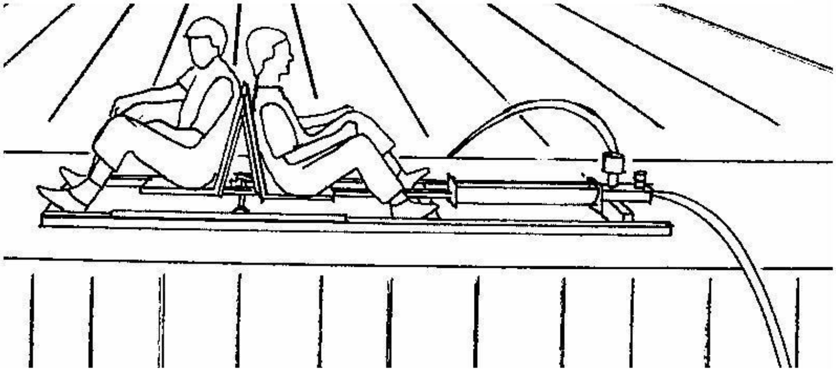
Home

List of Contents

Home"" """"> ar.cn.de.en.es.fr.id.it.ph.po.ru.sw

Index.htm



TWO MAN LOW LIFT WATER PUMP TROLLEY TYPE

ALEX WEIR

UNIVERSITY OF DAR ES SALAAM

FACULTY OF AGRICULTURE

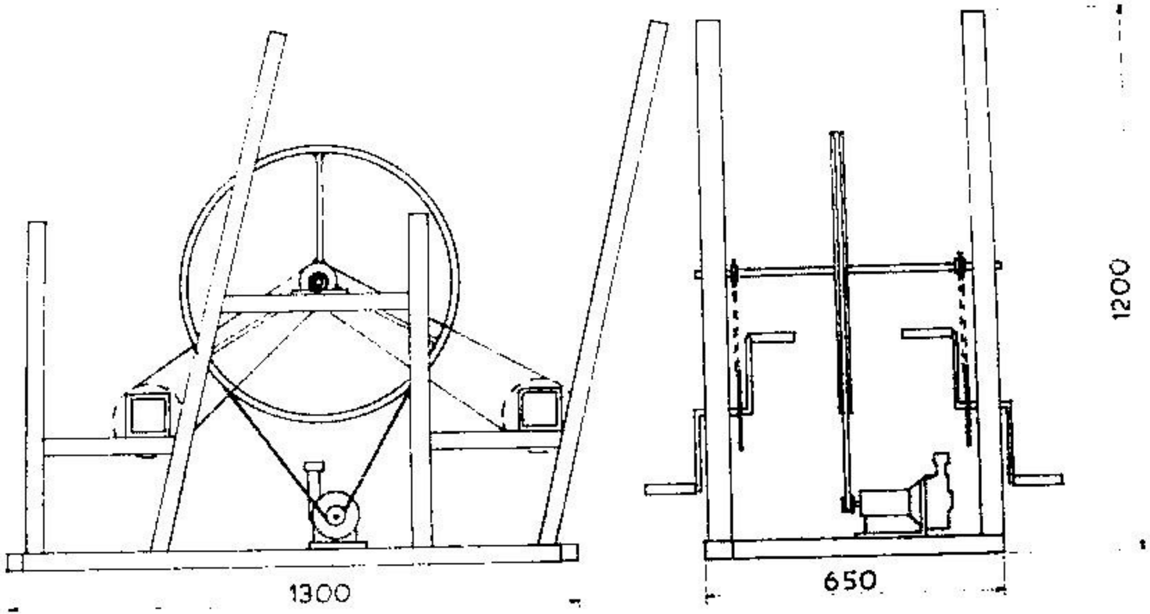
DEPARTMENT OF AGRICULTURAL ENGINEERING

MOROGORO TANZANIA 1979

(NOW SOKOINE UNIVERSITY)

Dwg002.htm

Index.htm



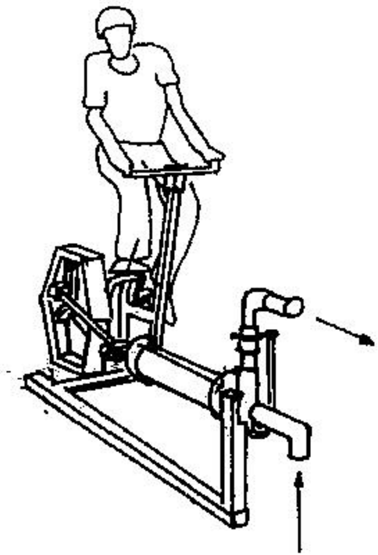
FOUR-MAN PEDAL CENTRIFUGAL WATER PUMP ASSEMBLY

STUART TURNER MODEL 25 PUMP WITH EATON VEE BELTING DRIVE AND BALL-BEARING MOUNTED LAYSHAFT DRIVEN BY 4 OPERATORS THROUGH BICYCLE CHAINS AND SPROCKETS

Dwg001.htm Dwg003.htm

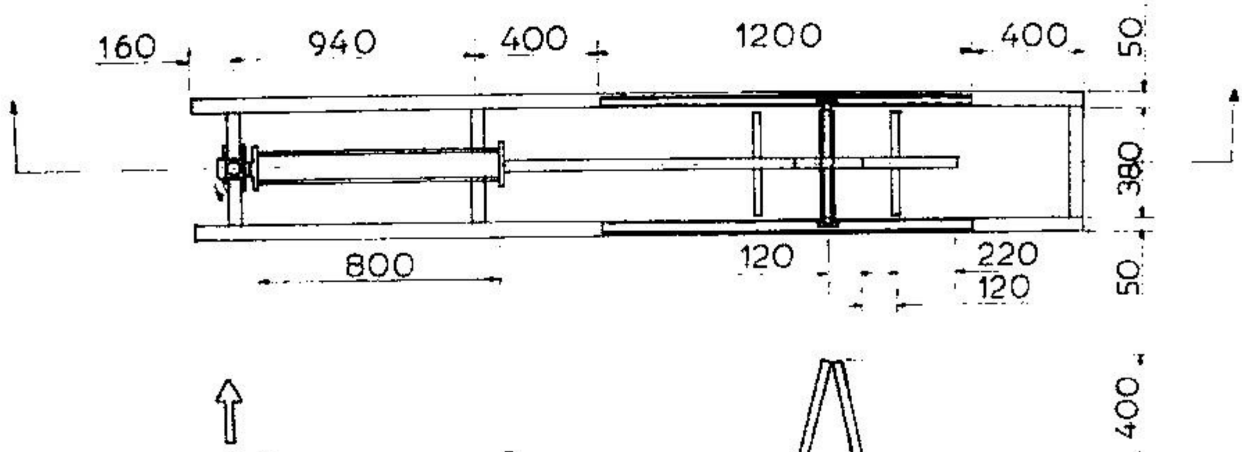
Home"" """""> ar.cn.de.en.es.fr.id.it.ph.po.ru.sw

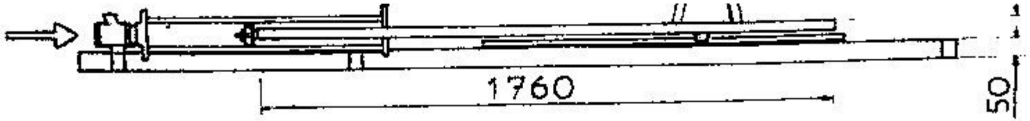
Index.htm



ONE MAN PEDAL PISTON PUMP WITH ADJUSTABLE LENGTH CRANK AND 3 INCH PVC PUMP BARREL

Index.htm





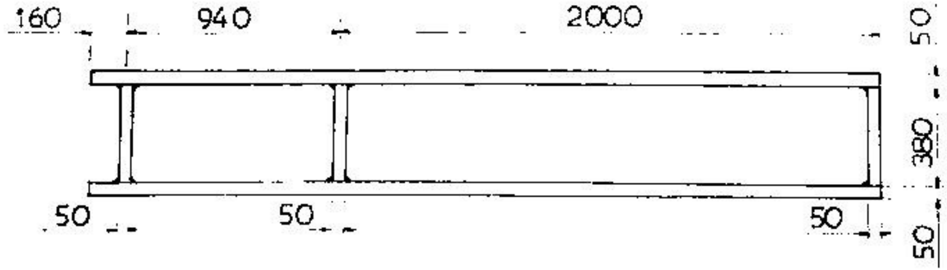
2 MAN LOW LIFT TROLLEY WATER PUMP ASSEMBLY -

WITHOUT FOOT VALVE AND OUTLET VALVE

Dwg003.htm Dwg005.htm

Home"" """"> ar.cn.de.en.es.fr.id.it.ph.po.ru.sw

Index.htm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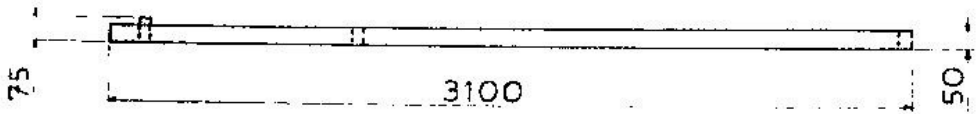

75
3100
50

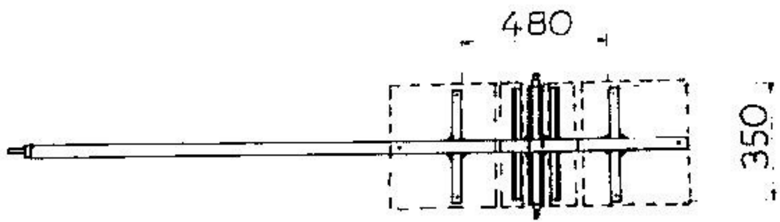
2 MAN LOW LIFT TROLLEY WATER PUMP FRAME ASSEMBLY, 1 PIECE, MILD STEEL RECTANGULAR HOLLOW SECTION 50 x 50 mm WITH ONE SECTION 380mm x 75 x 50 mm.

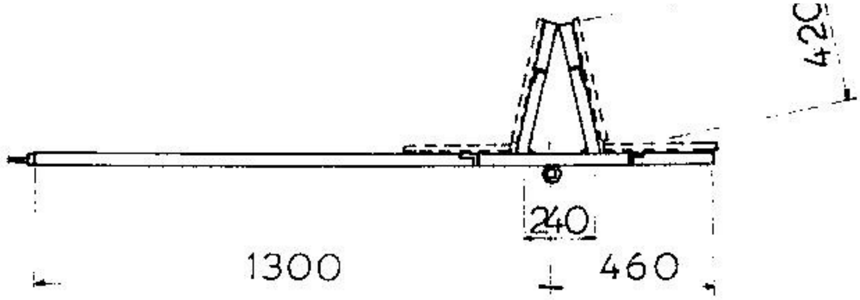
WITHOUT RAILS FOR BALL BEARING TRAVEL

Dwg004.htm Dwg006.htm

Home"" """"> ar.cn.de.en.es.fr.id.it.ph.po.ru.sw

Index.htm



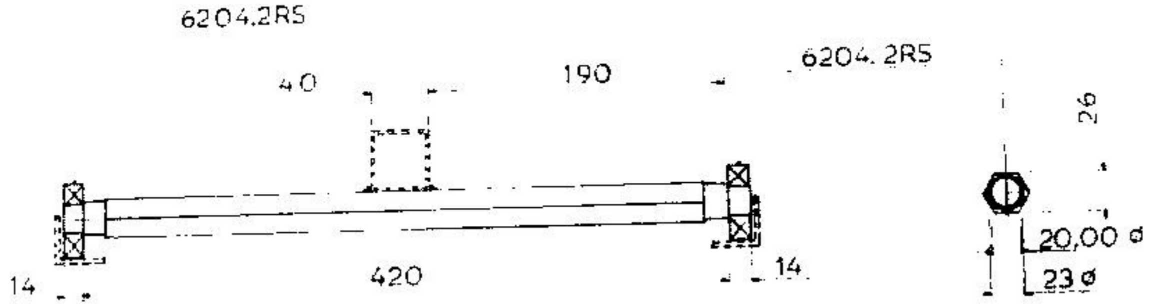


2 MAN LOW LIFT TROLLEY WATER PUMP, TROLLEY ASSEMBLY, 1 PIECE, MILD STEEL, COMPLETE WITH SEATING FRAME AND THREAD FOR PUMP PISTON LEATHER CUP.

Dwg005.htm Dwg007.htm

Home"" """"> ar.cn.de.en.es.fr.id.it.ph.po.ru.sw

Index.htm


6204.2RS
40
190
6204. 2RS
26
20,00 ø
23 ø
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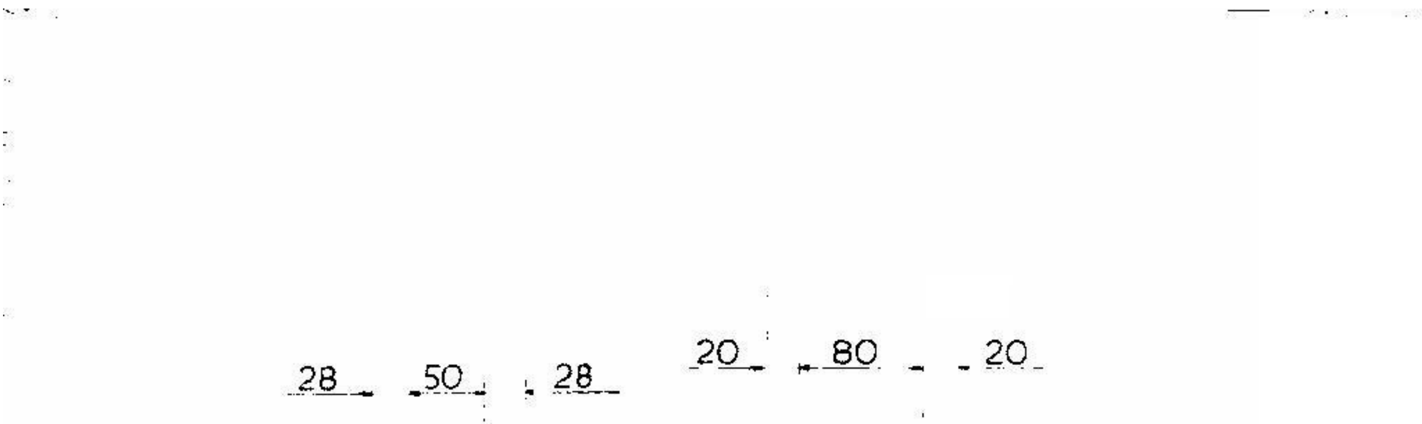
420
14.

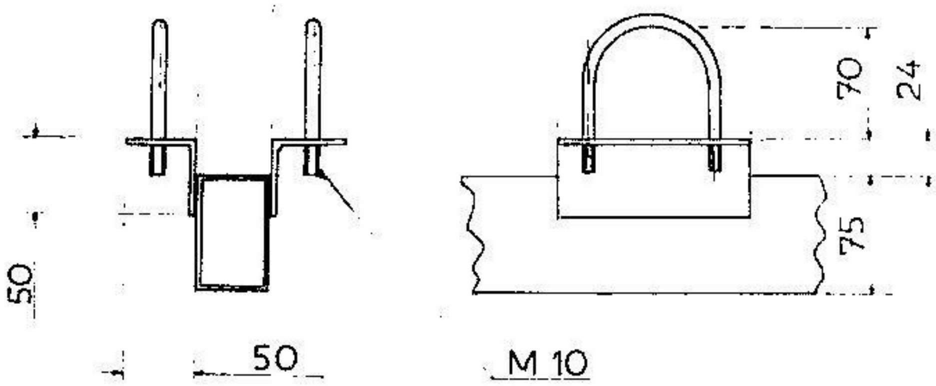
TWO MAN LOW LIFT TROLLEY WATER PUMP TROLLEY AXLE COMPLETE WITH BALL BEARINGS 2 OFF 6204.2RS RUNNING IN MS ANGLE IRON RAILS. ONE PIECE, MILD STEEL HEXAGONAL BAR WITH LATHE-TURNED ENDS

Dwg006.htm Dwg008.htm

Home"" """"> ar.cn.de.en.es.fr.id.it.ph.po.ru.sw

Index.htm





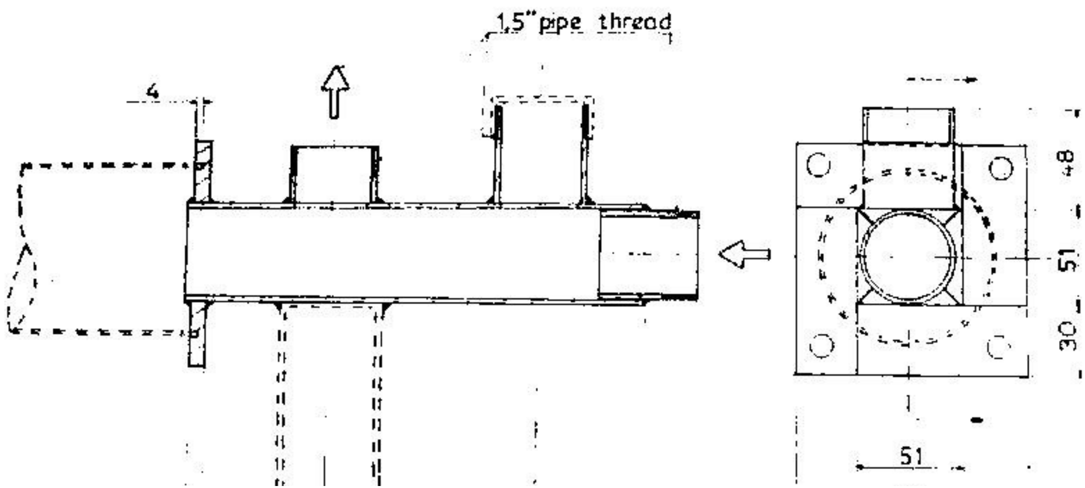
TWO MAN LOW LIFT TROLLEY WATER PUMP, PUMP/FRAME CLAMPING ASSEMBLY, 1 PIECE, MILD STEEL,

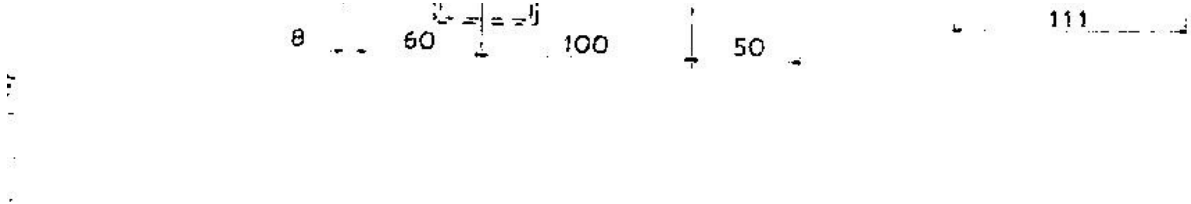
WELDED TO 75 X 50 mm RHS SECTION OF MAIN FRAME

[Dwg007.htm](Dwg007.htm) [Dwg009.htm](Dwg009.htm)

Home"" """"> ar.cn.de.en.es.fr.id.it.ph.po.ru.sw

Index.htm

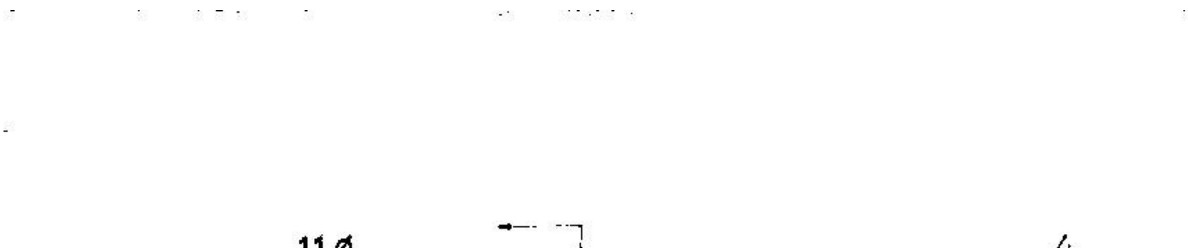


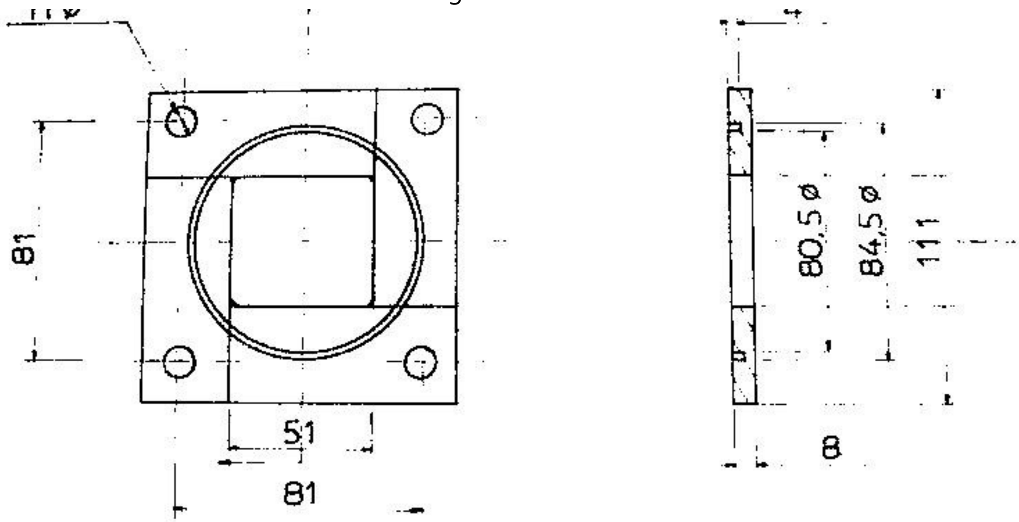


2 MAN LOW LIFT TROLLEY WATER PUMP, BARREL / FRAME / PIPES CONNECTION ASSEMBLY (LOW COST VERSION), 1 PIECE, MILD STEEL WELDED ASSEMBLY, SHOWING GROOVE FOR 80 mm RUBBER SEALING RING FROM FLANGE TO PVC PIPE BARREL.

Dwg008.htm Dwg010.htm

Home"" """"> ar.cn.de.en.es.fr.id.it.ph.po.ru.sw



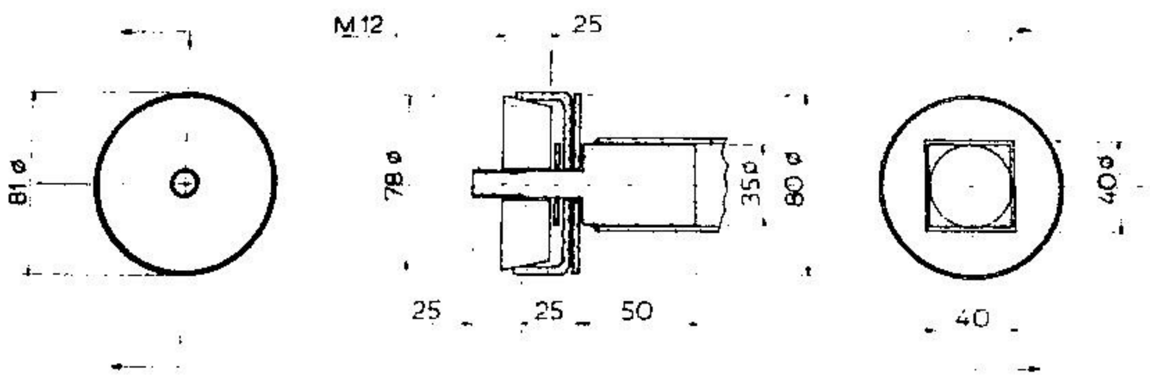


2 MAN LOW LIFT TROLLEY WATER PUMP PUMP BARREL REAR FLANGE ASSEMBLY, 1 PIECE, MILD STEEL, WELDED CONSTRUCTION, COMPLETE WITH MACHINED 80mm DIAMETER GROOVE FOR

LOCATION OF PVC BARREL

Index.htm Dwg009.htm Dwg011.htm

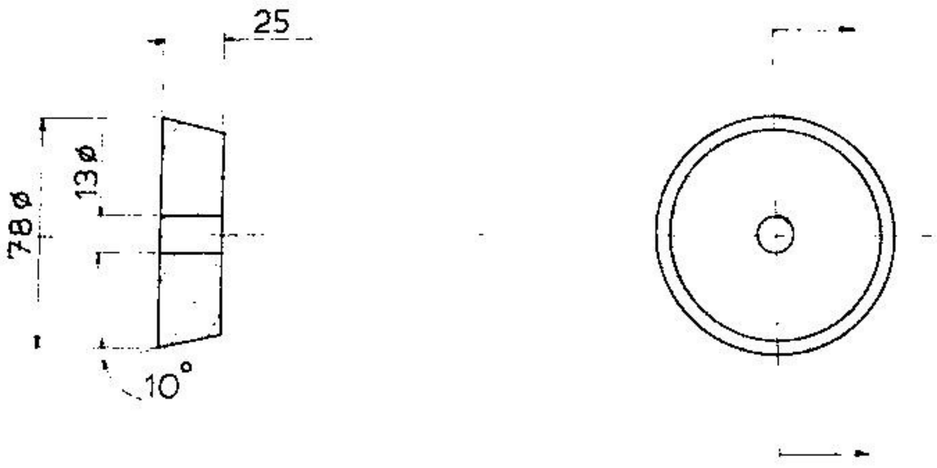
Home"" """""> ar.cn.de.en.es.fr.id.it.ph.po.ru.sw



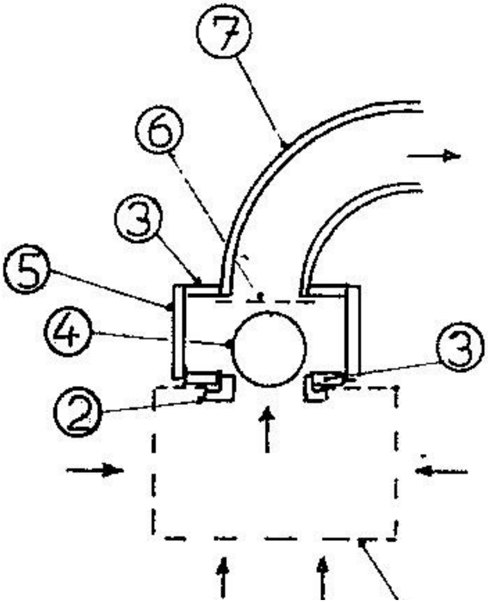
2 MAN LOW LIFT TROLLEY WATER PUMP - PISTON ASSEMBLY, 1 PIECE, MILD STEEL STUB AXLE WELDED INTO TROLLEY PUSHROD, WITH WOODEN TAPERED INSERT, STEEL SPACING WASHER(S), LEATHER PUMP CUP WASHER, AND MILD STEEL BACKING WASHER

Index.htm Dwg010.htm Dwg012.htm

Home"" """"> ar.cn.de.en.es.fr.id.it.ph.po.ru.sw



2 MAN LOW LIFT TROLLEY WATER PUMP - TAPERED WEDGE FOR LEATHER CUP WASHER EXPANSION, 1 PIECE, OIL-IMPREGNATED HARDWOOD, MACHINED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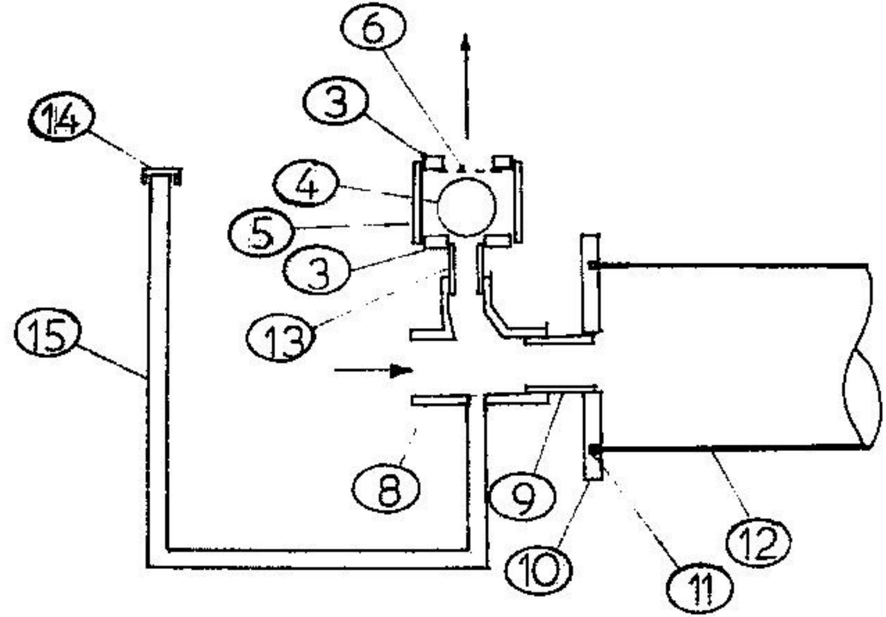
2 MAN LOW LIFT TROLLEY WATER PUMP FOOTVALVE / INLET VALVE ASSEMBLY, 1 PIECE

1. STRAINER, 120mm cube x 1 mm thick mild steel mesh with 4 mm diameter holes
2. REDUCING BUSH, 1.5 INCH X 1.25 INCH NOMINAL SIZE
3. REDUCING BUSH, 2.5 INCH X 1.5 INCH, 2 OFF
4. SOLID RUBBER BALL, 50mm DIAMETER
5. SOCKET, 2.5 INCH
6. SCREEN, 66mm DIAMETER X 1 MM thick mild steel mesh x 4mm holes
7. ELBOW, 1.5 INCH MALE TO FEMALE

Index.htm Dwg012.htm Dwg014.htm

Home"" """"> ar.cn.de.en.es.fr.id.it.ph.po.ru.sw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2 MAN LOW LIFT TROLLEY PUMP DELIVERY VALVE ASSEMBLY, 1 OFF

3. 2 PIECES REDUCING BUSH, 2.5 INCH X 1.5 INCH
4. SOLD RUBBER BALL, 50 MM DIAMETER
5. SOCKET 2.5 INCH
6. SCREEN, 66 MM DIAMETER X 1 MM THICK MILD STEEL MESH X 4 MM DIAMETER HOLES
7. No entry
8. REDUCING EYE TEE PIECE 2 INCH X 1.5 INCH
9. NIPPLE 2 INCH
10. FLANGE 2 INCH
11. RUBBER SEALING RING 3 INCH (CAN BE CUT FROM VEHICLE INNER TUBE)
12. PVC PIPE 3 INCH X 800 MM LONG
13. NIPPLE 1.5 INCH
14. CAP 0.5 INCH
15. PRIMING SYSTEM PIPING 0.5 INCH NOMINAL BORE (OPTIONAL)

Index.htm Dwg013.htm

Home"" """"> ar.cn.de.en.es.fr.id.it.ph.po.ru.sw

Home

List of Contents

Dwg005.htm

Dwg006.htm

Dwg007.htm

Dwg008.htm

Dwg009.htm

Dwg010.htm

Dwg011.htm

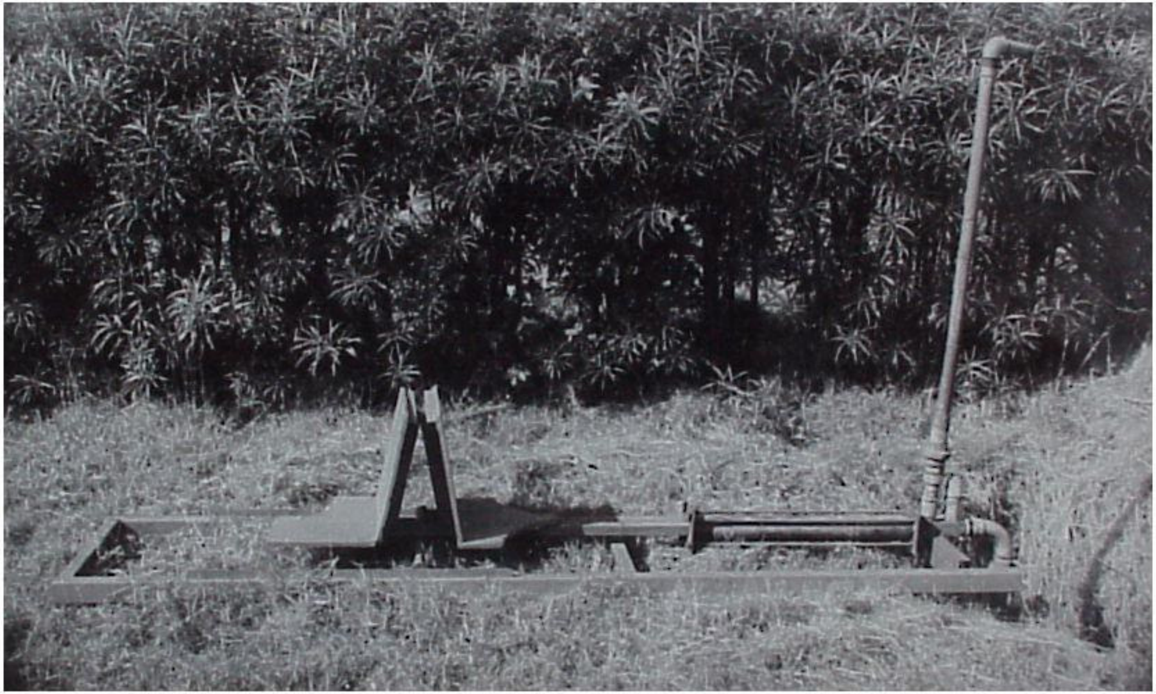
Dwg012.htm

Dwg013.htm

Dwg014.htm

Home"" """"> ar.cn.de.en.es.fr.id.it.ph.po.ru.sw

Index.htm

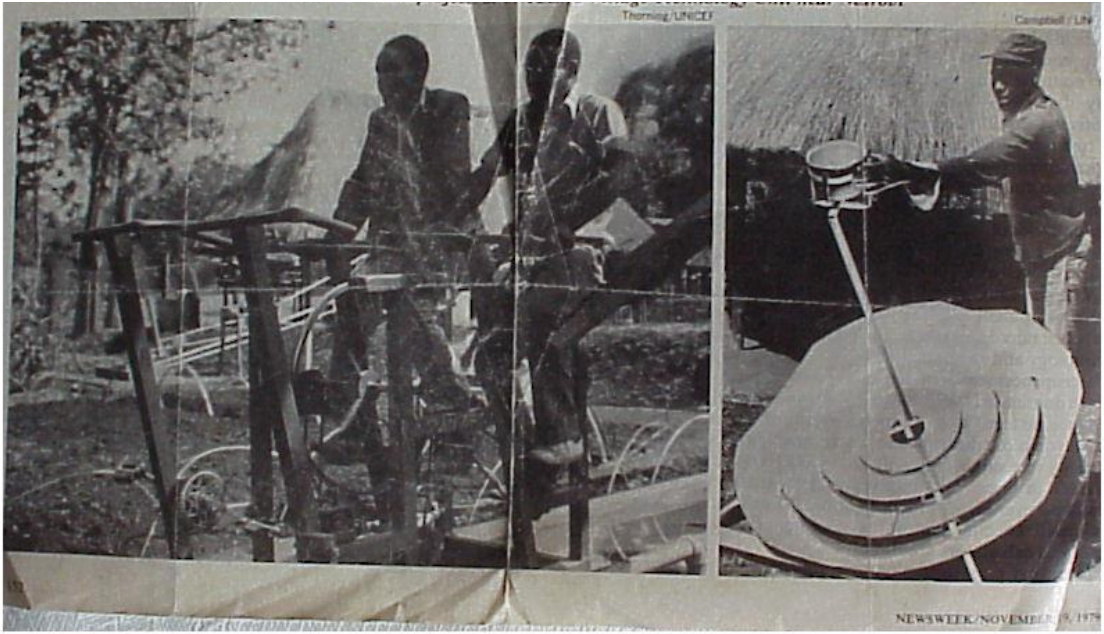


2 MAN LOW LIFT TROLLEY PUMP

Home"" """"> ar.cn.de.en.es.fr.id.it.ph.po.ru.sw

Index.htm

Old but new technology: A simple solar reflector makes an efficient cooking stove, and a bicycle built for two pumps irrigation water c
rate of three buckets per minute in demonstration projects at UNICEF's Village Technology Unit near Nairobi



4 MAN LOW LIFT CENTRIFUGAL WATER PUMP

Dwg001.htm

Home"" """"> ar.cn.de.en.es.fr.id.it.ph.po.ru.sw

Index.htm

INTRODUCTION 1999

This pump was built in 1978 and this report was written in 1979. I had one refusal from ITDG to publish it then and stupidly gave up instead of persevering. Recently I see that current designs of man powered pumps for use in 3rd world locations are not any better than what I was doing 20 years ago. And opportunities and media (e.g. the Internet) for dissemination of information have bettered by leaps and bounds during those 20 years. So here is the report. Note that some of the lengthy stuff like a survey of alternative pumps and a survey of human power output is shortened or deleted to avoid boredom or duplication with many other publications. There is nothing extremely clever or exceptional about this pump, but it is a nice design which works well with or without modification.

Alex Weir November 1999.

Alexweir@usa.net

Home"" """"> ar.cn.de.en.es.fr.id.it.ph.po.ru.sw

Index.htm

ACKNOWLEDGEMENTS

Some of the people listed below appear here, and I am the badly-dressed white guy with the beard

Many thanks to John Shetui (seen above) for working with me on the pump described in this report, and to David Wright of ITDG UK for the germ of the idea.

To the Ministry of Water Development in Morogoro and Dar es Salaam, UNICEF Dar es Salaam, and to Mount Carmel Rubber Factory Dar es Salaam for gifts, loans and sales of various parts.

To Howard Hepworth and Mr Ryoba of Ilonga Research Station and to the villagers of Ulaya Ijamaa Village for trying out an early prototype.

To the staff and students of the Department of Agricultural Engineering and Land Planning, University of Dar es Salaam, Morogoro Tanzania for help: John Mzuanda, John Sokoro, Ramadani Mhando, Rayner Kassana, Philbert Mendile, John Maswanya, John Shetui, Henry

Kamukara, Geoff Mrema, Kayumbo, Massawe, John Dumelow, Martin Parkes, Ranjiv Singh, Lalit Kumar, Frank Inns, Henrik Have, Professor Rana etc etc...

To the University of Dar es Salaam and the UK Ministry of Overseas Development (BESS) for paying my wages.

To the Small Industries Development Organisation (SIDO) Morogoro Branch for a development request in 1976, and to UNICEF for their 2 orders for prototype pumps.

To VITA (USA) www.vita.org vv@vita.org and ITDG (UK) www.oneworld.org/itdg itdg@itdg.org

for supplying reports on existing pumps.

Dwg003.htm

Dwg004.htm

Dwg005.htm

Dwg006.htm

Dwg007.htm

Dwg008.htm

Dwg009.htm

Dwg010.htm

Dwg011.htm

Dwg012.htm

Dwg013.htm

Dwg014.htm

Index.htm

INTRODUCTION

Irrigation has been practised in arid lands for thousands of years, using rivers as the source of water to grow essential food crops.

In many villages in Tanzania, relatively flat land alongside rivers and streams is used for irrigated production of onions, tomatoes, and other horticultural produce, often using buckets and watering cans, and sometimes using motorised pumps. In many large villages and towns, a good cash market exists for such crops, encouraging production for sale. Some cash is thereby available to provide production inputs additional to human labor.

In hilly areas, a gravity-fed water conveyance system is the main requirement for irrigated production. In other areas, water must first be raised from the river using a suitable water-lifting device or pump. The work described in this report puts forward a possible solution which could be viable from an economic viewpoint and attractive to users.

Dwg002.htm

Dwg003.htm

Dwg004.htm

Dwg005.htm

Dwg006.htm

Dwg007.htm

Dwg008.htm

Dwg009.htm

Dwg010.htm

Dwg011.htm

Dwg012.htm

Dwg013.htm

Dwg014.htm

Home"" """"> ar.cn.de.en.es.fr.id.it.ph.po.ru.sw

Index.htm

OBJECTIVES

To design a human-powered water-lifting device or pump which:

- can raise water from a river, stream, pond, dam or reservoir to a plot, operating through total heads of up to 6 metres.
- Can operate at a conversion efficiency of at least 50%
- Can effectively utilise the human mechanical power available, in an ergonomically satisfactory fashion.
- Can be locally produced
- Is reliable and long-lasting
- For which any required spare parts can be obtained or produced locally
- Which does not clog up easily when pumping from a river which has weeds and mud in the water flow
- Is of reasonably low capital cost in relation to output, and which competes economically with traditional bucket irrigation and with motorised pumps
- Can easily be carried or otherwise transported over short distances

Dwg001.htm

Dwg002.htm

Dwg003.htm

Dwg004.htm

Dwg005.htm

Dwg006.htm

Dwg007.htm

Dwg008.htm

Dwg009.htm

Dwg010.htm

Dwg011.htm

Dwg012.htm

Dwg013.htm

Dwg014.htm

Index.htm

REVIEW OF WATER LIFTING DEVICES AND PUMPS

(shortened from original 1979 report and with diagrams removed)

Shadoof

Cableway and bucket

Bucket and Chain pump

Persian Wheel

Archimedean Screw

Dragon-Tooth Pump

Washer Pump

Vane Pump

Hydrostatic Coil Pump

Piston Pump

Centrifugal Pump

Semi-Rotary Pump

Diaphragm pump

Inertia pump (flap-valve pump)

Axial flow pump

Quasi-centrifugal pump (inverse sprinkler)

Rope pump

RECOMMENDATIONS

Of the "Village Technology" solutions, the shadoof, the cableway-and-bucket, and the bucket-and-chain pumps appear to me the most suitable.

Of the "off-the-shelf" solutions, the piston pump and the semi-rotary pump appear the most useful.

The vane pump and the axial flow pump could be feasible innovative solutions.

For the urban or rural craft workshop level, the locally-produced piston pump is possibly the best solution.

Dwg006.htm

Dwg007.htm

Dwg008.htm

Dwg009.htm

Dwg010.htm

Dwg011.htm

Dwg012.htm

Dwg013.htm

Dwg014.htm

Home"" """"> ar.cn.de.en.es.fr.id.it.ph.po.ru.sw

Index.htm

LITERATURE REVIEW HUMAN ENERGY UTILISATION (abbreviated from 1979 report)

Krendel (1963)

VITA (1975)

Wilkie (1960)

Sutton (1974)

Note that an average adult male food consumption of 3,100 kilocalories per day is equivalent to 3.6 kiloWatt-hours of energy. It is reasonable to expect that a ceiling mechanical energy output per day is therefore in the region of 1 kiloWatt-hour (kWh)of mechanical energy.

Dwg008.htm

Dwg009.htm

Dwg010.htm

Dwg011.htm

Dwg012.htm

Dwg013.htm

Dwg014.htm

Home"" """"> ar.cn.de.en.es.fr.id.it.ph.po.ru.sw

Index.htm

PROGRAM OF PUMP DEVELOPMENT AT MOROGORO

Work was started by Professor Rana of the Agric Engineering Department in 1972. He adapted a commercial "Stuart Turner: single cylinder double acting piston pump to one-man pedal drive utilising a bicycle frame, bicycle chain and sprocket drive and a cement flywheel.

Msimbira (1974) made performance tests and at the request of Howard Hepworth, the pump was used at Ulaya Ujamaa Village for several months. Ryoba (1974) reported that the pump was effective.

However the output from the pump 0.25 litre per second was fairly low, and the cost of the pump alone was around US$ 150-00 in 1976 prices. For the pumping heads which we expected (typically 3 metres) then the water delivery per man-hour and the energy requirement in Watts were really too low, and a means of increasing output was sought.

It was realised that running piston pumps above their design speed results in severe efficiency losses in the valves; and it was found that larger commercial piston pumps were very expensive.

In 1976 the write produced a 4-man pedal centrifugal pump, using a commercial "Stuart Turner Model 26" pump driven at 3,500 rpm through a 2-stage chain and then belt drive. Flow was around 2 litre/second through 4 metres total head, with an efficiency of approximately 25% and a human power input requirement of approximately 80 watts for each of the 4 riders. Pump cost was US$ 150 (1976 prices) and the cost of the completed machine was US$ 400-00 (1976 prices) including labor, overheads and margins. It was sold to UNICEF for their Nairobi Village Technology Center and merited a photograph in Time Magazine. At that point in time I discontinued work on centrifugal conversions because of relatively low pump efficiency.

Kimboka (1977) designed, constructed and tested a man-powered tyre-diaphragm pump with a lever action. This pump was found to be 70% efficient when operated at 10 strokes per minute with zero suction head. Maximum suction head was 1.5 metres and efficiency fell rapidly with increasing suction head and increasing speed of operation.

Weir in 1977 developed a 2-man pedal piston pump, whose stroke could be adjusted by varying the throw of the crank, thus creating flexibility for different heads and operator fitness levels. Output was 1.5 litre/second at maximum stroke, and efficiency was about 60%. Estimated capital cost US$ 375 (1976 prices). The pump was demonstrated at the Rural Technology Meet at Arusha., Tanzania, September 1977. Because of the weight and size of the pump it was decided to simplify the drive mechanism. The resultant system is described in this report and a second machine of this type was sold to UNICEF for use on a Womens Project in Mali West Africa.

PUMP CONSTRUCTION..Pump090.htm

PUMP DRIVE MECHANISM...Pump100.htm

PUMP PERFORMANCE..Pump110.htm

DRIVE MECHANISM COMPARISON..Pump120.htm

Home"" """"> ar.cn.de.en.es.fr.id.it.ph.po.ru.sw

Index.htm

PUMP CONSTRUCTION

The single-acting pump has normally a 3 inch (80mm) PVC barrel and 1.5 inch (40mm) inlet and outlet connections. The 3 inch barrel can be altered to 2 inch for high heads and 4 inch for very low heads. The piston is a single 3 inch leather cup washer with a mild steel back plate and a tapered wooden disc (tufnol or other non-water-exposure-warping plastic might be more suitable in prolonged useage) in front, which is tightened into the cup washer by a nut on the end of the pushrod.

The function of this tapered wooden disc is to produce a grip between the leather cup washer and the PVC barrel which is tight enough to provide good suction and a low seepage, without being so tight as to reduce efficiency below an acceptable level. An appropriate solution is obtained by fitting a suitable number of steel washers between the cup washer and the disc.

A priming system is incorporated to cope with suction heads of greater than 5 metres, or in caes where the leather cup washer has worn and has not been adjusted or replaced.

For short suction lines, only a delivery valve and a footvalve should be required; for longer suction lines then a third non-return valve at the pump inlet is probably necessary. A commercially available footvalve and outlet valve could be used, but for the prototypes so far built at Morogoro, locally-made ball valves were constructed, using solid rubber balls sealing in conical seatings machined in standard pipe reducing bushes. Each valve ball is restrained when open by a mild steel screening which is brazed to the upper reducing bush using oxyacetylene and copper brazing rods.. These features can be seen by reference to the accompanying drawings.

For the inlet pipe, 1.5 inch low-pressure grade galvanised steel pipe (GSP) or ployethyelene (PE) pipe is recommended. PE fittings in Tanzania in 1976 were more expensive than GSP fittings but the pipe itself was cheaper per metre, so for anything over 10 metres length PE was usually cheaper; PE is also easier to lay and has lower pipe friction and therefore pumping losses. However if a PE inlet pipe is used then the footvalve should be fastened to an anchored timber float to prevent it from resting on river or pond bed and sucking in mud and silt.

For the delivery pipe, 1 inch or 1.5 inch low pressure PE or GSP is recommended. 1.5 inch is more expensive but has lower pumping losses and less operator effort.

The PVC barrel is held tightly between the 2 steel flanges by 4 x 10mm diameter mild steel tension studs or bolts (home-made studs from 10mm mild steel bar threaded with 10mm dies and using commercial nuts is a good quality and cost solution). The barrel is sealed against the front flange by means of a rubber sealing ring sitting in the machined (lathe) flange groove. Such sealing rings can be bought commercially or better still can be cut from old vehicle tyre inner tubes.

The unit which comprises the front flange, the inlet and outlet connections, and the priming system (if required) is fastened to the main frame of the machine, and can be made in either of 2 ways:

The original design was made entirely from standard pipe fittings, and was clamped to the machine frame by 2 locally-made mild steel U-bolts. In order to save costs, the modified design (as shown here) was made entirely of standard steel sections and galvanised steel pipe (GSP), welded and brazed into an assembly, and welded to the machine frame. This design resulted in greatly reduced material costs, but requires more skilled man-hours. Which design is chosen will depend on local skill availability and relative pricing of skilled labour and pipe fittings.

[Dwg001.htm]

[Dwg002.htm]

[Dwg003.htm]

[Dwg004.htm]

[Dwg005.htm]

[Dwg006.htm]

[Dwg007.htm]

[Dwg008.htm]

[Dwg009.htm]

[Dwg010.htm]

[Dwg011.htm]

[Dwg012.htm]

Dwg013.htm

Dwg014.htm

Home"" """"> ar.cn.de.en.es.fr.id.it.ph.po.ru.sw

Index.htm

PUMP DRIVE MECHANISM

The piston stub axle is welded to a pushrod made of 40 x 40mm mild steel rectangular hollow section. This pushrod connects the piston to the trolley axle, which is 1300 mm away. As mentioned above, if high heads are to be used then a 2 inch PVC pump barrel should be used, and then at least part of this pushrod should be replaced say by 1 inch GSP steel pipe, to avoid running against the rear steel flange which clamps the PVC barrel.

Pressed on the machined ends of the trolley axle are 2 double-rubber-sealed ball bearings, which run directly on 2 guide rails of 30 x 30mm mild steel angle section. These 2 guide rails are welded to the main frame of the machine. On to the pushrod and trolley axle assembly is welded a framework for the 2 timber seats, back to back along the machine axis. Two fixed footrests are an integral part of the machine frame, but of course adjustable timber or steel footrests can or should be fitted if required to cope for varying heights of operator, and to increase operator efficiency and comfort.

To pump water, 2 people sit back to back on the timber seats and push alternately against their footrests, thus moving themselves, the trolley and the pump piston through a stroke of up to 700 mm.

ADDENDUM 1999:

1. Note that the Trolley concept can be easily extended to a four-man or 4-person system, with 2 persons side by side back to back with another 2 persons side by side. Also the trolley system can easily be adapted to power traditional mortar-and-pestle milling by using a rope and 2 pulleys (the mortar and pestle unit itself would still require one operator for guidance, who would not however need to make any physical exertion). It should also be possible to link a 4, 6, 8 or more person trolley system to a crank and flywheel for powering other devices such as a grain thresher or alternator or dynamo for battery charging or direct powering of electrical devices. This last concept of course competes with the more traditional 4-person dynapod as shown in one of the accompanying drawings with the centrifugal water pump.

2. Note that it should be possible to design a system which can easily be changed between 3 inch, 4 inch and 2 inch pump barrels, and also with varying valve sizes (valves should anyway always be easily changed for maintenance, cleaning or replacement).

3. Note that it should be simple to design a pump of this type which can be used with a trolley mechanism or with a pedal mechanism. That would require some minor changes only to the design as shown here.

Dwg003.htm

Dwg004.htm

Dwg005.htm

Dwg006.htm

Dwg007.htm

Dwg008.htm

Dwg009.htm

Dwg010.htm

Dwg011.htm

Dwg012.htm

Dwg013.htm

Dwg014.htm

Index.htm

PUMP PERFORMANCE

Brief tests were carried out on an early version of the trolley pump, using a 4 inch barrel, and using rather small valve balls of 38mm diameter. Suction pipe diameter was 2 inch and delivery pipe diameter 1.5 inch. Both pipes were vertical.

Suction head was 1.37 metres and delivery head 1.65 metres. A half-cycle time of 1.5 seconds was used for both the suction and delivery strokes during testing. The empty trolley was pulled by hand using a spring balance. The average force on suction strokes was 23 kg force and 36 kg force on delivery strokes. Discharge was not measured.

From the above figures, pump efficiency was found to be 45%, assuming a pump discharge coefficient of 100%.

Because of this rather low efficiency figure, it was decided to fit larger valve balls, as specified in the accompanying drawings. The use of 55 mm diameter valve balls with a 3 inch valve barrel should give a pump efficiency of 60% or greater, depending on cup washer adjustment.

With a 620mm stroke, a 3 inch barrel, and a 3 second cycle time, the pump flow rate will be 1 litre per second. With 3 metre suction head, 3 metre delivery head and 60% efficiency the average work rate per operator will be 50 watts mechanical power. From the literature review of Human Energy Utilisation, such a work rate is easily sustainable by a reasonably healthy adult for long periods without undue strain.

For a horticultural crop with a peak water requirement of 10mm per day rainfall equivalent, the pump can irrigate an area of 0.25 hectares if used for 7 hours per day (0.25 ha is 2500 metres squared a rectangular plot 70 x 35 metres or a semi-circular plot of 40 metres radius).

Dwg001.htm

Dwg002.htm

Dwg003.htm

Dwg004.htm

Dwg005.htm

Dwg006.htm

Dwg007.htm

Dwg008.htm

Dwg009.htm

Dwg010.htm

Dwg011.htm

Dwg012.htm

Dwg013.htm

Dwg014.htm

Home"" """"> ar.cn.de.en.es.fr.id.it.ph.po.ru.sw

Index.htm

DRIVE MECHANISM COMPARISON

It is mentioned above that the trolley pump was chosen in preference to the 2-man pedal pump. The advantages of the trolley pump are:

- the pump is simpler to construct it requires less man-hours, less skill, and less steel. It is therefore cheaper to produce
- two rubber-sealed ball bearings replace effectively the 2 wooden rotating bearings, the one wooden oscillating bearing, and the one wooden sliding bearing of the pedal pump, thus increasing efficiency and reducing maintenance. However, by redesigning the pedal pump, ball bearings could be used instead of 3 of the above 4 bearings.
- because no flywheel is required, mass is greatly reduced. In addition the trolley system is dimensionally more compact.

However, the pedal pump did have also some advantages:

- the flexibility to adjust to different pumping heads and to operators of different physical abilities is largely lost this was possible with the pedal pump by a simple adjustment of the crank throw. With the trolley pump however, some flexibility can be provided by varying cycle time and crank stroke. Also during manufacture it is possible to choose between several cylinder diameters.

Ergonomically it would appear that pedalling is superior to the action required for this pump, which is similar to rowing. However Wilkies (1960) objection about energy wasteage due to the acceleration and deceleration of the whole body is probably not as valid as it is for rowing, since that energy can be absorbed by the pump suction or delivery actions.

Nevertheless, it is true that the effort exerted by each operator is concentrated over 25% of each pump cycle during that period the operator not only provides power for the suction or delivery of water, he also accelerates the combined mass of both operators, trolley and pushrod. Towards the end of his half of the pumping cycle, however, the deceleration of this combined mass provides stored energy for the suction or delivery of water.

As an example, it requires an additional 34 watts of power to accelerate a mass of 140 kg (2 adults?) from rest through a distance of 350mm in 1 second. The required acceleration is fairly low, at 0.07 g . These figures are probably typical for a cycle time of 3 seconds, and do not appear excessive.

More troublesome, speaking from experience, is the learning curve of 2 operators learning to push at times which suit each other. For operators comfort, adjustable footrests would seem to be important.

No village trials have yet been conducted at Morogoro, and no news has filtered back from the prototype sold to UNICEF for the project in Mali, but peoples reaction to the drive mechanism should be interesting.

Summing up, the writers prejudices would suggest that the technical simplicity of the trolley pump outweighs any advantages when compared with the previous design of pedal pump, but this is not yet borne out in practice.

PRODUCTION COSTS...Pump130.htm

Dwg009.htm

Dwg010.htm

Dwg011.htm

Dwg012.htm

Dwg013.htm

Dwg014.htm

Home"" """"> ar.cn.de.en.es.fr.id.it.ph.po.ru.sw

Index.htm

PRODUCTION COSTS

6.9 metres x 50 x 50 x 2 mm MS RHS	
5 metres x 30 x 30 x 3mm MS Angle Iron	

1.8 metres x 40 x 40 x 1.8 mm MS RHS	
0.5 metres x 26mm MS Hexagonal Solid Bar (but can probably substitute with something lighter)	
1. metres x 50mm diameter MS Round Bar	
0.7 metres x 30 x 8mm MS Flat Bar	
0.4 metres x 100 x 50 x 2 mm MS RHS	
Total Steel Sections (39 kg @ US$ 1250/tonne)	US$ 50
Leather Cup Washer + PVC Pipe	US$ 13
Outlet Valve Assembly	US$ 25
Foot Valve and Strainer Assembly	US$ 27
3 man-days skilled labor	US$ 25
Total Basic Cost	US$ 140
Overheads and Margins @ 30%	US$ 42
Pump Selling Price	US$ 182
10 metres x 1.5 inch suction pipe (GSP or PE) including connectors	US$ 75

40 metres x 1.5 inch PE delivery pipe plus connector	US$ 100
OR 40 metres x 1inch PE delivery pipe plus connector	US$ 75
Total Cost, using 1 inch delivery pipe	US$ 332

Dwg005.htm

Dwg006.htm

Dwg007.htm

Dwg008.htm

Dwg009.htm

Dwg010.htm

Dwg011.htm

Dwg012.htm

Dwg013.htm

Dwg014.htm

Home"" """"> ar.cn.de.en.es.fr.id.it.ph.po.ru.sw

Index.htm

OPERATIONAL COSTINGS

The following table compares the initial cost of the pump with that of some commercially-available pumps:

Pump Type	Output (litre/second)	Cost in US$
Bare-shaft piston pump	0.25	150
Bare-shaft centrifugal pump	2	150
Trolley Pump	1	182
Motorised Centrifugal Pump	4	1250

Now if we assume the following:

Operational life of motorised centrifugal pump = 2500 hours

Total pumping head = 6 metres

Pump efficiency = 25%

Petrol Engine efficiency = 20%

Petrol Calorific Value = 11 kW-hour/litre

Petrol Cost = US$ 0.40/litre

Interest Rate: 0%

Then we find that:

Unit fuel cost = US$ 0.015 / metre cubed of water raised

Unit Capital Cost = US$ 0.040 / metre cubed of water raised

This can be compared with paid or self-employed labor supplying water in 20 litre buckets lifted through 6 metres head at a rate of 25 buckets per man-hour for 6 hours per day, and being paid US$ 2 per day. The resultant net work rate is only 10 watts but gross work rate is probably 100 watts. Cost is US$ 0.670 / metre cubed of water raised.

Now consider the trolley pump with the US$ 332 cost amortised over 7 years at average utilisation of 500 hours per year. Take labor cost as US$ 0.25/hour per person and output as 1 litre/second for 2 operators.

Thus unit capital cost = US$ 0.030 / metre cubed raised

And unit labor cost = US$ 0.150 / metre cubed raised

The above unit cost figures for the trolley pump compare well with using direct labor with buckets, and not too badly with the motorised pump, when one considers the following:

- streams and dams may not have enough capacity to utilise a pump passing 4 litres per second
- a quoted operational lifetime of 2,500 hours may be wildly optimistic under prevailing conditions of maintenance and repair
- in most 3rd world countries, the import content of the motorised pump would be much

higher than the trolley pump and the use of shadow price factors for imports would greatly decrease the unit cost advantage of the motorised pump

- applying an interest rate of 5% through 50% per annum would also greatly change the numbers on trolley pump vs. Motorised pump

Finally, the average value of horticultural produce from a 0.25 hectare plot, asuming yields of 10 tonnes/hectare per 120 day growing season and a saleable crop value of US$ 0.75 per kg will be US$ 1750 per season. That compares well with the pump + piping cost of US$ 332 and a pump operator labour cost of well under US$ 480 per season.

Dwg004.htm

Dwg005.htm

Dwg006.htm

Dwg007.htm

Dwg008.htm

Dwg009.htm

Dwg010.htm

Dwg011.htm

Dwg012.htm

Dwg013.htm

Dwg014.htm

Index.htm

SUMMARY AND CONCLUSIONS

The pump described is a competitively cheap, simple and potentially reliable source of irrigation water for use in flat areas with streams, rivers, ponds, dams, lakes or reservoirs. It is compact, easy to transport, and its simplicity makes it suitable for local production on small-scale or large-scale.

However there will also be cases when other sources of irrigation water will be more suitable, whether gravity-fed, man-powered, engine-driven, animal powered or replying on so-called unconventional sources of energy such as wind or solar.

Dwg005.htm

Dwg006.htm

Dwg007.htm

Dwg008.htm

Dwg009.htm

Dwg010.htm

Dwg011.htm

Dwg012.htm

Dwg013.htm

Dwg014.htm

Home"" """"> ar.cn.de.en.es.fr.id.it.ph.po.ru.sw

Index.htm

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Dwg004.htm

Dwg005.htm

Dwg006.htm

Dwg007.htm

Dwg008.htm

Dwg009.htm

Dwg010.htm

Dwg011.htm

Dwg012.htm

Dwg013.htm

Dwg014.htm

Home"" """"> ar.cn.de.en.es.fr.id.it.ph.po.ru.sw

APPENDIX - RYOBA, J.M. (1974) "Report on the Irrigation System in Ulaya Ujamaa Village", internal report, Agricultural Field Officer Grade II, Ilonga Research Station, Kilosa, Tanzania

Ulaya Ujamaa Village is one of the six villages visited by the food technology extension team from Ilonga. The activities carried out in this village are food demonstrations and horticulture.

The horticulture plot was started in the village with an area of 0.25 acre (0.1 hectare) in which cabbages, onions, tomatoes and egg plants (aubergines) were planted, each in a small area. The expansion of the area was made difficult by the irrigation system used at the time. If the whole area was to be irrigated adequately, more villagers had to come down every morning and evening to do the watering before going out to other village projects. This slackened down other projects in progress and made it difficult to grow vegetables during the dry season.

The installation of the pedal pump eliminated the irrigation and enabled the villagers to expand their horticulture plot to about 1 acre (0.4 hectare). The pump also reduced the number of people who did the watering. Instead of ten, now only 2 people could do the watering, one pedalling and the other watering with a hose pipe. The ploy expanded rapidly to about 1.25 acres and enabled the villagers to sell about 100 kg of vegetables ervy week, being the most productive village the same project was carried out in the other five villages, but with bucket irrigation.

As the pump was installed at a small well near the plot, it made it possible to produce vegetables far into the dry season and long after other villages had stopped producing due to the dry spell.

The village obtained more then US$ 125 from their plot in comparison with the five others, which each obtained not more than US$ 25......

.........If vegetable growing is to be regarded as one of the cash earning enterprises for the Ujamaa Villages, then hand pumps or pedal pumps preferably of higher output but cheap and easily made and repaired should be designed and made available for the villagers to buy.

This will encourage vegetable growing both for village consumption and also for selling, whereby the purchasing power of the villagers can be greatly increased.

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Dwg001.htm

Dwg002.htm

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