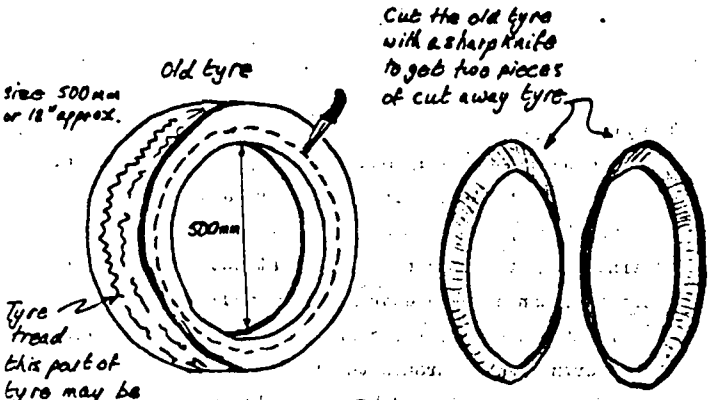


Fig 3

Cut-away tyres

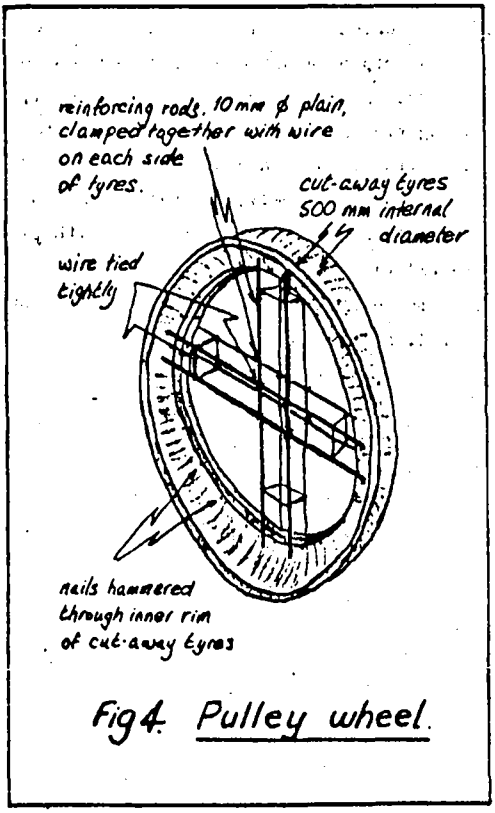


Fig 4. Pulley wheel.

4.5 The Axle.

The axle may be made from a piece of timber 1,5m long and a minimum of 75 by 50mm in cross-section. Starting at a distance of 100mm from each end of the axle, a section of the axle, 200mm long is rounded to fit the wooden bearings later on.

Be careful to shave only a minimum amount of wood from the rounded portion in order to maintain the strength of the axle.

The axle may be from any available piece of timber such as a treated gum pole so long as it is not less than 75 x 50mm in cross-section. This is because lighter sections may crack when the pump is operated.

If a gum pole is used the ends of the pole may be squared off by chisel to take the handles and the centre squared up by adding pieces of timber so that it will fit the hub of the pulley-wheel closely.

The details are shown on the accompanying diagram Fig. 5.

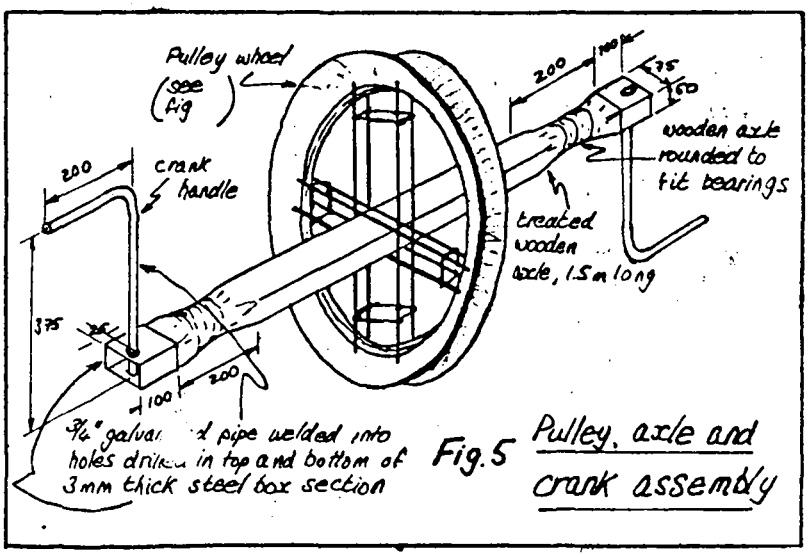


Fig. 5 Pulley, axle and crank assembly

4.6 The Handles.

(a) Method 1.

The handles may be made in a number of ways, but the simplest is to form them from a piece of steel rod - 1,5m long and 10mm in diameter. The rod is bent into the correct shape.

A piece of steel or plastic tubing may be fitted over the rods to make it more comfortable to operate the pump.

(b) Method 2.

The handles are made by welding a length of galvanised pipe ($\frac{3}{4}$") into a welded steel box section which fits over the axle.

The details are shown on the accompanying diagram Fig. 6.

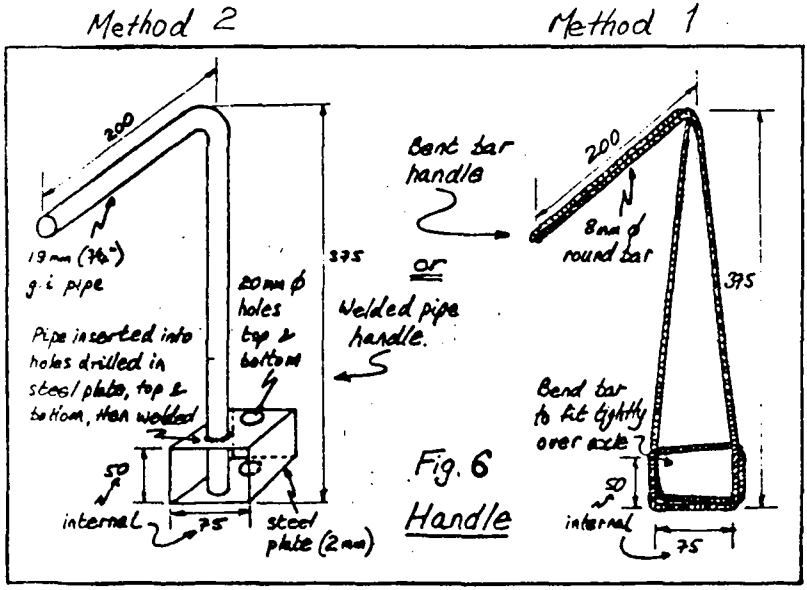


Fig. 6 Handle

4.7 The Bearings.

The axle and pulley-wheel are supported on wooden posts driven into the ground beside the well. Simple wooden bearings hold the axle on the posts. A circular slot is cut in the wooden posts at the desired height above ground level. This is best done when installing the pump.

Two pieces of timber 0,5m long and 75 x 50mm in cross-section are suitable for clamping the axle to the posts. They should have a circular slot cut in them to fit over the axle on the posts. The bearings are clamped to the post using rubber straps or wire if a more permanent fixture is required. Nails or bolts are not recommended as they will work loose or split the timber.

The details are shown on the accompanying diagram Fig. 7.

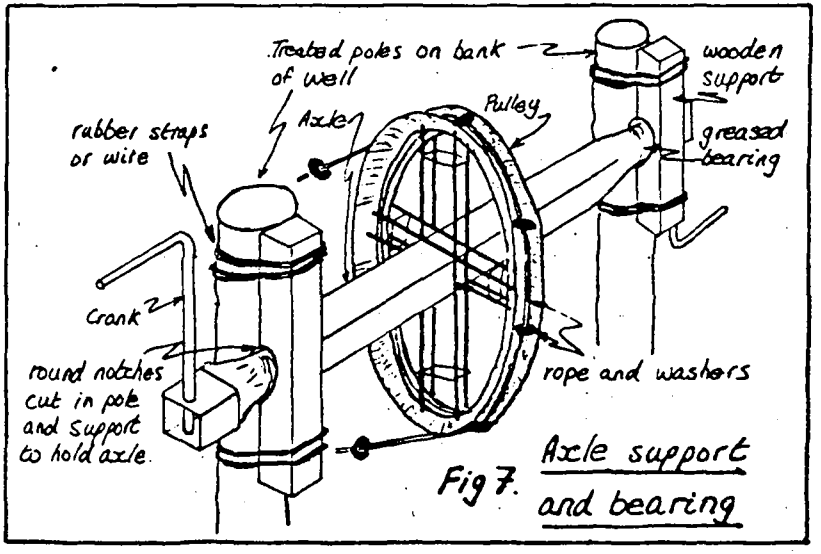


Fig 7. Axle support and bearing

4.8 The Pipe-Stand and Rope-Guide.

The pipe-stand is made from pieces of round steel bar, 10mm thick, two pieces 1,6m long, and one piece 0,4m long. The two long pieces are bent into a triangular shape as shown on accompanying Fig. 8.

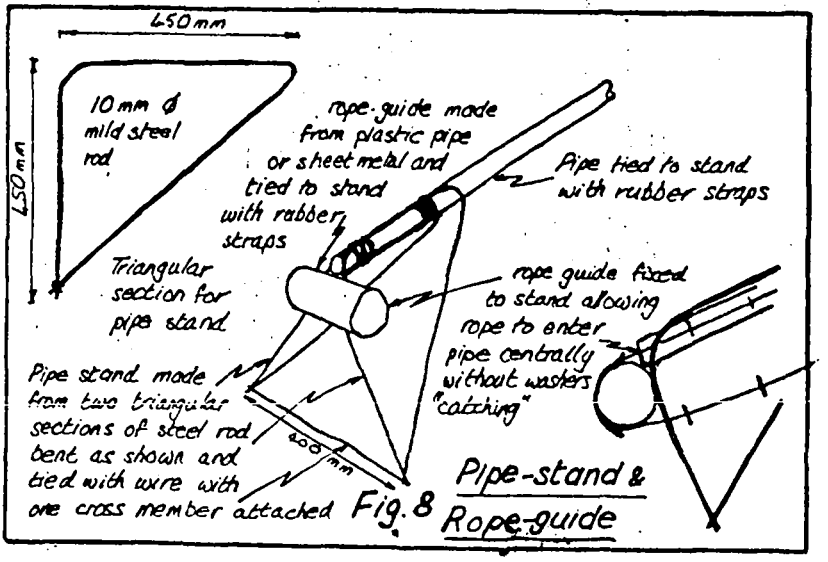
These triangular pieces are joined along one edge by tying with wire. The short length of rod is tied with wire to these pieces as a cross member.

The rope-guide, which can be of a variety of materials, is tied tightly to the pipe-stand with wire. The exact placing of the rope-guide is important as it must guide the rope centrally into the pipe without the washers catching on the pipe lip.

The pipe is attached to the pipe-stand by placing it underneath the top bars of the stand and tying tightly with rubber straps. There should be a space of about 50mm between the end of the pipe and the rope-guide.

During operation, as the rope and washers pass over the guide, the washers flatten against the rope guide and so enter the pipe at an angle. It is useful to check the action of the guide by passing the rope and washers through the pipe over the guide a few times before installation.

Note that the lubricating action of the water in the well greatly assists the entry of the rope and washers so a 'dry-run' will not be as smooth as when water is being pumped.



SECTION 5.

INSTALLING AND OPERATING THE PUMP.

5.1 The Well Site.

This pump is designed for installation beside an open, unlined, shallow hand-dug well. At the point where the pump is to be installed there should be a slope down into the well. The pump should be installed on a raised bank at the well - usually there is a raised bank anyhow due to the soil that has been thrown out while digging the well.

Reasonably firm soil is needed for the three poles which support the pump and pipe.

5.2 The Poles.

Holes are made for the three poles on a triangular layout. The pipe support pole is placed close to the well and the axle support poles are placed one metre back from the pipe support and one metre apart as shown on the accompanying diagram Fig. 9.

To set the poles in position the soil is returned to the hole around the poles and rammed tightly into place, taking care that the soil at the bottom of the hole is firmly rammed.

Wooden stays are fixed to the poles as during operation of the pump the tension on the rope tends to pull the axle poles and pipe support together.

When the poles are firmly set in the ground at the correct spacing, two circular notches are cut in the axle support poles. These should be cut at a height of about one metre above ground. If they are too high the handles are uncomfortable to turn. It is better to have to bend a certain amount when turning the handles as this brings the back muscles into play along with the arm and shoulder muscles, especially important for women.

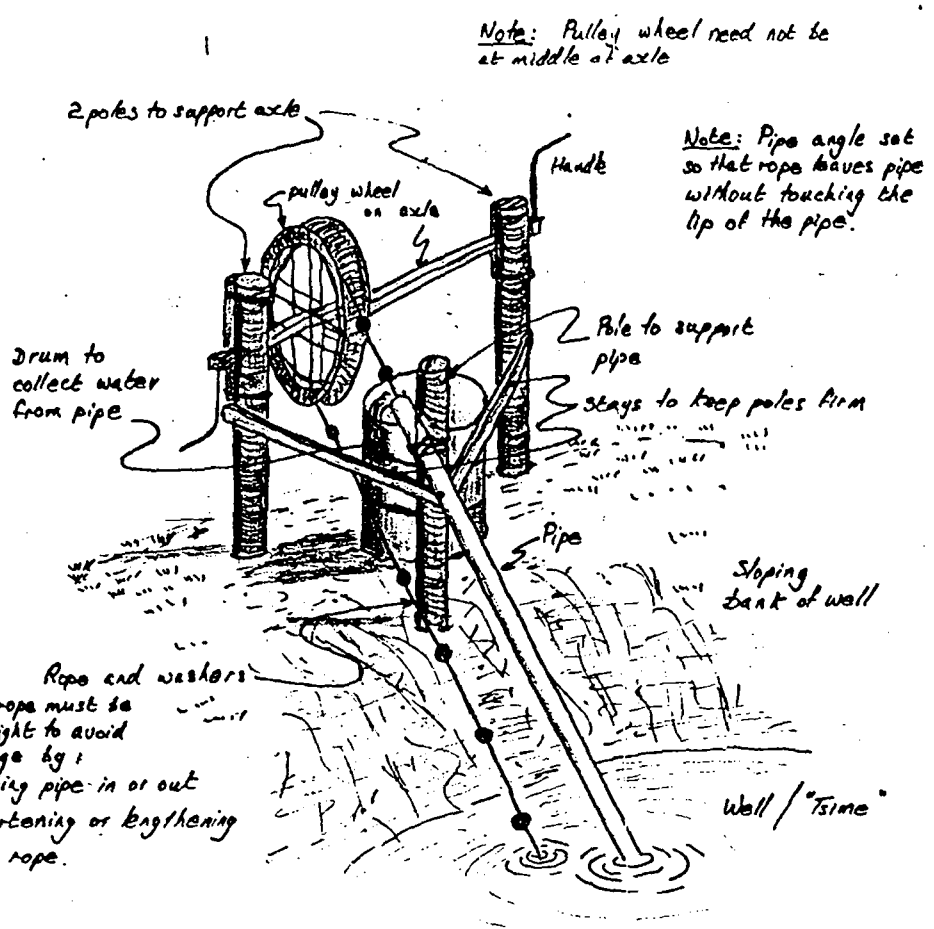


Fig. 9

Pump Installation

5.3 The Axle and Pulley-Wheel.

The pulley-wheel is fitted to the axle and the axle clamped to the axle support poles at the prepared notch. The bearing clamps are tied to the poles with rubber straps and wire may be used if a permanent fixture is required.

The axle should be horizontal and the pulley-wheel free to slide along it.

The handles may then be fitted into place on the axle.

5.4 The Pipe and Rope.

The rope is passed through the pipe by attaching a piece of string to a stone and dropping this through the pipe first. The string can then be used to pull the rope and washers through the pipe.

The pipe, with pipe-stand and rope-guide attached, is lowered into the well and the pipe tied with rubber straps to the pipe support pole. The height on the pole at which the pipe is attached is chosen so that the rope emerging from the pipe to the top of the pulley-wheel does not rub the edges of the pipe which would lead to increased wear.

The final adjustment is made later.

5.5 The Drum.

If a drum is used to collect the water from the pipe it should be set in the ground close to the pipe support pole. It may be necessary to lower the drum into the ground so that it can fit under the pulley-wheel, and so that the pipe is at the correct height with regard to the pulley-wheel.

It should be set to one side of the centre-line from the pipe support pole to the middle of the axle. This is to allow the rope to return to the well from the pulley-wheel with minimum obstruction from the drum.

5.6 Tying the Rope.

To determine the exact place at which the rope is to be tied, the pipe is tied tightly to the pipe support pole so that the mouth of the pipe sits just over the edge of the drum. If a drum is not used and the water goes directly into a channel then the precise location of the pipe is not so important.

After tying the pipe tightly to the pole the rope is passed over the pulley-wheel, and the two ends of the rope brought together to determine the exact point at which the rope is to be tied.

It is best to make the rope as tight as possible at this stage as there will be a certain loosening up during continual operation. Tie the ends of the rope together using rubber straps first until satisfied with the positioning of rope, pipe, etc. Wire may be used to strengthen the joint if desired.

5.7 Final Adjustments and Operation.

After having tied the ends of the rope together it is again passed over the pulley-wheel. The pipe is tied tightly to the pipe support pole. The pipe-stand should be inspected to ensure it is sitting horizontally on the bottom of the well.

Turn the handles of the axle and the rope with washers should pull the water up through the pipe and into the drum.

5.8 Possible Faults.

Listed below are some possible faults and suggested remedies :-

Rope-slipping.

The rope will slip if it gets too loose, or if the washers get stuck at the bottom of the pipe.

A loose rope may be caused and remedied in a number of ways :

- rope too long; cut it and rejoin at correct length.
- pipe slipped up along support poles; check and adjust.
- pipe support pole and axle pole being pulled together by the tension of the rope; tie the stays firmly to the poles to prevent movement.

Rope and Washers stuck.

If the washers get stuck at the bottom of the pipe there may be a number of reasons :

- pipe stand has fallen over; check that the stand is sitting correctly on the well bottom.
- rope guide has shifted on the pipe stand, or is incorrectly attached; check and adjust.
- washers are too big; there may be a 'rogue' washer or the washer may be a little too close fitting. Trim to correct size.

Provided the washers are not stuck and the rope is not slipping then the pump should be easy to operate and cope easily with mud or weeds.

5.9 Performance.

The output of the pump depends on the energy of the people pumping, the size of the pipe, the difference in level of the water in the well and the top of the pipe, and the overall efficiency of the pump.

With a pipe 50mm in external diameter (46mm internal) it is possible to fill a 200 litre drum in two minutes lifting the water over a 1,5m lift.

SECTION 6

COST.

The following approximate prices, in Zimbabwe dollars, current in early 1986, may be used as a guide to the cost of the pump.

(i)	Pipe, 3m length @ $2,50/m	7,50
(ii)	Round bar, 8m @ 50c/m	4,00
(iii)	Rope, 10m @ 90c/m	9,00
(iv)	Tyre, for washers and pulley	1,00
(v)	Timber	5,00
(vi)	Wire, rubber straps, nails	5,00
	Sub Total	$ 31,50
	Including a 10% contingency	
	Total	$ 35,00

In addition poles will be needed to support the pump and if the drum and siphon method is used then these items must also be bought or procured.