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## Chinese Chain and Washer Pumps

Edited by: Simon Watt

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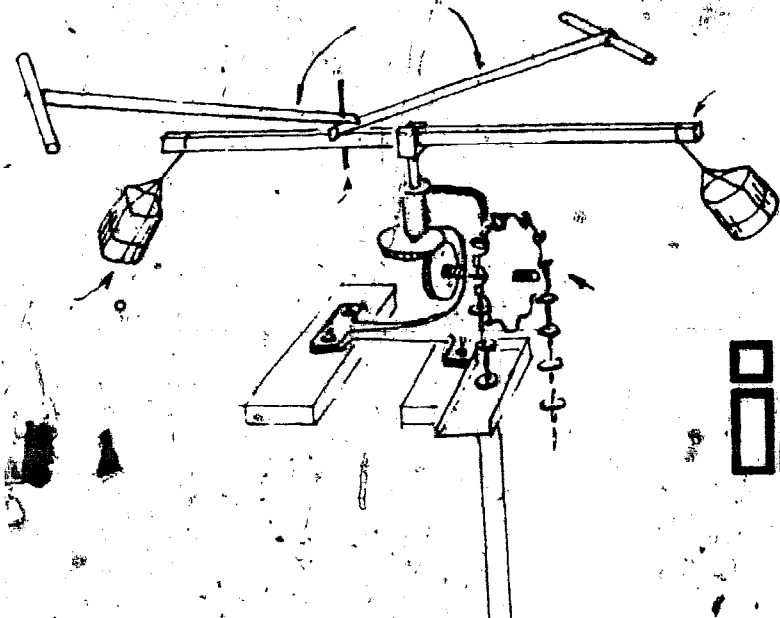
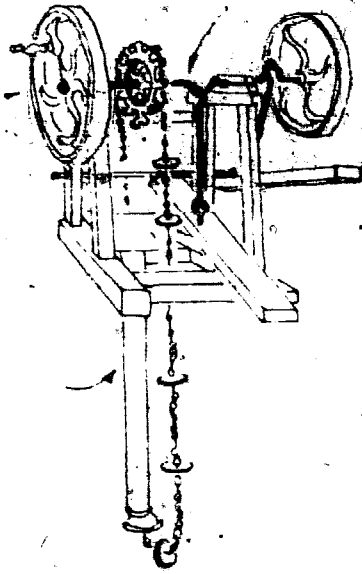
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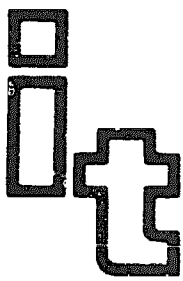
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# CHINESE CHAIN AND WASHER PUMPS



**Intermediate  
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The Intermediate Technology Development Group was formed in 1965 by a group of engineers, economists, scientists and others from industry and the professions, to provide practical and effective self-help techniques for developing countries. It is a non-profit organisation registered as a charity.

Its aim is to demonstrate and emphasise that aid must be designed to help the poor to help themselves.

The most urgent and intractable problem of the less developed countries is rural unemployment and mass migration to the cities. The highly sophisticated capital-intensive, labour-saving methods and equipment currently being exported create few jobs and waste scarce capital resources, whereas the technologies most likely to be appropriate for the poor countries are those which are labour-intensive, capital saving, use local materials and are simple enough to be used and maintained by the people themselves.

The Group is an action group which concentrates on research and development into self-help technologies for use in rural and village life; tests and demonstrates the results through field projects, programmes and consultancies; communicates the information to the developing countries through governments, organisations and individuals and by publishing material through its subsidiary, Intermediate Technology Publications Ltd.

**INTERMEDIATE TECHNOLOGY DEVELOPMENT GROUP,  
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# 21 CHAIN AND WASHER PUMPS

from the 1958 Peking Agricultural Exhibition

Compiled by

Simon Watt

*with an appendix by*

*John Collett*

April 1976

The logo for Intermediate Technology Publications Ltd features the word 'Intermediate' in a bold, sans-serif font above the word 'Technology'. The 'I' in 'Intermediate' is stylized with a square above it. The 'T' in 'Technology' is stylized with a cross-like shape. To the right of 'Technology' is the text 'Publications Ltd'. Below this, the address '9 King Street, London WC2E 8HN, England' is printed in a smaller font.

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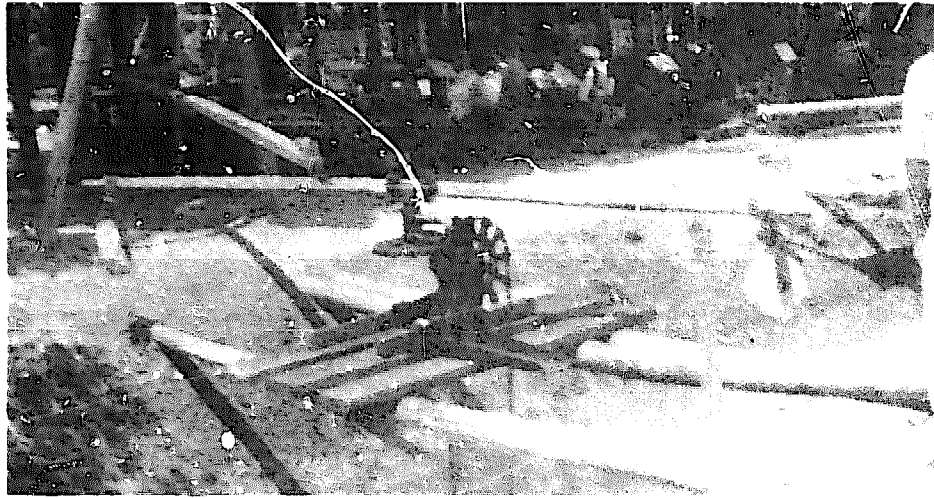
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Since the descriptions of the pumps included in this publication are translations of material circulated at the 1958 Peking Exhibition, publication does not imply that ITDG recommends any or all of the pumps. However, as the original leaflets are no longer available and the pumps are reportedly in general use, it was felt that publication of this information would be welcomed.

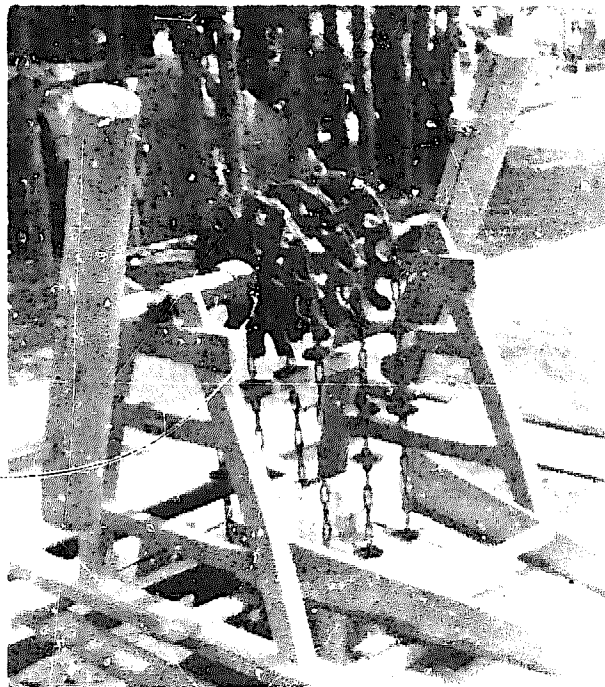
## ACKNOWLEDGEMENTS

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*We would also like to thank Dr Joseph Needham, Master of Caius College, Cambridge, for allowing us to use the original information sheets collected by him at the 1958 Peking Agricultural Exhibition, China. We would also thank Paul Y.S. Cheung, student in electrical engineering at Imperial College, London, for translating the information sheets from Chinese into English.*



Paternoster pump and 'fly-wheel' weighted with two mill-stones, manually operated by eccentric, connecting-rod and hand-bar as in the traditional mills, (orig. photo., Exhibition of Agricultural Machinery, Peking, 1958).



Triple paternoster pump manually operated with two cranks (orig. photo., Exhibition of Agricultural Machinery, Peking, 1958). The discoidal diaphragms (*phichhien*) can readily be seen.

**PLATE 1 CHAIN PUMPS FROM THE 1958 PEKING AGRICULTURAL EXHIBITION FROM J. NEEDHAM – 'SCIENCE AND CIVILISATION IN CHINA'**

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## PREFACE

This publication contains twenty one versions of the chain and washer water lifting device, displayed at the 1958 Peking Agricultural Exhibition, China. Each version of the pump was designed and built by separate communes, using local materials, skills and tools. A description of each pump with performance figures was written up in the simple information sheets that have been literally translated for this publication. The drawings presented on the information sheets have also been copied to allow anyone with a basic understanding of mechanics to build one of the devices; construction details are not included in this publication.

We have chosen only twenty one designs from the one hundred and twenty simple pumping devices that were on display. They were chosen to show how different materials can be used to make the pumps, and the various ways they can be powered by hand, foot, animal, wind or motor power. General technical information on the design, constructional features, and mode of operation of chain and washer pumps is included in the first part of this publication.

We hope that this publication will demonstrate the basic principles and potential of the device for use in rural areas, and show the wide variety of ways that it can be built.

S.B.Watt.

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## **1. AN INTRODUCTION TO THE 1958 PEKING AGRICULTURAL EXHIBITION**

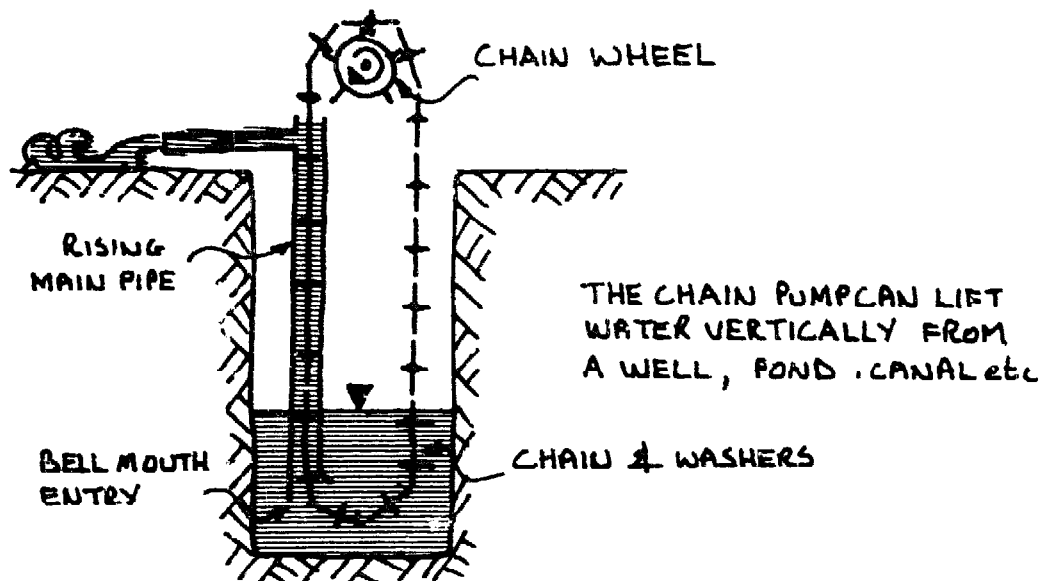
The national exhibition held in Peking in 1958 put on show agricultural equipment devised and manufactured by communes throughout China. Each exhibit on display was written up in short information leaflets, and a selected sample of these leaflets describing chain and washer pumps, literally translated, is presented in Section 6 of this publication. They demonstrate the enthusiasm and skills of different communes to make equipment appropriate to their needs at that time with their available resources.

China is still largely an agricultural nation, with the majority of the people engaged in the primary production of foodstuffs and the raw materials for industry. The policy of self reliance encouraged the local peoples to use their own intelligence and enthusiasm to improve their existing skills and living conditions to the best of their ability. It is not often understood that technological development must be as much concerned with the attitude of the users of the equipment, as it is with the physical nature of the equipment; the confidence of the users to adapt, improve, and innovate equipment is as important as the equipment itself. This exhibition demonstrated the high degree of effort and conviction held by the users to make and improve what is essentially a very simple pump.

The principles of operation of the chain and washer pump, and the important design features, are described in some detail in the following sections.

## **2. BACKGROUND OF THE CHAIN AND WASHER PUMPS**

The chain and washer pump, sometimes called the paternoster pump because of its resemblance to a string of rosary beads, is a pumping device that has been known and used for many centuries both in China and Europe. It works by the action of the chain and washers which are pulled in a continuous loop up inside a closely fitting pipe over a geared chain wheel, and down again to the bottom of the pipe. Water is carried up between each washer from the mouth of the submerged pipe, and discharged at the top of the pipe into a trough:-



The maximum practical lift for this sort of pump is about 15 to 20 metres and several chain and washer assemblies can be fitted on the same axle. The chain and washer pump is large and bulky, and can be described as a high mass/low power ratio pump. This means that each component of the device is not under great load or highly stressed, allowing relatively soft materials such as wooden or rope chains, oiled wood bearings etc., to be used.

The pump was widely used in Europe from the 16th Century onwards to drain mine workings, and was used in preference to the piston suction pump because of its low cost, ease of construction, and reliability. The pipe was usually built from iron bound timber planking, and the washers were made from balls of leather-covered horse hair. The balls were fairly flexible and made a good fit inside the pipe even if the diameter of the pipe varied. The leather bound ball washers were often replaced with bundles of rags which were cheaper and although less efficient, served the same purpose in lifting the water up the pipe.

The pumps described in this publication work on exactly similar principles. The leather or cloth balls are replaced with discs made from wood or iron plates, and the discs are often fitted with a rubber seal to reduce water leakage down past the discs.

Chain pumps have many advantages over other types of pumping devices. They are robust and can be made from local materials to low construction tolerances by local craftsmen; they are slow moving and the rate of wear of the parts will not be excessive because the power loading is spread out over the large mass of the

machine; this means that the corrosion, wear, or failure of one part will not usually prevent the pump from working. The pumps can manage water containing silt and other solids, and they can be easily maintained and serviced. They are slow moving devices, and can therefore be powered by men, animals, wind power, or slow turning internal combustion engines, with the minimum of gearing or high performance bearings. Their reliability is such that they were used up until the second half of the 19th Century as bilge pumps for the ships of the British Royal Navy.

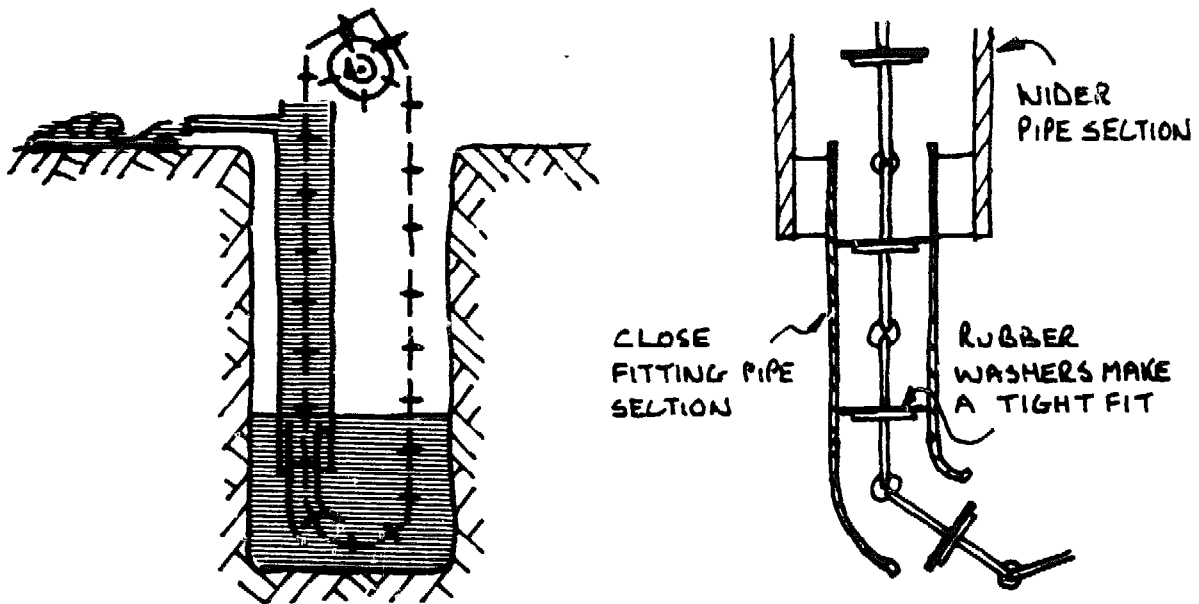
### 3. PRINCIPLES OF OPERATION

The robust chain and washer pump with its high mass, low power ratio, contrasts with the more modern and widely used smaller centrifugal pumps, which have a low mass/high power ratio. With the chain pump, therefore, the sturdy slow moving components do not need great skill and tolerance in manufacture, or skilled maintenance. The centrifugal pump, on the other hand, is relatively small, and has to concentrate the pumping effort through the faster moving, smaller components that need to be made from stronger materials with very accurate workmanship.

Centrifugal pumps, to work at their best efficiencies, need to turn many hundreds of times faster than the rate of rotation that can be delivered by men or animals, and to make them work at all expensive gearing would have to be used. This gearing, if it is not to waste most of the pumping energy during transmission, must be accurately made and maintained. Perhaps the greatest advantages of the chain and washer pump for rural areas are the slow speed of rotation and the steady unvarying rate of working that are completely compatible with the speeds at which men, animals, wind machines and slow speed diesel engines, can work.

The continuous loop of linked chain and washers is pulled up the rising main pipe, carrying water with it between the washers. Unless the washers are a reasonably tight and accurate fit, water will leak back down the pipe, and the pump will not work at all efficiently. However, the 'cascade' of washers will probably limit the leakage to acceptable amounts. An alternative design quoted in one of the

information sheets has an accurately made and close fitting section of pipe at the submerged lower end of the pipe. The accurately cut or rubber sealed washers make a tight fit in this section of pipe (which may be steel or plastic), and fit only loosely in the wider section of pipe above. The washers do the work of lifting in the close fitting section, reducing leakage to a minimum; in the looser and cheaper section of pipe above, they do no lifting work, but they also do not wear themselves out against the sides of the pipe in friction:-



This is a most useful innovation. It might be possible to manufacture the washers and the lower pipe section in a workshop, then distribute them to local areas to be built into the locally made body of the pump. Other innovations include a bell mouth entry at the bottom of the pipe to guide the washers into the pipe, and a non-return ratchet on the chain wheel to prevent the chain from running backwards under the weight of water in the pipe.

#### 4. COMPONENTS OF THE PUMP

##### 4.1 The Rising Main Pipe.

This pipe holds the water between the chain washers as it is being lifted up to the surface. It must be smooth inside to prevent leakage past the washers, and to reduce wear on the washers as they rub against them. It must be robust, watertight, cheap and easily made or replaced.

The pipe is hung down into the water from the surface. It has only to support its own weight and to stay steady as the chain passes through. It does not have to carry the weight of water inside the pipe.

Many different materials can be used to make the pipe, - timber, bamboo, iron, waterpipe, plastic, asbestos, etc., and the shape can either be square or circular. However, due to the difficulties of making sure that square washers enter the square pipe at the correct angle, this arrangement is inadvisable; it is normally used where the only material that can readily be used is timber planking. The internal diameter of the pipes does not generally exceed 10cm.

We have already mentioned the innovation of using a close fitting short section of smooth, accurately-made pipe at the lower submerged end of the rising main, which prevents leakage past the washers. This may be made of plastic, smooth iron, or a carved hardwood resistant to decay. It may be fitted at the end of a cheaper, loose fitting pipe, which may then be of any shape and made from any material so long as it is water tight. At least two washers must be passing through the lower section at any one time.

Some rising main pipes that are commercially manufactured have iron pipes flanged at the top and bottom so that the pipe may be lengthened deeper into the water. Iron piping is, of course, very much heavier than the equivalent plastic or timber pipe, and will need supporting on solid ground under the water.

Bell mouth entry sections are usually fitted to the bottom end of the rising main pipe to guide the chain and washers into the pipe. These are made of timber, or more often, galvanised iron sheeting.

#### 4.2 The Chain and Washers.

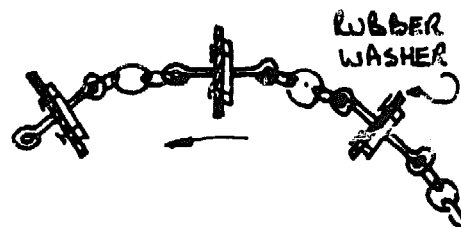
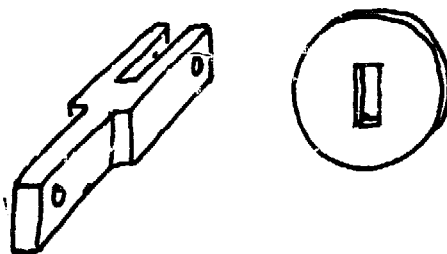
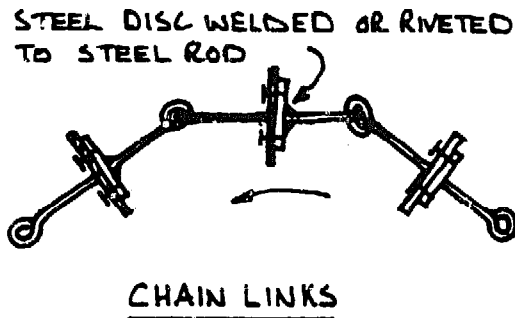
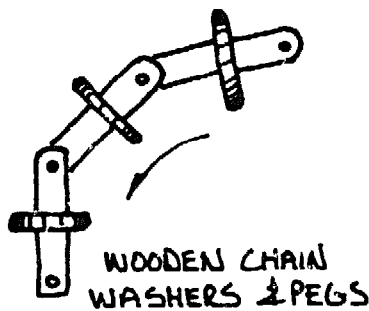
The original leather and horsehair or rag balls that were used as washers in the early chain pumps moulded themselves to the varying shape of the rising main pipe, reducing leakage to a minimum, but had high friction losses as they were pulled up the pipe. They would wear away quickly and probably rot in the water after a few months.

The washers that are mostly used today are wood or steel discs cut accurately to fit exactly into the rising main pipe.

They must have a short section of solid chain passing through them to hold them in the correct position both as they enter the pipe and pass up the pipe. The washers must be supported both below and above on the chain link to carry the weight of water and take the full load on the chain as it is turned on the cogged teeth of the chain wheel.

The careful and accurate construction of the washers will reduce water losses and wear, but will increase costs and a balance must be made between the increased costs of this component with the increased efficiency. As the chain and washers and rising main pipes are the most important parts of the pump, it is perhaps worth the extra expense to fit the washers with rubber seals.

The chain is made from pegged, shaped wooden rods, rope, or 5mm diameter steel chain links:-



The links must support both the weight of the loop that hangs from the chain wheel, and the weight of water in the rising main pipe. In a typical pipe of 10cm internal diameter, the weight of water supported over a 20 metre lift would be about 150 kgm; with a smaller pipe of 7cm internal diameter, and a 10 metre lift, the weight of water supported would be 50 kgm. Deep wells and large pipes therefore need strong metal chains; wooden or rope chains should only be used for the shorter lifts.

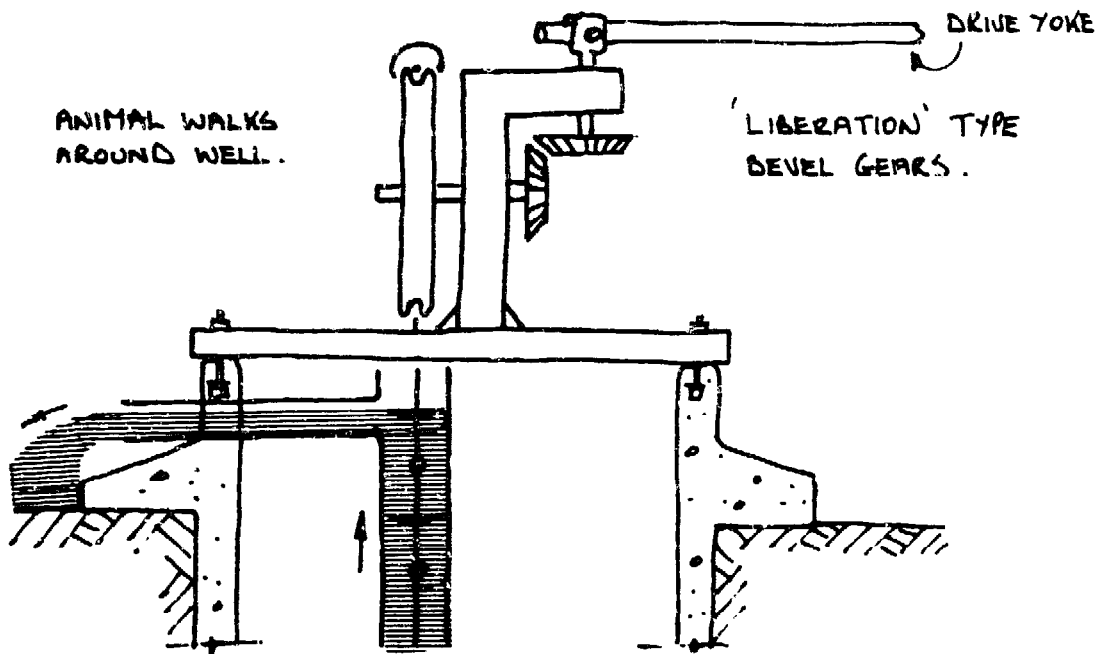
Nylon rope and rubber balls are a useful possibility for the chain and washers, but the chain would need to be made carefully to fit exactly on the cogged teeth of the chain wheel. There would also be difficulties if the nylon rope stretched under load, as the discs

or balls would not then coincide with the chain wheel.

#### 4.3 The Structure.

The framework that supports the chain and washers, rising main pipe, and chain wheel, must also be braced against the power source applied to it. This may be hand crank, or a geared driving arm powered by oxen or horses. The solid timber framework of most of the examples demonstrates the size of structure needed.

Some chain pumps are built using the back axle and differential assembly of a motor vehicle as a transmission gear to take the power from an animal-drawn driving arm onto the pump axle. Special cast iron gears are used on the 'Liberation' type pump; pegged timber gears are widely used in Asia.



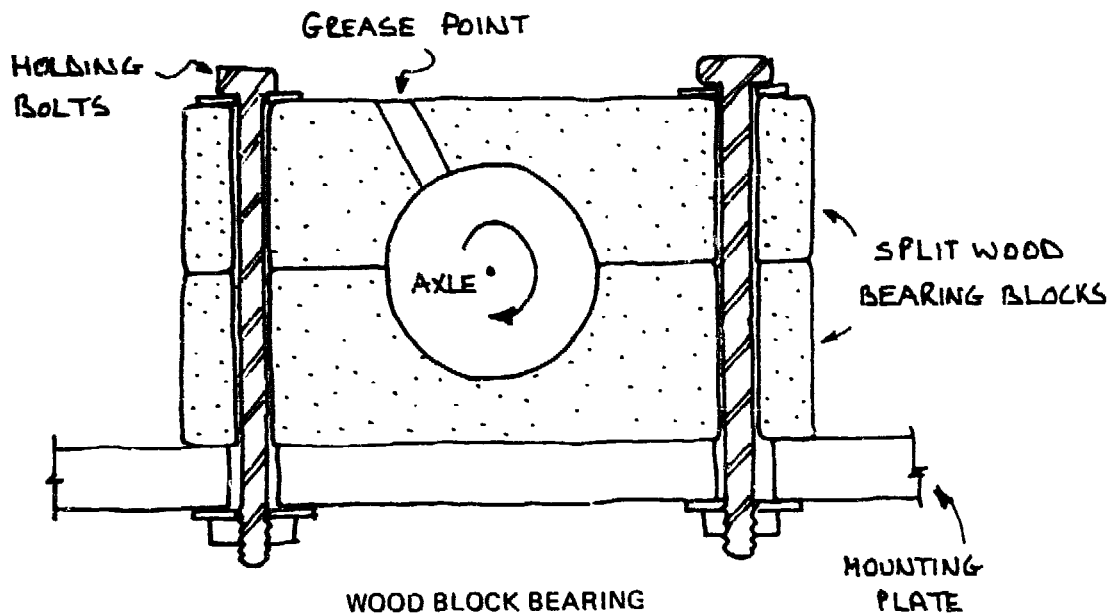
CHAIN PUMP MOUNTED OVER WELL

#### 4.4 The Bearings.

The bearings that support the chain wheel axle will provide most of the frictional resistance of the pump, and much of the power loss will occur here. There is a dilemma in choosing the bearings for devices that are to be used in rural areas; they may be expensive, high performance, sealed bearings that will have to be completely replaced when they are worn out, or oiled wood block bearings which



are not designed to keep the dust and sand out, but can be cheaply renewed when they are worn. Wood block bearings, if they are carefully made, prepared, and greased, are very suitable for the slow moving chain and washer pumps; wood bearings could not, of course, be used in high speed pumping devices.



#### 4.5 The Chain Wheel.

The various designs of the chain wheel are shown in the illustrations in Section 6. They range from cut down wooden cart-wheels, to the especially prepared cast iron wheels of the 'Liberation' type pump. The wheels support the chain at a radius of between 20 to 30cm and must be robustly made to support the weight of the chain and pumped water in the rising main pipe. They are slow turning, and do not have to be dynamically balanced. The size is such that they can be made from cast iron in one small casting; a larger casting requires considerable skills and equipment.

The chain wheel is mounted in the centre of the axle shaft, which must be strong enough to support the complete pumping assembly. The axle may be made from wood, steel rod or pipe, but the ends must be made exactly circular to fit into the wood bearings. If a steel axle is used, the wood block bearing will wear away before the steel, and the axle will continue in good condition almost indefinitely.

Occasionally, as many as five chain wheels are fitted onto a single axle, each chain wheel with its own chain and rising main pipe. The loops of chain and washers may then be added as they are needed to provide a crude but effective form of gearing.

## **5. SOURCES OF POWER AVAILABLE FOR WATER PUMPING, AND POSSIBLE PUMPING RATES**

It is useful to begin this section by examining the various power sources that are available to man for water pumping and agriculture. Fossil fuels in the shape of petroleum provide perhaps the most convenient and power packed energy source known to man, but it is becoming increasingly apparent that these are limited in supply, and wind and solar energy may in the future provide the best long term hope for power for most of the world. But it is only possible in this publication to give a brief description of those power sources that are immediately suitable for water pumping in rural areas with their dispersed populations.

### **5.1 Man Power.**

Man powered pumps are widely used to lift the small amounts of water needed for domestic supplies, stock watering, and micro-irrigation. For larger scale irrigation and water lifting, other power sources should be employed wherever possible to release the skills and time of men for more productive work.

In many parts of the world, however, farmers and their families are often the only source of power available for water lifting. This is not as close to slave labour as might appear at first sight, as small amounts of water pumped over a few weeks can save a crop or even double its yield. In Bangladesh, for instance, farmers are irrigating small areas of land from their hand pumps to achieve an extra crop in the dry season. The exhibition of locally manufactured water pumps described in this publication, had a majority of man powered devices, reflecting the hard economic conditions at that time. Man powered pumps are generally small, portable, and have a water lifting capacity suited to small fields.

The most efficient way that a man can work is through his legs, not through his arms. Leg muscles are stronger than the muscles in the upper part of the body, and a healthy man can comfortably develop about 75 watts (0.1 h.p.) over long periods by pedalling, and 0.4 h.p. for short periods of a few minutes. The many low lift pumping devices used throughout S.E.Asia over the centuries generally use leg power.

Man powered pumping devices are small, usually cheap to make, and should not be overlooked in areas where a small amount of work will bring a good return.

## 5.2 Animal Power.

Animal power is widely used in most parts of the world. Draught animals if they are well looked after, and the equipment is suitable, can make a substantial contribution to irrigation farming and water pumping. Very often, animals used for general farm work, - ploughing, ridging, seeding, etc., are released for long periods, especially during the dry season. This spare capacity can be very usefully employed in water pumping, if adequate fodder is available for the animals.

Draught animals need great care and must be managed with affection and respect if they are to work well. The cost of veterinary care, feeding, harnessing, purchase cost, must be balanced against the work that they can manage and the side benefits of meat, hides, manure, etc.

The following table is often quoted to show the power output from various types of animals:

Animal	Weight (kg)	Draft Force (kg)	Average speed (m/sec)	Power	
				(kgm/sec)	(HP)
Horse	400-700	60-80	1.0	75	1.00
Bullock	500-900	60-80	0.6-0.8	56	0.75
Cow	400-600	50-60	0.7	35	0.45
Mule	350-500	50-60	0.9-1.0	52	0.70
Donkey	200-300	30-40	0.7	25	0.35

In areas where animals are not trained and used for general farm work, the cost of buying and training the animals must be related directly to the benefits resulting from water pumping.

The commonly used animal powered pumping devices range from a draw rope pulling a water-filled leather bucket up out of a well to vertical axis geared turbine pumps. The first is very inefficient, as the animal is obliged to retrace its steps without doing any work; the second is very expensive, and requires skilled maintenance. To use animal power effectively the pump should demand a constant loading, and power take off gearing is necessary. This gearing can vary from simple timber cogged wheels, to especially made steel crown and pinion gears, Plate 2.

These power take off gears are very expensive, sometimes being even more expensive than a small motor pump set. There must be an urgent need for the local manufacture of these gear sets, which could be made in a small workshop. The 'Liberation' type gears and chain and washer pumps described in the next part of the paper were distributed widely throughout China to encourage local manufacture. Many innovations were made, and some of these are shown in Section 6.

### 5.3 Wind Power.

Wind power has been used throughout history for a wide variety of tasks - corn grinding, timber sawing, etc., in addition to water pumping. During the last 50 years, wind power has been neglected by power engineers, and the recent upsurge of interest obviously reflects doubts about the long term availability of fossil fuels.

Water pumping is probably the most useful way to use wind power, as the machine can be allowed to run over the whole day, and work whenever there is enough wind. Wind powered piston pumps are used widely on the Great Plains of the U.S.A., throughout Australia, and many parts of Africa, and they have been developed to great robustness and simplicity.

A great variety of wind power devices are known. The most useful for powering the chain and washer pump, are probably the slow speed, high torque devices, such as the multi blade wind wheel, or the traditional Chinese vertical axis device, Plate 3. A sail cloth machine combining wind and hand power is described in Section 6. A useful combination would be to attach a vertical axis wind machine above

the power take-off gears for the chain and washer pump. The pump would work whenever there was enough wind, and in calm spells the wind machine could be removed or disconnected, and animals used as a stand-by power source.

The power available from the wind depends on the swept area that intercepts the wind, and the speed of the wind. Wind power devices can only take a small proportion of the total wind energy passing through them, and the overall working efficiency is unlikely to be more than 30%.

The power available from the wind device can be expressed as:

$$P = E \times 0.0006 \times A \times V^3 \quad \text{Where } A = \text{swept area in metre}^2$$

$V = \text{wind velocity in metre/sec.}$   
 $P = \text{power in kw.}$   
 $E = \text{efficiency of device}$

Wind wheels developed historically on a craft basis, and the optimum size for simple water lifting devices seems to have been arrived at intuitively. The power from a wind wheel depends on the square of the linear dimension, the weight and cost depends approximately on the cube; to double the size of the wind wheel is to therefore quadruple its power, and to multiply its use of material and cost by a factor of eight. Most small water pumping wind wheels have a diameter of less than 5 metres.

Wind wheels must be designed to start and work in very low wind speeds, and have a governing device built into them to prevent them from being destroyed in high winds. Wind wheels must be designed as if they were a toy bicycle to work on the power of a child, yet be able to withstand or cut off from an equivalent power source such as that from a motor car engine during strong gales.

#### 5.4 Solar Power.

Solar energy is perhaps the largest and most permanent source of power available to man, and great efforts are at last being made to convert it into mechanical power suitable for water pumping, with varying degrees of success. Integrated daily solar energy on a horizontal surface on good days in low latitudes can be as much as 6 to 8 kilowatt hours per square metre, - but this value will be very much less on cloudy days. The great difficulty is to convert

solar energy into a different form of power that can be stored and used.

At the present moment, existing solar water pumps are expensive and very complex although new discoveries and mass production will inevitably bring the price down. One of the potentially most promising devices is the Fluidyne engine, which has no moving parts and works on a Stirling cycle. It is unlikely that solar power will ever be used directly with a chain and washer pump.

### 5.5 Electric and Fossil Fuel Power.

Diesel and petrol powered pumps are well known and need no comment in this publication. Experience will have shown the most suitable types that can be successfully used in rural areas. Centrally generated electric power, with its very high transmission costs, will probably always be out of the question for much of the world's area. An example of a motor powered chain pump is given in the next section; the power from the motor is transferred by a belt drive. This pump is made from cast iron, and is sturdily and accurately constructed.

It is also possible to use a low speed diesel engine coupled directly to a traditional pump. An example of a motor powered pallet pump from Thailand is shown in Plate 4; this shows how a traditional pump can be very successfully adapted for use with an internal combustion engine.

### 5.6 Possible rates of Pumping with the Chain and Washer Pump.

There have been very few measurements of the actual efficiencies of chain pumps. The main power losses between the power applied to the device, and the work done of the water that is actually lifted, will be caused by leakage, friction losses of the washers in the rising main and friction losses in the bearings.

The probable efficiency of these pumps if they are made in village workshops without ball bearings is therefore unlikely to exceed 50%. You should take care if you intend to build one of these pumps to reduce these losses to a minimum by paying careful attention to the following:-

- i. accurate shaping of washers
- ii. use of modified rising main pipe described in Section 4.1
- iii. accurate cutting and preparation of oil soaked wood bearings or use of ball bearings.
- iv. well shaped teeth on chain wheel
- v. correct dimensions of hand crank, driving arm etc.

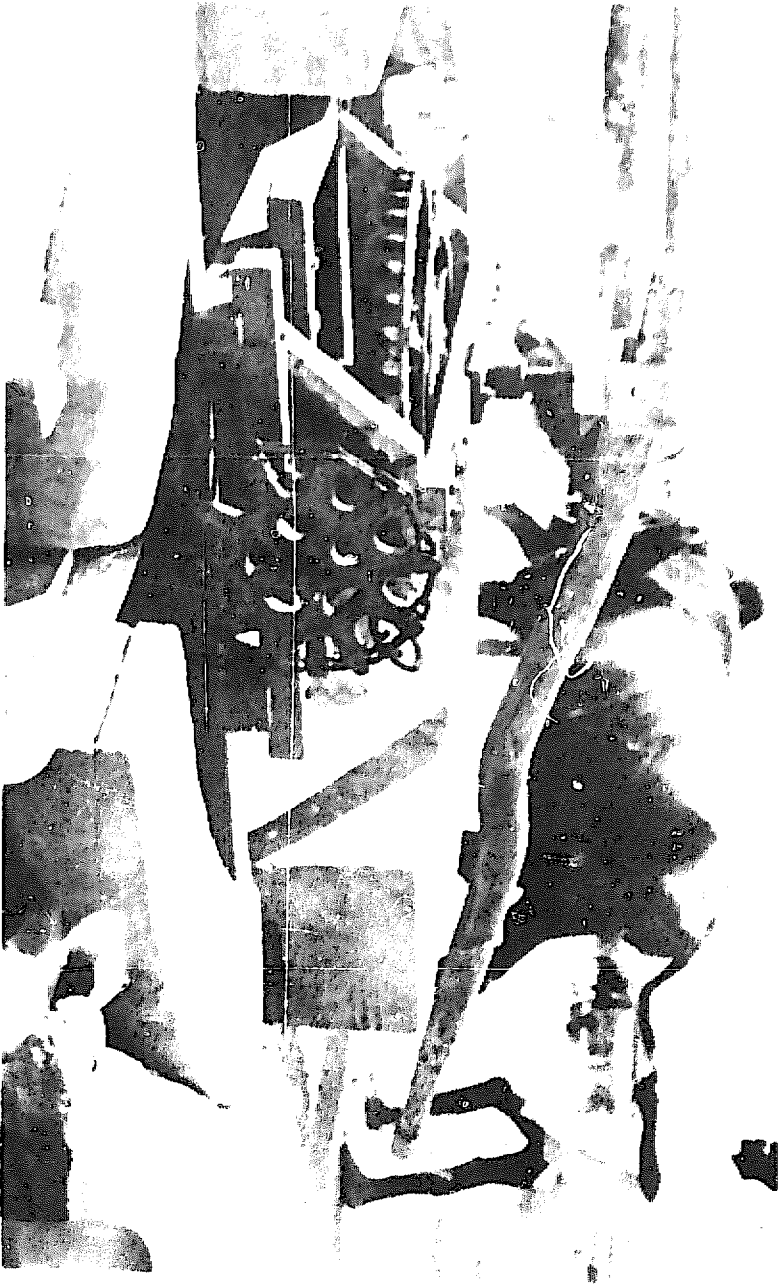
The losses will of course increase with increased lift, as the weight of water being carried up the rising main pipe will give increased leakage past the washers, and increasing friction in the bearings and drive mechanisms. In addition, the power available from a pair of animals, in an animal-powered pump, will be less than twice the power of a single animal, as the animals have to coordinate their movements.

In some of the illustrations in Section 6, reference is made to pumps with as many as five sets of chains and pipes.

There are, of course, many different techniques of lifting water to heights of less than 2 metres, and in some cases, these will be preferable because of their simplicity. However, the chain pump, if it is designed and constructed to carry more than one set of chains, will have a built-in gearing system that can be quickly altered to suit local circumstances. Indeed, if the correct number of chain sets is not matched to the power source and water depth, then the efficiency of the device will be substantially reduced, or the power source will not be allowed to work at its most efficient rate.

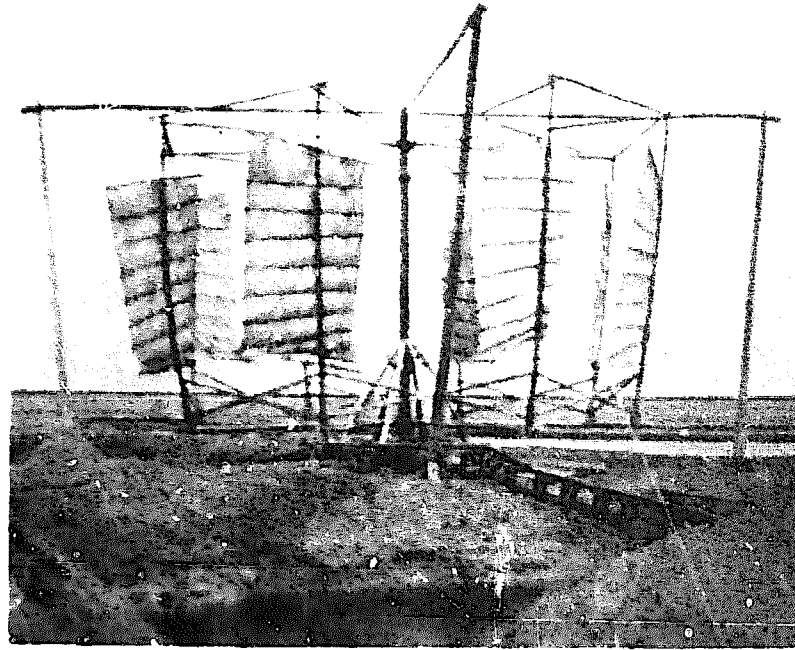
In this publication no recommendation is made for the best number of chains and pipes for each situation, or the best speed of rotation and lift velocity of the chain. The nature of the pump is such that the chain should not move up the pipe at speeds greater than about 1 metre/sec. If, therefore, the pipe has a sectional area of 50 square centimetres, and the chain moves at 1 metre/second, then the maximum possible rate of pumping will be 18 cubic metres per hour per chain. This will give some indication of the number of pipes and chains needed.

It is doubtful if more than 5 sets of chains and pipes would ever be installed on one pump, and this will effectively limit the pumping rate to 90 cubic metres of water per hour for each 5 chain machine.



**PLATE 2 ANIMAL POWERED CHAIN PUMP. INDIA (Photo OXFAM)**





Typical Chinese horizontal windmill working a square-pallet chain-pump in the salterns at Taku, Hopei. The fore-and-aft mat-and-batten type sails luff at a certain point in the cycle and oppose no resistance as they come back into the eye of the wind.

**PLATE 3 VERTICAL AXIS WIND MACHINE DRIVING LOW LIFT PALLET PUMP. CHINA. (From J. Needham).**

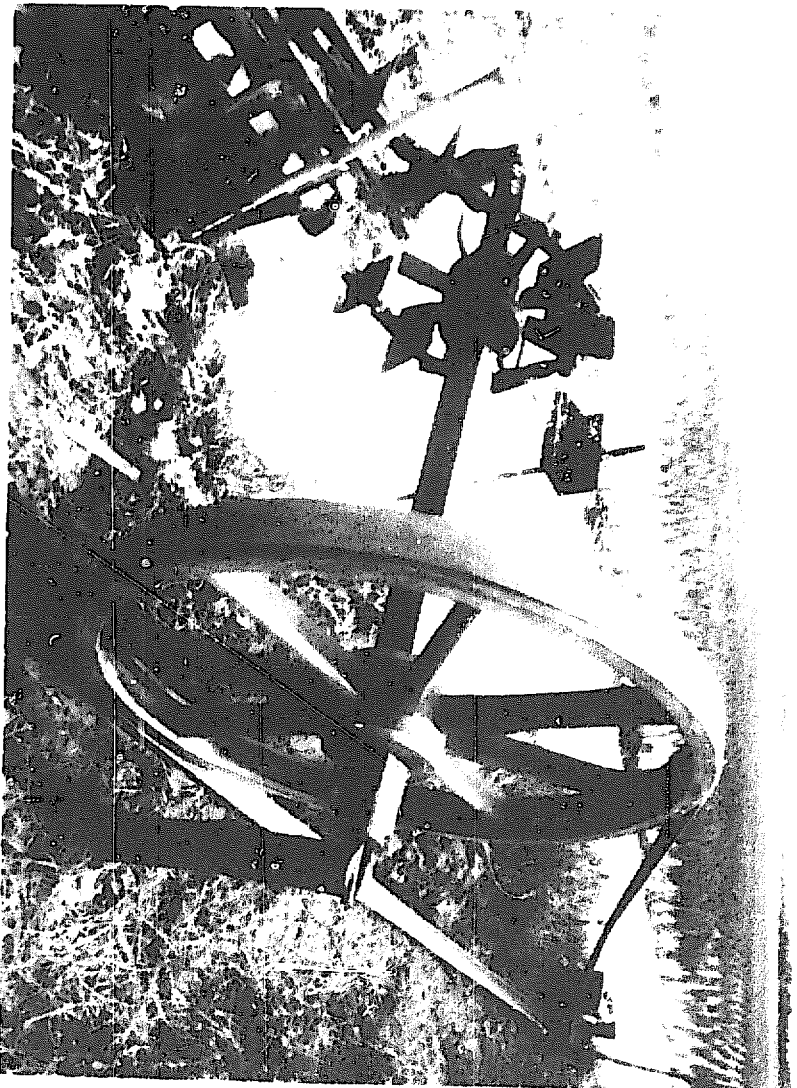


PLATE 4 SLOW SPEED DIESEL DRIVING PALLET PUMP. THAILAND. (Photo  
*N. Hudson 1).*

In this publication no recommendation is possible for the best number of chains and pipes for each situation, or the best speed of rotation and lift velocity of the chain. The nature of the pump is such that the chain should not move up the pipe at speeds greater than about 1 metre/sec. If, therefore, the pipe has a sectional area of 50 square centimetres, and the chain moves at 1 metre/second, then the rate of pumping will be 18 cubic metres of water per hour per chain. This will give some indication of the number of pipes and chains needed:-

Example: A pair of bullocks, lifting water 4 metres.

From Table 1, pumping rate is 50 cubic metres/hour  
and the pump will need  $\frac{50}{18}$ , say 3 chain and pipe sets.

It is doubtful if more than 5 sets of chains and pipes would ever be installed on one pump, and this will effectively limit the pumping rate to 90 cubic metres of water per hour for each 5 chain machine. In the table, however, we have included all the calculated pumping rates for consistency.

## 6. TWENTY ONE EXAMPLES OF THE CHAIN AND WASHER PUMP

The twenty one examples of chain and washer pumps in this section of the publication, have been selected because they demonstrate the wide variety of ways that the pumps can be made and powered. Each sheet is a literal word by word translation from the information sheets published for the Exhibition. Notes have been added to point out important features of the design.

The pumping rates quoted in the examples have also been taken directly from the information sheets. They do not give enough information to be verified in every case, but we have included them for consistency. Most of the quoted performance figures are of similar scale; the figures quoted in Example No.2 indicate that the rate of work of one man is about 100 watts if we take a pump efficiency of 50%, and this is a reasonable assessment.

The approximate dimensions of the pump to suit man and animal power can be obtained from the examples given. It is essential, however, to understand that all power sources have an optimum rate of working, and the pump should be designed accordingly.

No.1

SPEEDY WATER PUMP

Typical

Raising water from very large diameter wells, or deep ponds, where the power source must be separate from the pump.

Application:

Rate of

Two men can water 0.8-0.9 hectares of land in one working day.

Pumping:

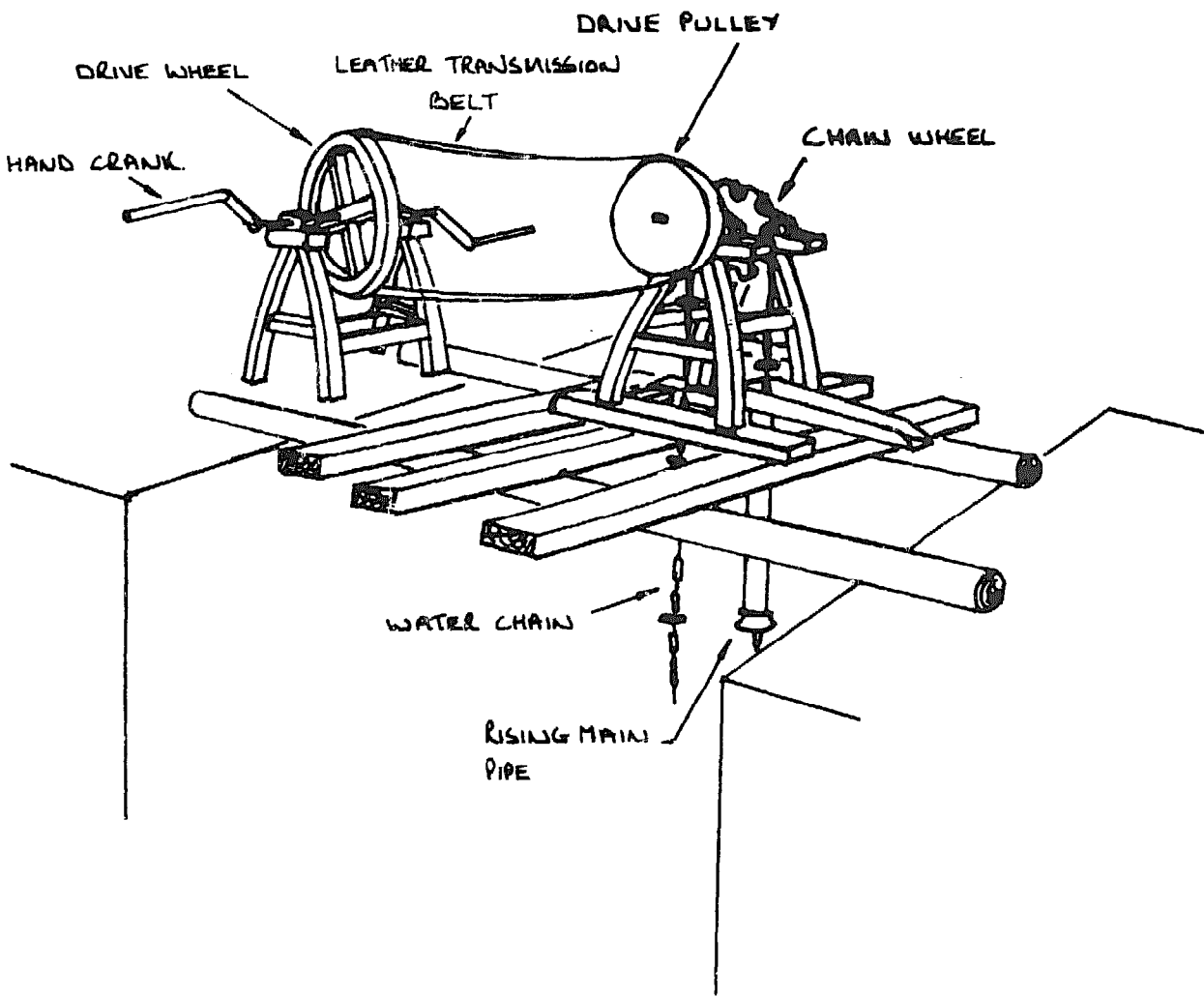
Construction:

The pump is constructed in two separate parts, the chain wheel mechanism and the hand crank which has a drive pulley.

The chain wheel, water chain, and the rising main pipes are typical basic components of the 'Liberation' type of water pump. The chain wheel and drive pulley are made of wood, have a diameter of 45 cm and are mounted on the same iron shaft. The bearings supporting the shaft are simple wooden blocks soaked in oil. The shaft is rigidly supported on a solid 100cm high wooden frame, mounted on logs which are placed across the well, pond or ditch. The pumped water is led away in a chute. The water chain is of standard make, with iron chain links and wooden washers. The rising main pipe is made from sheet metal and has a diameter of about 10cm. The hand crank part is also mounted on a 100cm high wooden frame of similar dimensions to the chain wheel frame. It has a drive wheel of 77cm diameter turning on an iron shaft with wood block bearings and a crank handle on either side. The drive wheel and the pulley are connected by a leather transmission belt.

NOTE:

This device has been designed specifically to allow the pumping mechanism to be located directly over a wide well, with the hand driven power take off on the side. The transmission belt will cause considerable power losses if it is not correctly adjusted. The hand crank can of course be replaced by a petrol or diesel engine.



SPEEDY WATER PUMP

No.2

HAND OPERATED - SPOKED WHEEL WATER PUMP

Typical Application:

Lifting water from small diameter hand dug wells or ponds.

Rate of Pumping:

One or two men can use the device to lift 3-6 cubic metres/hour over a lift of up to 5 metres to irrigate more than 0.25 hectares in one day.

Construction:

This pump consists of a frame, a hand operated crank, and a water lifting mechanism. It is made of wood throughout.

A wooden shaft of 10cm diameter is fixed onto a frame 80cm by 80cm by 50cm wide, and a wooden crank handle is fixed at each end of the shaft. The shaft is caged in a box at each end.

Fixed in the middle of the shaft is a modified large cart wheel which acts as the chain wheel; the rim of the wheel has been cut away leaving notched spokes of 12cm length which act as the chain wheel teeth. The wheel drives a chain made completely from wood, linked together with pegs and carrying circular wooden washers. The chain passes through the rising main pipe which is carved from two pieces of square timber to have a circular passage inside of 7.5cm when they are joined together.

NOTE:

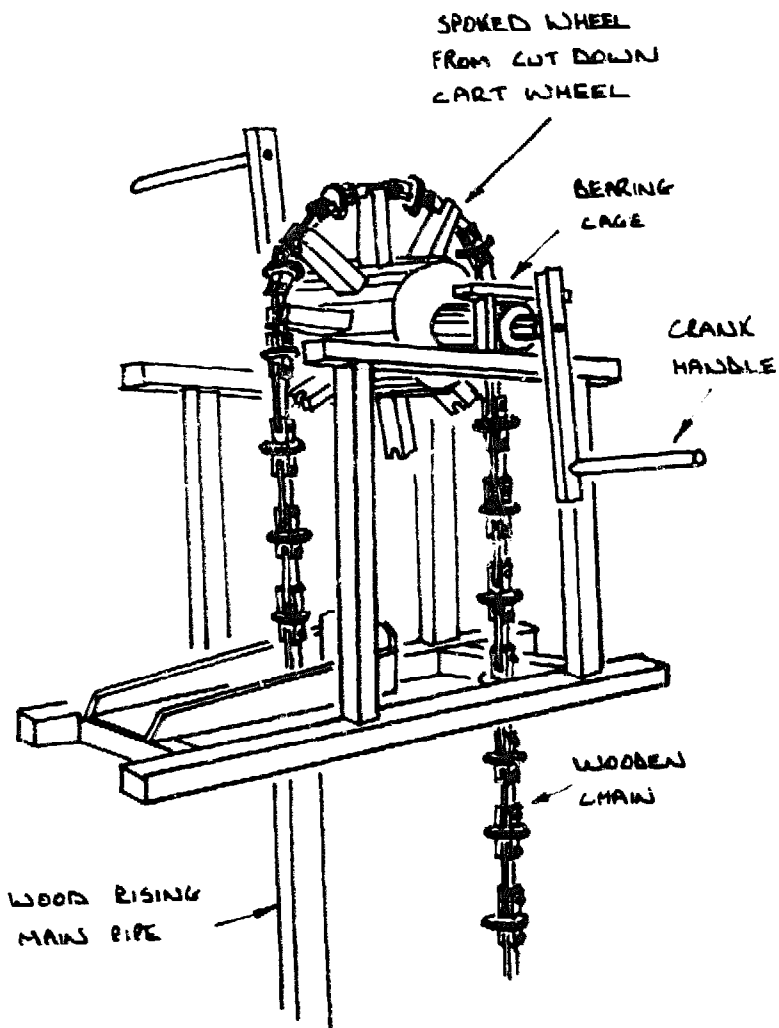
The bearing arrangement for the shaft on the frame in this device is not satisfactory. The shaft will tend to move around the cage as the crank handles are turned, causing excessive wear and tear, and a large power loss. This situation could be improved upon by the use of split wooden block bearings to locate the axle on top of the frame. There is a danger also that the wooden washers and the carved wood rising main pipe, will swell when they are wet and jam. The frame of this device could be braced to make it stronger.

The device shows, however, an ingenious use of scrap materials - in this case an old spoked cart wheel. If a cart wheel is not available a simple chain wheel could be made by mounting wooden spokes in a wooden hub.

No.2

HAND OPERATED - SPOKED WHEEL WATER PUMP

- Typical Application: Lifting water from small diameter hand dug wells or ponds.
- Rate of Pumping: One or two men can use the device to lift 3-6 cubic metres/hour over a lift of up to 5 metres to irrigate more than 0.25 hectares in one day.
- Construction: This pump consists of a frame, a hand operated crank, and a water lifting mechanism. It is made of wood throughout.
- A wooden shaft of 10cm diameter is fixed onto a frame 80cm by 80cm by 50cm wide, and a wooden crank handle is fixed at each end of the shaft. The shaft is caged in a box at each end.
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- NOTE: The bearing arrangement for the shaft on the frame in this device is not satisfactory. The shaft will tend to move around the cage as the crank handles are turned, causing excessive wear and tear, and a large power loss. This situation could be improved upon by the use of split wooden block bearings to locate the axle on top of the frame. There is a danger also that the wooden washers and the carved wood rising main pipe, will swell when they are wet and jam. The frame of this device could be braced to make it stronger.
- The device shows, however, an ingenious use of scrap materials - in this case an old spoked cart wheel. If a cart wheel is not available a simple chain wheel could be made by mounting wooden spokes in a wooden hub.



HAND OPERATED - SPOKED WHEEL WATER PUMP



### No.3

### PUSH-PULL TYPE WATER PUMP

#### Typical

This pump can lift water to a height of about 10 metres.

#### Appication:

#### Rate of

#### Pumping:

This pump is five times more efficient than the 'Liberation' type pump, and existing pumps can be very cheaply modified. Eight people working in shifts over 24 hours can irrigate 2 hectares.

#### Construction:

The main modifications are as follows:

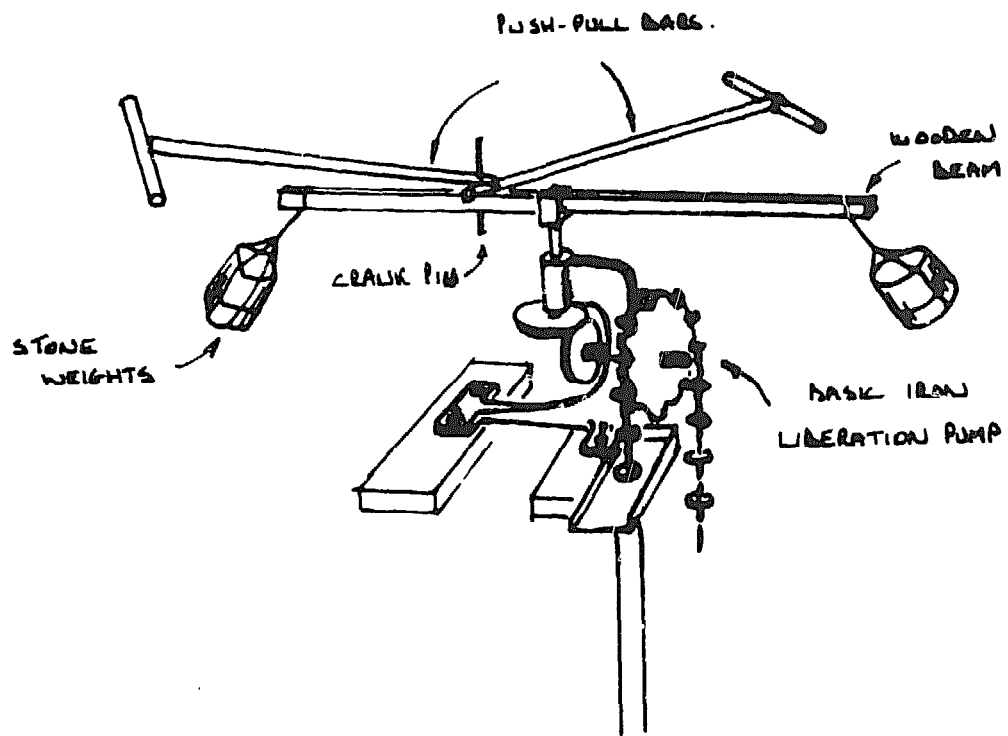
The short handle bar on the 'Liberation' type pump is replaced by a long wooden beam 4 metres long and 13cm square. It is clamped symmetrically on the central shaft, in the same way as the handle bar in the traditional machine. Attached to each end of the beam are stone weights of about 15kgm, these provide angular momentum to the turning beam. A hole is made 80cm from the mid-point of the beam to hold the crank pin. If the hole is too close to the central axle the crank arm and the mechanical advantage will be small; if the hole is too far away, the pump will be inconvenient to operate.

A 30cm long iron crank pin is inserted in the hole, and two push-pull bars 4m long and 7cm in diameter are fixed on the pin in such a way as to allow rotational movement. A wooden 'T'-handle is connected at the ends of the push-pull bars. The water chute should be enlarged to accomodate excess water.

The push-pull motion on the bars causes the beam to rotate which in turn drives the chain wheel. The number of push-pull bars can be increased to 3 or 4, allowing more than two people to operate the pump.

#### NOTE:

This innovation on the 'Liberation' pump is an ingenious way of allowing more people to work the pump together. The push-pull bars and the beam in effect act as a 'gearing up' mechanism, and this can be altered by shifting the position of the crank pin. The weights on the beam behave like a large fly wheel when the beam is turning.



PUSH-PULL TYPE WATER PUMP

No.4

WINDLASS TYPE WATER PUMP

Typical

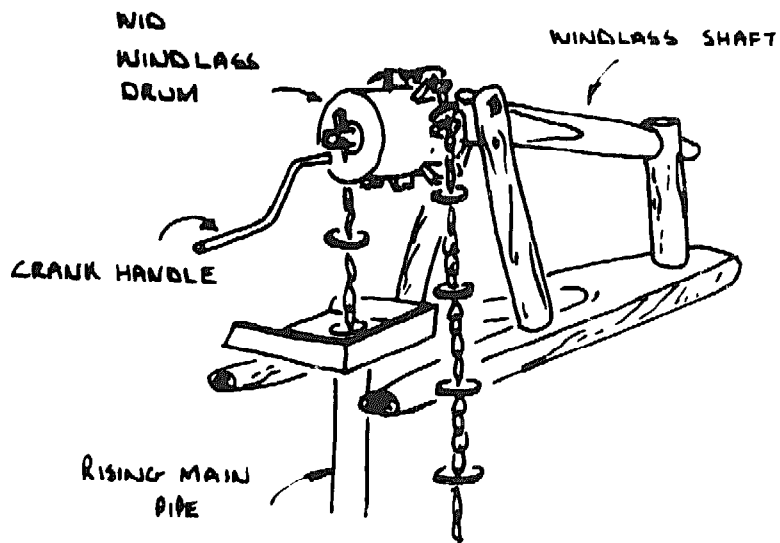
Application: Water lifting for animals, domestic use.

Rate of

Pumping: (None quoted).

Construction: The windlass shaft is supported by two 85cm high front posts and an 80cm high rear post, mounted on a V-shaped wooden base. The windlass drum has a diameter of 20cm, and runs on the shaft which is kept greased. On the drum are 12 tapered gear teeth in the shape of the beak of a duck, 8cm long and 5cm wide. A crank handle is attached firmly onto the windlass drum.

NOTE: This device must be one of the simplest types of chain pump, and is of traditional design.



WINDLASS TYPE WATER PUMP

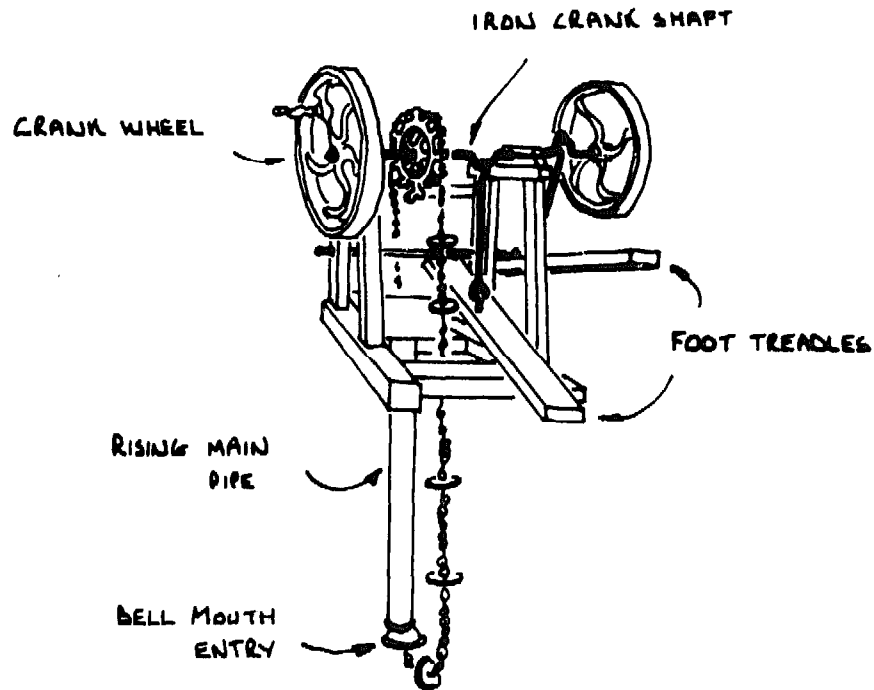
## DUAL-DRIVE THREE WHEELS PUMP

Construction: This water pump is a modification of the small '5 wheels water pump'.

On top of the timber frame (90cm x 60cm x 70cm) a 90cm long, 3cm diameter iron crank shaft is located. One end of the shaft has a square cross section to which a cast iron crank wheel is attached. The other end carrying the counter balance fly wheel has a circular cross section. A small '5 wheels water pump' chain wheel is located at the middle of the crank shaft, and two metal rods are connected between the treadles and the cranks. This water pump can be operated by hand cranking or by using the foot treadles.

NOTE:

The iron crank shaft is held in place by oiled wooden bearing blocks. The two fly wheels balance the crank shaft helping to even out the wear on the bearings. Foot treading is one of the most efficient uses of human power.



DUAL-DRIVE THREE WHEELS PUMP

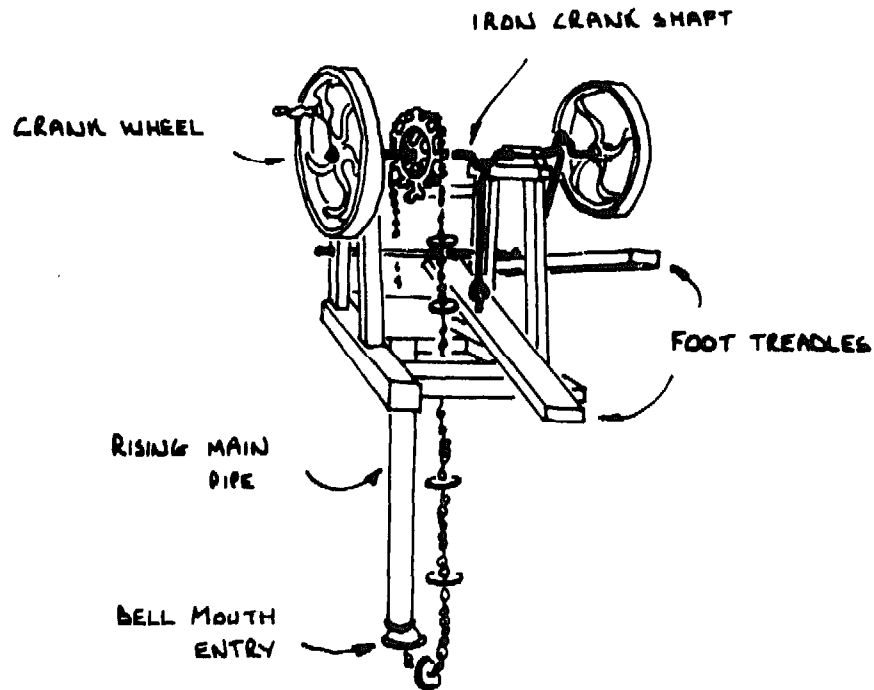
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NOTE:

The iron crank shaft is held in place by oiled wooden bearing blocks. The two fly wheels balance the crank shaft helping to even out the wear on the bearings. Foot treading is one of the most efficient uses of human power.



DUAL-DRIVE THREE WHEELS PUMP

No.6

IMPROVED "LIBERATION TYPE" WATER PUMP

Rate of Pumping:

For wells of 3 to 4 metres in depth, one man can irrigate 0.5-0.6 hectares/day.

Construction:

Just like a farmers' beam mill, a horizontal wooden beam of length 4m and diameter roughly 10cm, is fixed through the central axle of the 'Liberation' pump by screws. Stone weights of about 9kgm are fastened to each end of the beam. An iron crank pin, 33cm long and 2cm diameter is fixed vertically through the beam at about 70cm distance from the central axle.

A crank beam 4m long, with a diameter of 7 to 10cm, is attached to this pin. At the other end of the beam, a handle bar is secured as shown in the drawing.

A tripod frame made from 3 wooden poles is located over the handle bar so that the beam can be suspended from the tripod at a height (near breast height) that is convenient to operate.

Advantages of this pump:

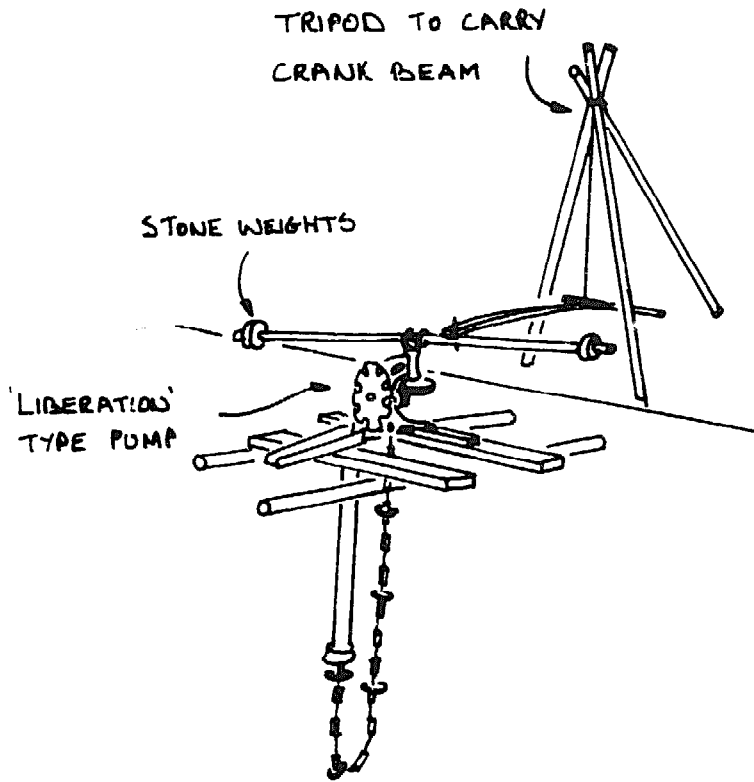
- i. Cheap and easy modification to the 'Liberation' pump.
- ii. Saves energy - suitable for places where animal or man power is in short supply and where the water has to be lifted large heights.
- iii. The push-pull mechanism makes the pump very easy to operate.
- iv. High work load.

Observations:

- i. The water chain has to be correctly adjusted so that it will not slip when the pump is working at high speed.
- ii. It is safer to build a mud wall in front of the operator to avoid the danger of being hurt by a loose stone.
- iii. Make the water chute bigger to take the higher flow.
- iv. Make sure that the stones are tied securely.
- v. Stop the pump slowly.

NOTE:

This device is a similar one to that described in No.3, except that only one crank beam is used. The advantages of suspending this beam from the tripod are obvious - the user does not have to hold up the weight, he only has to work the beam forwards and backwards.



IMPROVED LIBERATION TYPE

Rate of

Pumping: Two men can irrigate 0.5-0.7 hectares/day

Construction: This water pump is a modified Liberation type fixed on a wooden frame. The principle is to drive two fly wheels by hand cranks. The water is lifted by water chains driven by spoked wheels.

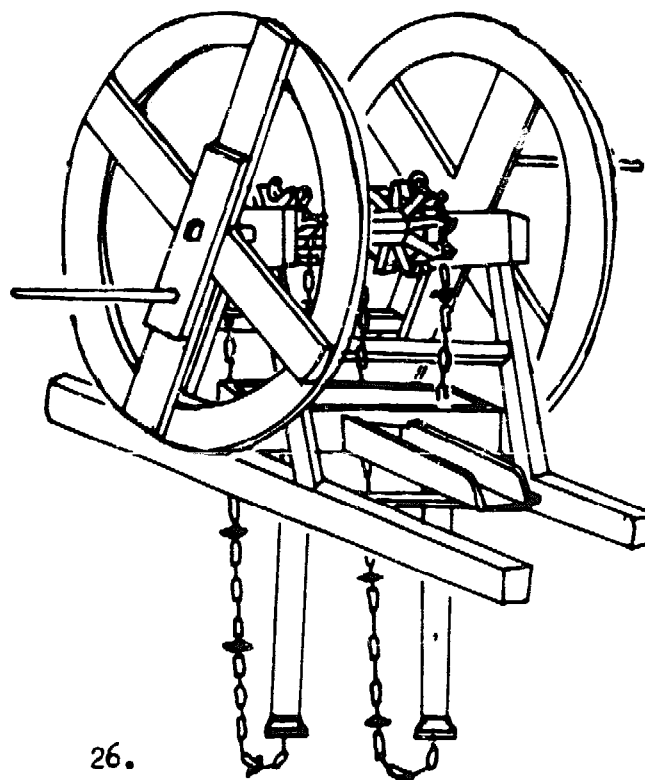
1. Frame. 100cm high, 100cm wide, 60cm long at the top, and 200cm long at the bottom. A wooden shaft 130cm long is located on the frame in wooden bearings. Two wooden fly wheels, each 167 cm in diameter are fixed at either end of the shaft, and a crank handle is attached to both fly wheels.

2. Water lifting mechanism. Two wooden spoked wheels are fixed near the middle of the shaft. Each carries a water chain passing through a sheet metal rising main pipe, as in the Liberation type water pump. The fly wheels are cranked by two persons.

NOTE:

The pump is made almost completely out of wood, except the water chain and pipe. The bearings are oiled wood. Note the crank handles set on the opposite poles of the pump shaft - this will allow the pump to operate smoothly as each man alternates the forcing down stroke of the handle.

DOUBLE WHEEL - DOUBLE PIPE  
HIGH SPEED WATER PUMP

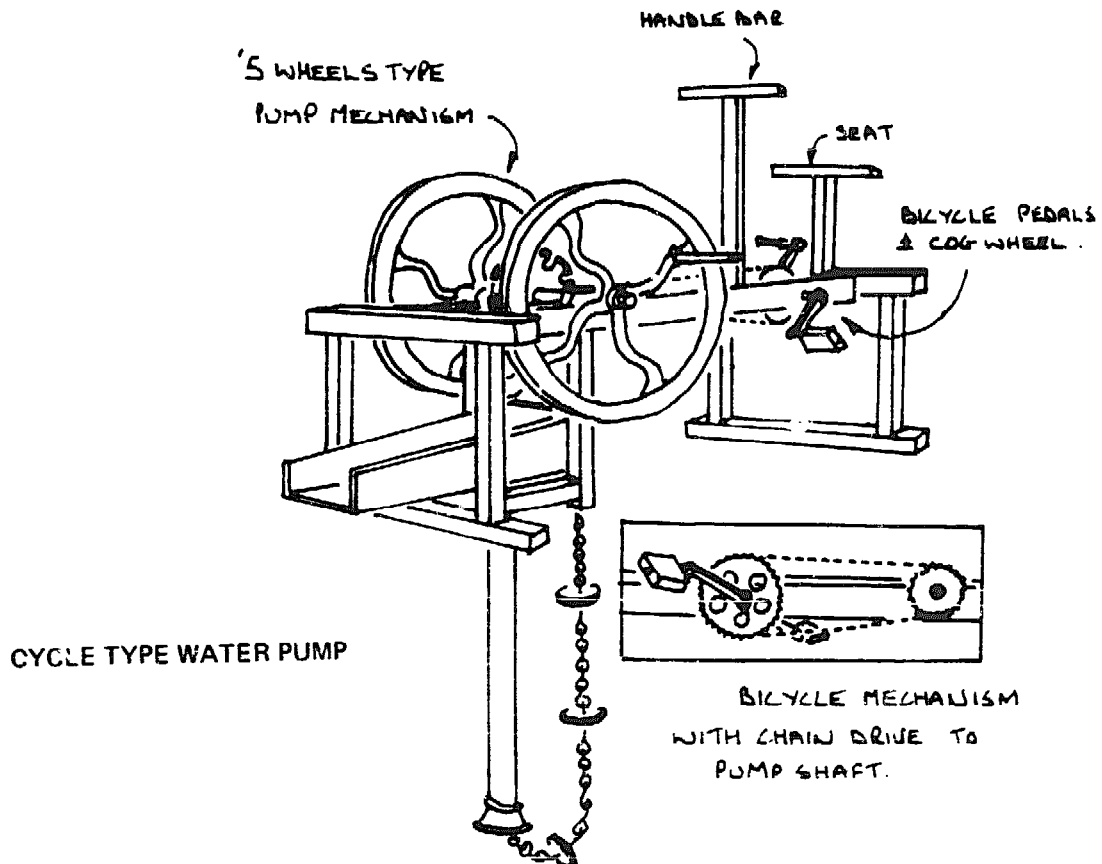




Rate of Pumping: One man pumping over a 10 hour day can irrigate 0.7 hectares.

Construction: The pump consists of a wooden frame, fly wheels, water lifting mechanism, and drive mechanism taken from a bicycle. The wooden frame is 190cm long, and 90cm wide with a square iron shaft section (2.5cm x 2.5cm) located at the front. On both ends of the shaft there is a large fly wheel of 80cm diameter. A '5 wheels' water pump's chain wheel, water chain, chute and rising main pipe, are utilised for the lifting part of the pump. The driving part is composed of the foot crank cog wheel, chain and bearings; these have been taken from a bicycle and mounted between the iron shaft and the wooden frame.

NOTE: This device uses human power to its best advantage, but it is necessary to design the sizes of the chain cog wheel, the pump chain wheel and rising main pipe, in order to obtain a gear ratio that can be pedalled easily. The device can also be turned by hand using the hand cranks on the fly wheels.



No.9

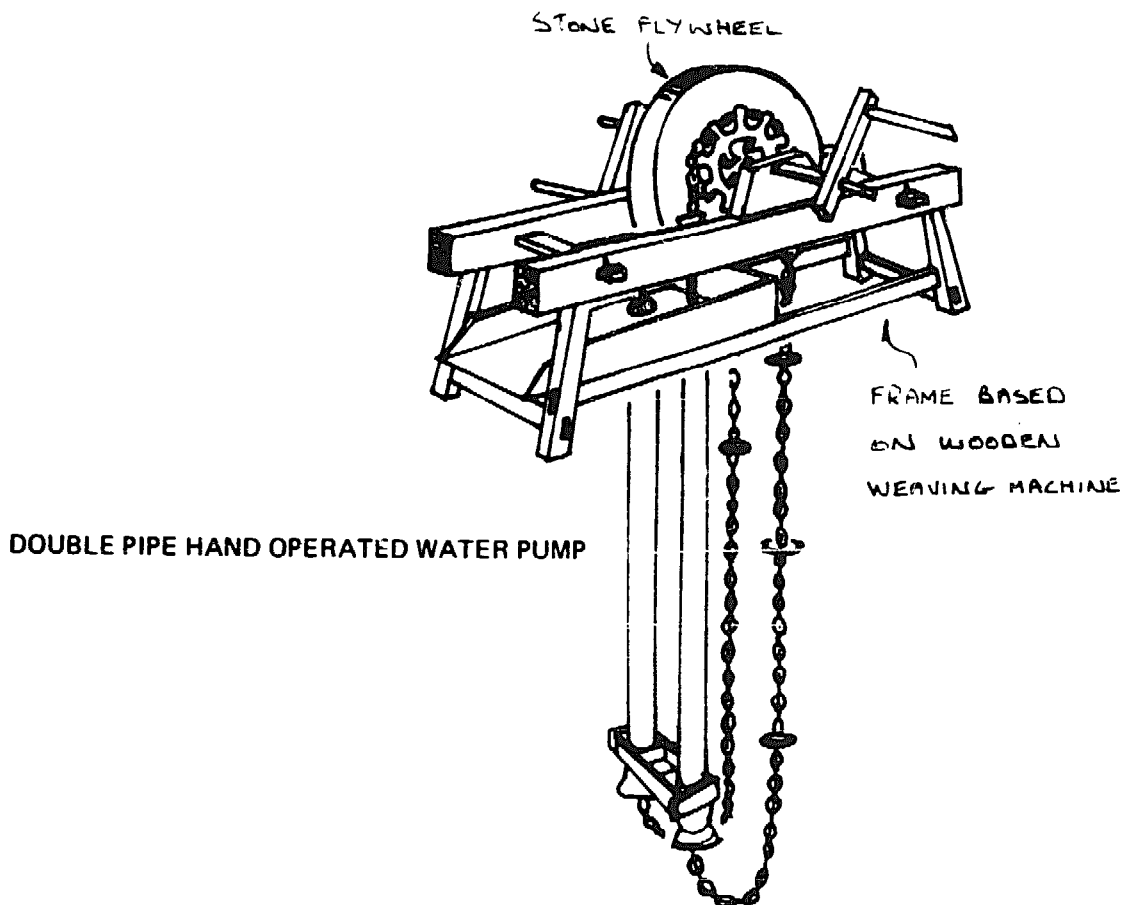
**DOUBLE PIPE HAND OPERATED WATER PUMP**

**Typical Application:** Suitable for lifting water from gutters, drains, ditches and pools.

**Rate of Pumping:** One man can irrigate 0.5 hectares/day using this device.

**Construction:** The pump consists of a rectangular wooden frame, a cranking mechanism, and a water lifting mechanism taken from the '5 wheels' water pump. The frame is 180cm long, 60cm wide and 70cm tall. This frame was modified from a weaving machine. A wooden shaft with a square cross section is fitted on the frame with crank handles at each end. In the middle of the shaft is a stone fly wheel of diameter 65cm, and thickness 12cm taken from a worn out knife grinding mill. On each side of the flywheel is a chain wheel from a small '5 wheel water pump', a water chain and rising main pipe. The pipes open out into the water chute at the top.

**NOTE:** The bearings on this device are not clear; the shaft must be circular at the bearing blocks. The use of existing scrap equipment is a feature of this device.



No.10

**HAND OPERATED WOOD FRAME PUMP**

Typical

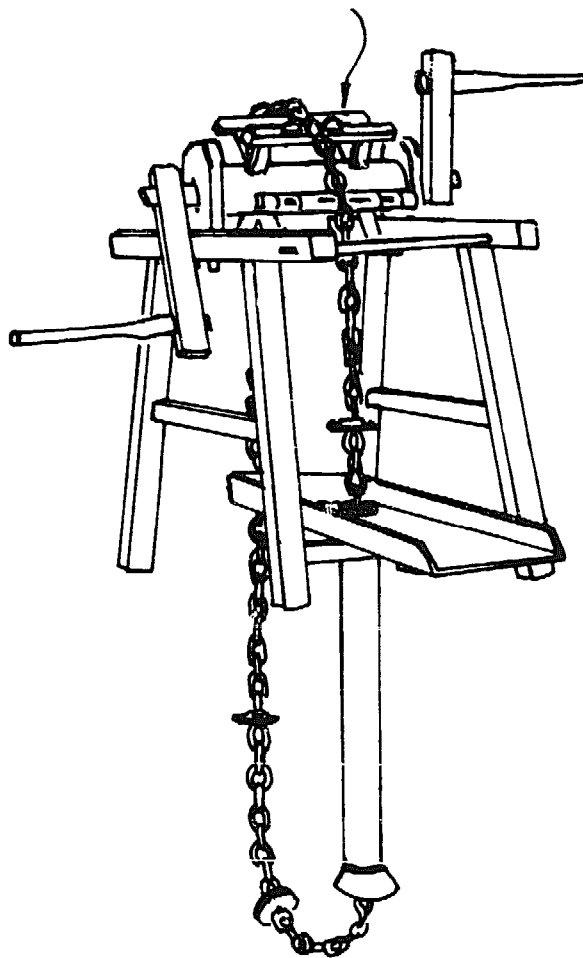
Application: Suitable for ditches and shallow wells.

Rate of Pumping: Operation by two people if the water is deep, and by only one if it is near the surface. Can irrigate 0.3 hectares/day.

Construction: A wooden cylindrical chain wheel is located on the top of a wooden frame, 90cm long, 75cm high, and 50cm wide. The wooden chain wheel is made from 8 wooden bars connected together. In the middle of each bar there are two flat prongs to hold the chain.

NOTE: The chain wheel in this device can take several chains if extra rising main pipes are added.

8 BAR WOODEN CHAIN WHEEL



HAND-OPERATED WOOD FRAME PUMP

**No.11.**

**HAND CRANKED WATER PUMP WITH FLY WHEEL**

**Typical**

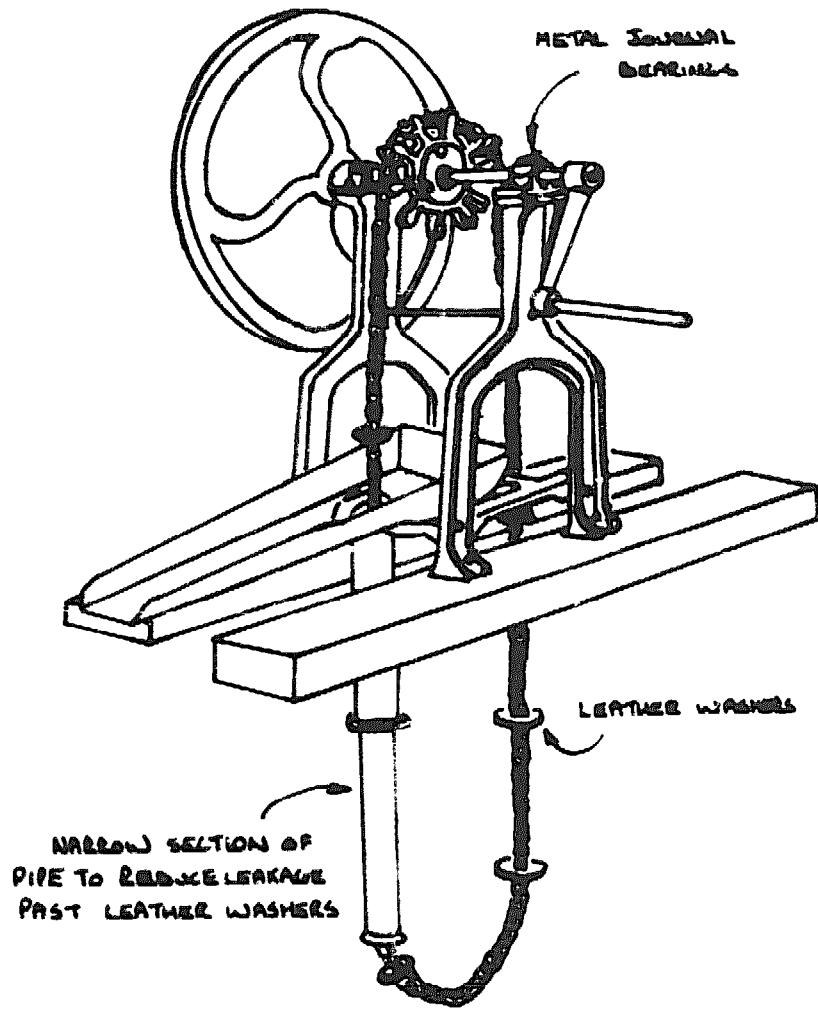
**Application:** Suitable for wells of 7m in depth.

**Rate of Pumping:** One person can lift up to 7 cubic metres of water in one hour.

**Construction:** A circular metal shaft 60cm long, 3cm in diameter, is mounted in two metal journal bearings on an iron frame, of dimensions 45cm long, 40cm wide, and 70cm tall. On one end of the shaft is a fly wheel with a diameter of 75cm, the other end has a crank handle. At one end of the shaft, there is a ratchet to stop the pump running backwards under the weight of water in the pipe. On the middle of the shaft is a chain wheel carrying a steel water chain and discs with leather washers. The rising main pipe has two sections of different diameters, the wider pipe at the top reduces friction, the narrower section at the bottom end prevents leakage. The top section is 4m long, with an internal diameter of 8cm, the lower section is 2.4 metres long, of internal diameter 6.4cm.

**NOTE:**

The pump is made almost completely of cast iron. The water chain washers have leather pads, which will fit tightly into the narrower lower section of the rising main pipe to give good pumping efficiency. The wider upper section will reduce wear on the washers, and lower friction losses. This is a most ingenious innovation. The shaft bearings are made of iron, lubricated with grease.



HAND CRANKED WATER PUMP WITH FLYWHEEL

No.12

**WOODEN HAND CRANKED WATER PUMP**

Rate of Pumping:

Operated by two persons, 15 cubic metres of water can be pumped each day through a lift height of 3 metres, irrigating 0.3 hectares/day

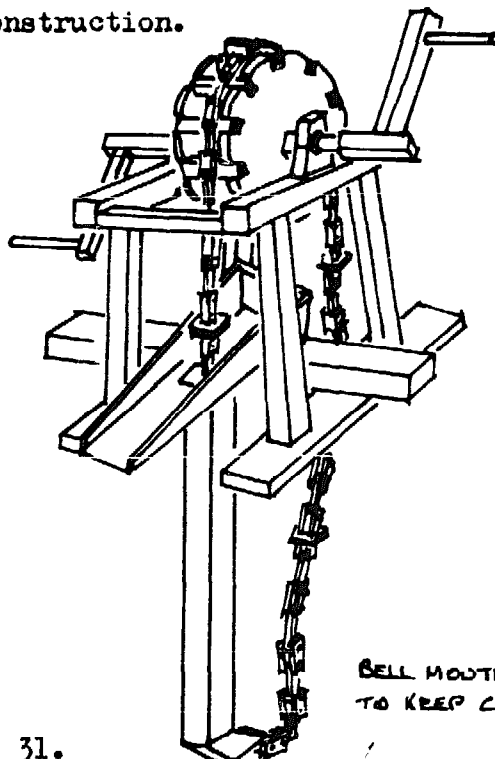
Construction:

On a wooden frame 130cm long x 70 cm wide x 100 cm high, there is fixed a wooden axle 80cm long, with a square cross section of 5.5cm x 5.5cm. Crank handles are attached each end of this axle. In the middle of the shaft, two wooden discs are located connected by wooden bars, forming a windlass type chain wheel with a diameter of 40cm. A wooden water chain with square shaped washers, is hung on the chain wheel and passed through a square wooden pipe, of internal cross section 6cm x 6cm. A water chute is located on top of the pipe. The square wooden pipe is best made of willow or 'abele' wood, and the chain from leguminous or other hard wood.

NOTE:

The square washers are a feature of this device; this allows an easily made square rising main pipe to be used, where timber planking is the only available material. Because of the use of wood, there is the difficulty of making the washers fit accurately in the pipe. Notice the wide bell mouth at the bottom of the pipe. The chain wheel is also of a different construction.

WOODEN HAND CRANKED WATER PUMP



BELL MOUTH ENTRANCE  
TO KEEP CHAIN STRAIGHT

No. 13

**HAND OPERATED WATER PUMP**

Typical

Suitable for lifting water from a shallow well of 5m depth.

Application:

Construction:

A cast iron frame 90cm high, is fitted on a wooden base, 150cm long, 60cm wide. An axle is carried on the frame with a crank handle each side.

On the axle between one side of the frame and the crank handle, is a flywheel which has six spokes made of iron bars 60cm long with an identical metal piece at the end of each spoke. The spokes are tensioned by an iron wire. A pawl and ratchet is fitted on the axle as shown in the diagram.

On the same axle are two other gear wheels (the large one has 48 teeth). About 35cm below this axle is a second axle 3cm in diameter and 45 cm in length. Its bearings are fixed on the frame and can be positioned in any of the three holes available, so that the gear ratio of the machine can be changed very conveniently.

On the inner side of the bearing is a larger gear wheel (64 teeth) which meshes with the gears on the axle above it. In the middle of this second shaft is a chain wheel with its water chain.

The rising main pipe is 11cm internal diameter.

NOTE:

This device incorporates a very simple arrangement of gears that allows the user to select the ratio that will allow him to work at the most convenient rate.

The fly wheel is also a clever innovation. It uses small metal weights at the end of spokes that allow the angular momentum of the flywheel to be large. A flywheel of solid iron with comparable angular inertia would need a lot more steel and would be difficult to cast.

Typical

Suitable for lifting water from a shallow well of 5m depth.

Application:

Construction:

A cast iron frame 90cm high, is fitted on a wooden base, 150cm long, 60cm wide. An axle is carried on the frame with a crank handle each side.

On the axle between one side of the frame and the crank handle, is a flywheel which has six spokes made of iron bars 60cm long with an identical metal piece at the end of each spoke. The spokes are tensioned by an iron wire. A pawl and ratchet is fitted on the axle as shown in the diagram.

On the same axle are two other gear wheels (the large one has 48 teeth). About 35cm below this axle is a second axle 3cm in diameter and 45 cm in length. Its bearings are fixed on the frame and can be positioned in any of the three holes available, so that the gear ratio of the machine can be changed very conveniently.

On the inner side of the bearing is a larger gear wheel (64 teeth) which meshes with the gears on the axle above it. In the middle of this second shaft is a chain wheel with its water chain.

The rising main pipe is 11cm internal diameter.

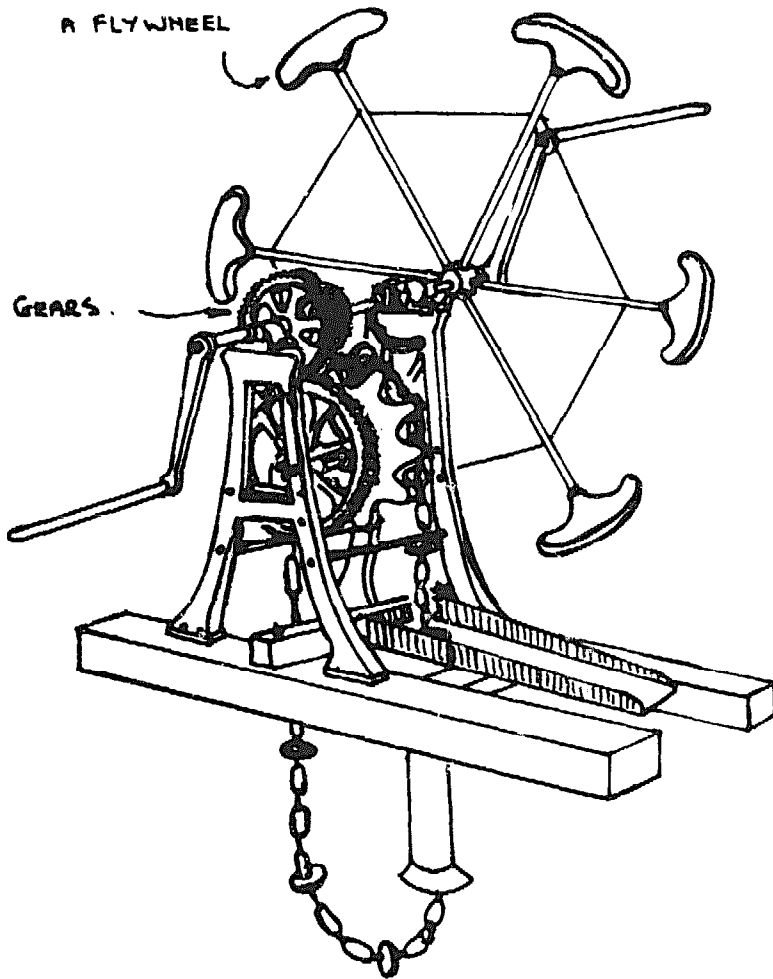
NOTE:

This device incorporates a very simple arrangement of gears that allows the user to select the ratio that will allow him to work at the most convenient rate.

The fly wheel is also a clever innovation. It uses small metal weights at the end of spokes that allow the angular momentum of the flywheel to be large. A flywheel of solid iron with comparable angular inertia would need a lot more steel and would be difficult to cast.



SMALL WEIGHTS ON  
SPOKES ACTING AS  
A FLYWHEEL



HAND OPERATED WATER PUMP

No.14

**PUSH-PULL WATER PUMP**

Rate of

For shallow wells less than 2m deep, can lift 20 cubic metres/hour

Pumping:

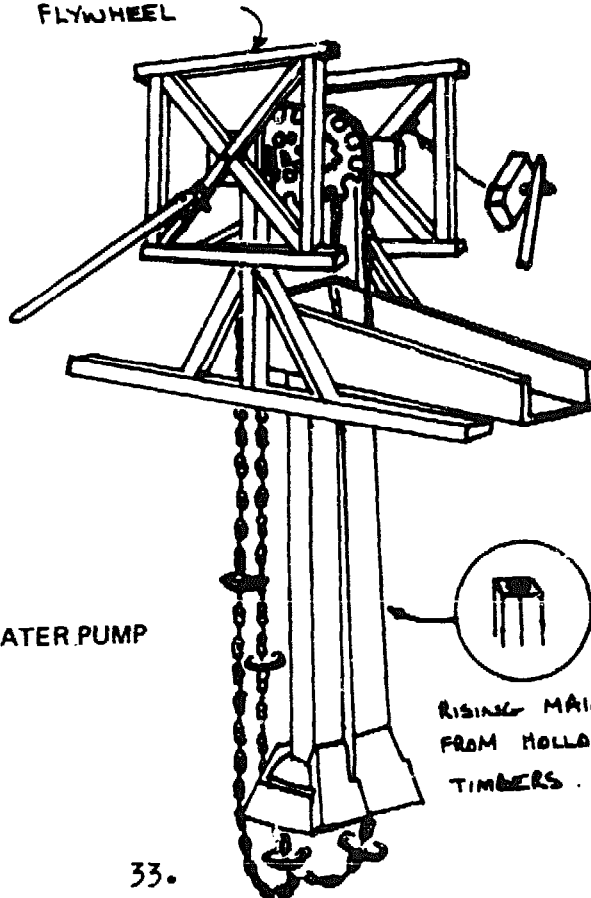
Construction:

This pump consists of a triangular braced frame, a push-pull mechanism and a typical water lifting mechanism from a 'five wheels' pump. A metal shaft of 2.5cm in diameter is fitted in wood bearings on two supports braced by the triangular structure. On each end of the axle is a square wooden frame 80cm square. A 2m long push-pull bar is held by a crank pin on each wheel. In the middle of the shaft are two iron wheels 40cm in diameter and 10cm apart. The water chains with round metal washers run over each wheel and pass through a square rising main pipe with a circular internal cross section. The internal diameter of the pipe is about 6.5cm. The chain wheels and chains were salvaged from an old 'five wheels' pump. Two people pushing and pulling on the crank bars make the square wheels rotate.

NOTE:

This device is of great simplicity and uses salvaged components of an old pump. The fly wheels of the device are square - these are much easier to make than a circular fly wheel.

SQUARE TIMBER  
FLYWHEEL



PUSH-PULL WATER PUMP

RISING MAIN PIPE  
FROM HOLLOWED SQUARE  
TIMBERS.

No. 15.

**TRIPLE CHAIN HAND OPERATED WATER PUMP**

Typical

Suitable for rivers and shallow wells with a lift less than 4m.

Application:

Rate of

Able to irrigate 0.9 hectares of land a day with 2 people pumping. Cost of construction is only one third of the 'Liberation' type.

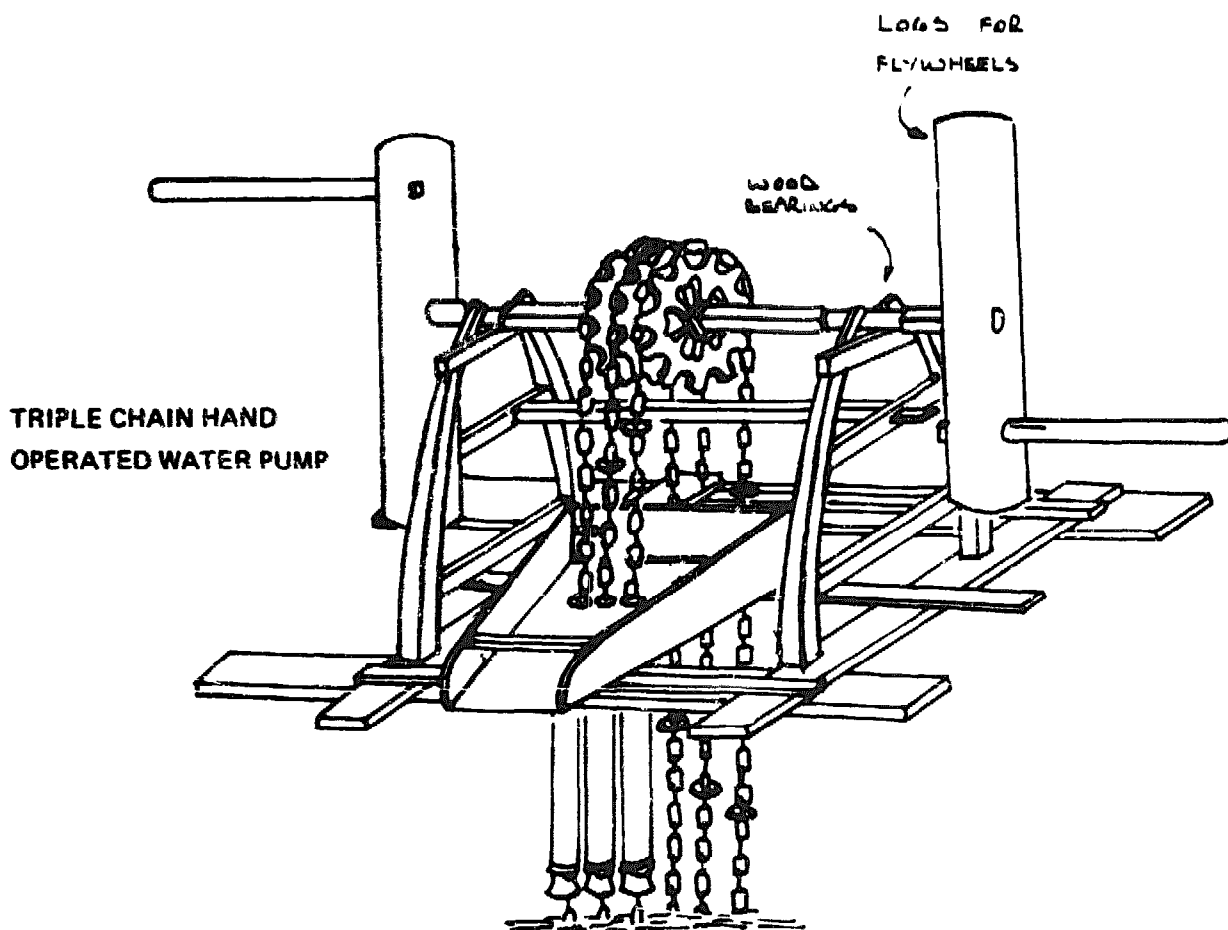
Pumping:

Construction:

The special feature of this pump is that the water is lifted by three water chains simultaneously with two people pumping. On top of the wooden frame work, 100cm long, 120cm wide and 100cm high, is mounted a wooden axle 170cm long, with square cross section 7cm x 7cm. A large wooden log is fixed to each end of the axle - these act like fly wheels. A crank handle is connected to each log for hand cranking. Three 'Liberation' type chain wheels are located near the middle of the axle about 8cm apart. Each wheel has its own water lifting chain.

NOTE:

The use of logs to act as fly wheels, are a main feature of this pump. Notice how the axle shaft has been rounded at the bearings, and the way the bearings are arranged.



Rate of Pumping:

One man operating can pump up to 20 cubic metres/hour

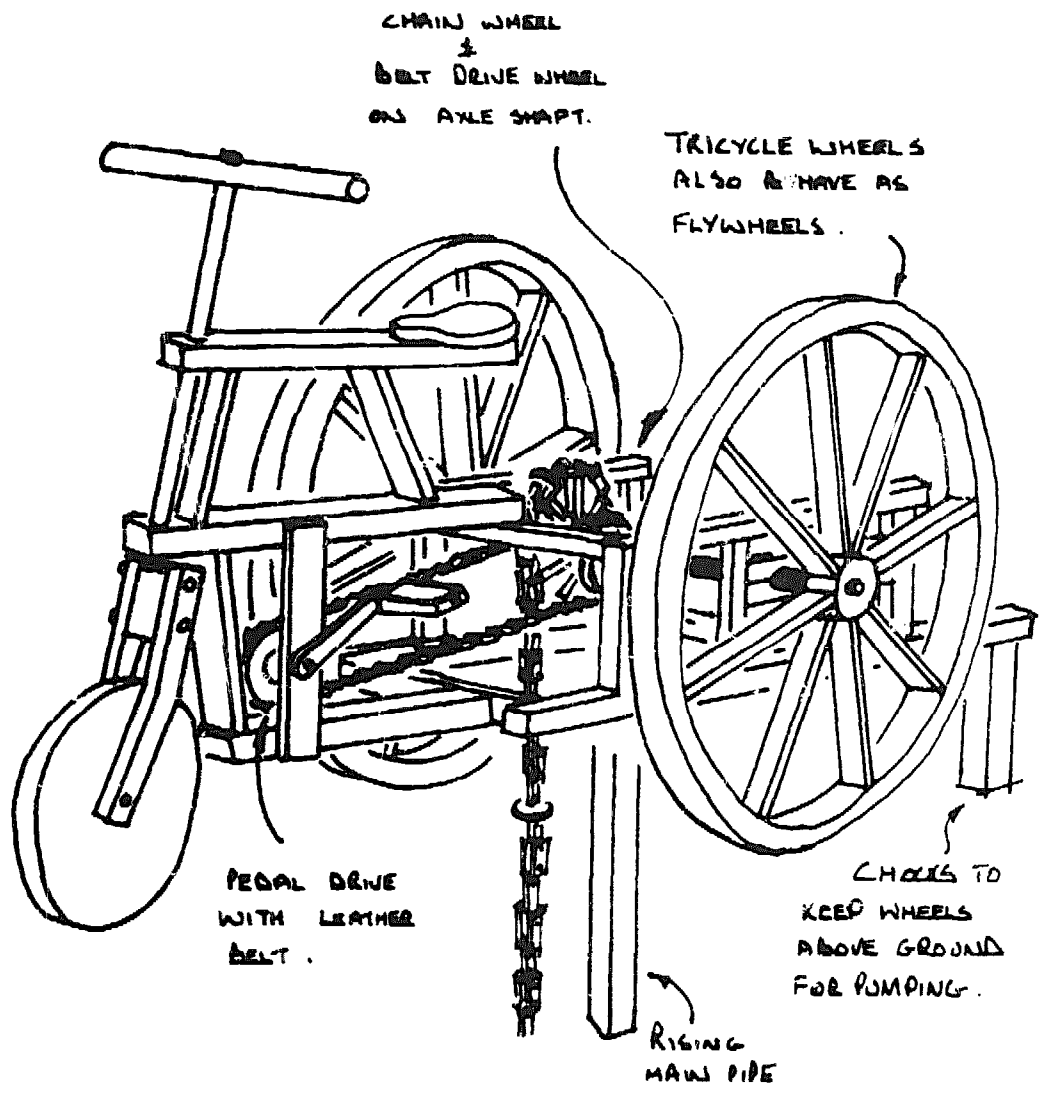
Construction:

Composed of frame work, pedals, and water lifting part. The main frame work is 120cm long, 50cm wide, and 35cm high. On top of it is located a 75cm long iron axle, of 3cm diameter. At each end of the axle is a wooden fly wheel of 90cm diameter. A wooden chain wheel with a water lifting chain is located at the right hand side of the axle.

A bicycle type wooden frame with a handle bar and pedals, is connected to the front part of the main frame. On the pedal axle there is a belt drive wheel with a leather belt running back and a pulley wheel on the axle shaft. On pedalling, the motion is transmitted to the back axle. The distance between the belt wheels on the pedal axle and the back axle is 82cm.

NOTE:

This device uses man power to its best advantage, i.e. by using leg muscles. The water chain is lifted from the chain wheel, the water pipe disconnected, and the whole pump can be wheeled away for use somewhere else. When it is set up for pumping, the frame is propped up on chocks and the wheels become fly wheels. An ingenious innovation.



TWO WHEELS PEDALLING TYPE WATER PUMP

No.17.

## SLANTING PUMP

Typical

Application:

Can be used over a well or at a slanting angle on a pool.

Construction:

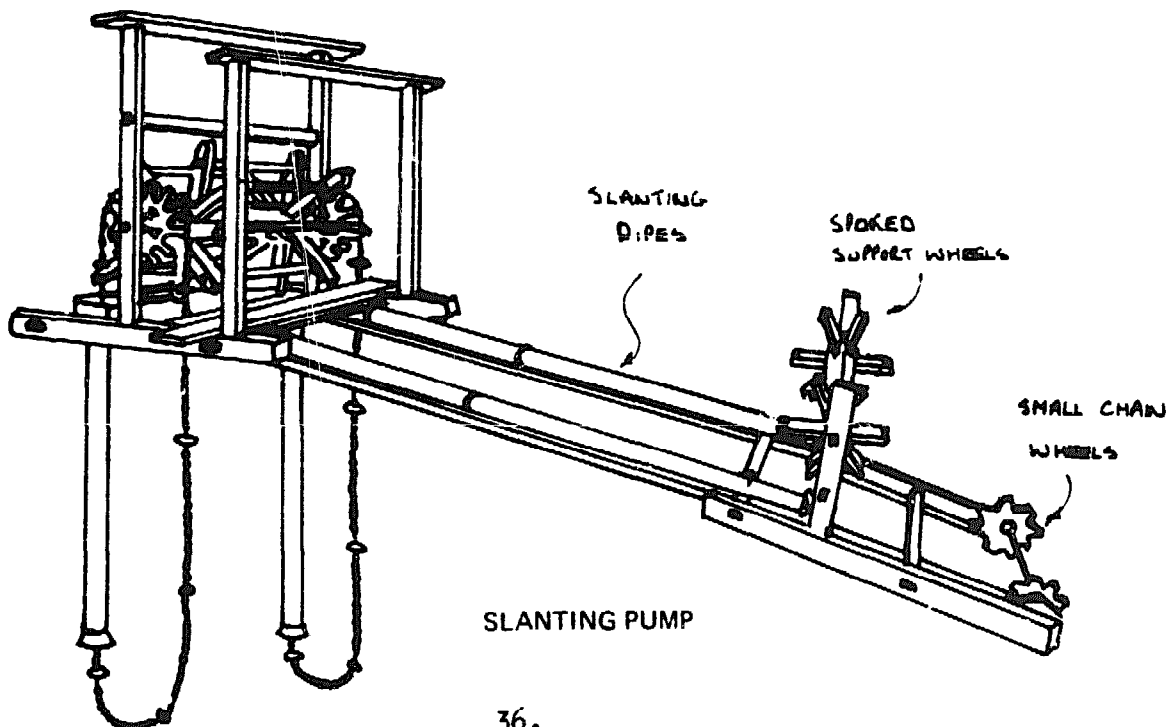
This is a modification of the old type pumps. It can be operated vertically over a well, or at a slanting angle on a pool.

The main structure is a wooden frame 160cm long, 180cm wide, and 160cm high. This has an iron axle and a large wooden treadle mill fixed to it. On each side of the mill is a chain wheel, with separate water chains and rising main pipe.

There are two ways to connect the water-lifting part. One is the ordinary vertical arrangement, the other is the slanting arrangement. When the latter is used, the water pipes have to be fixed on the frame at a slanting angle. On the end of the frame are two small chain wheels that carry the water chain into the pond. In the middle of the frame are two spoked wheels to support the chains as they rotate. The frame has a bench and a handle bar so that during the operation two persons can sit on the bench and pedal mill.

NOTE:

This device demonstrates how the old type of pallet pump was arranged and shows how the chain pump can be adapted for pumping at an angle. When used for pumping a pond, the ends of the water pipes must be submerged.



No.18.

**SAND FIELD WATER PUMP**

Rate of Pumping:

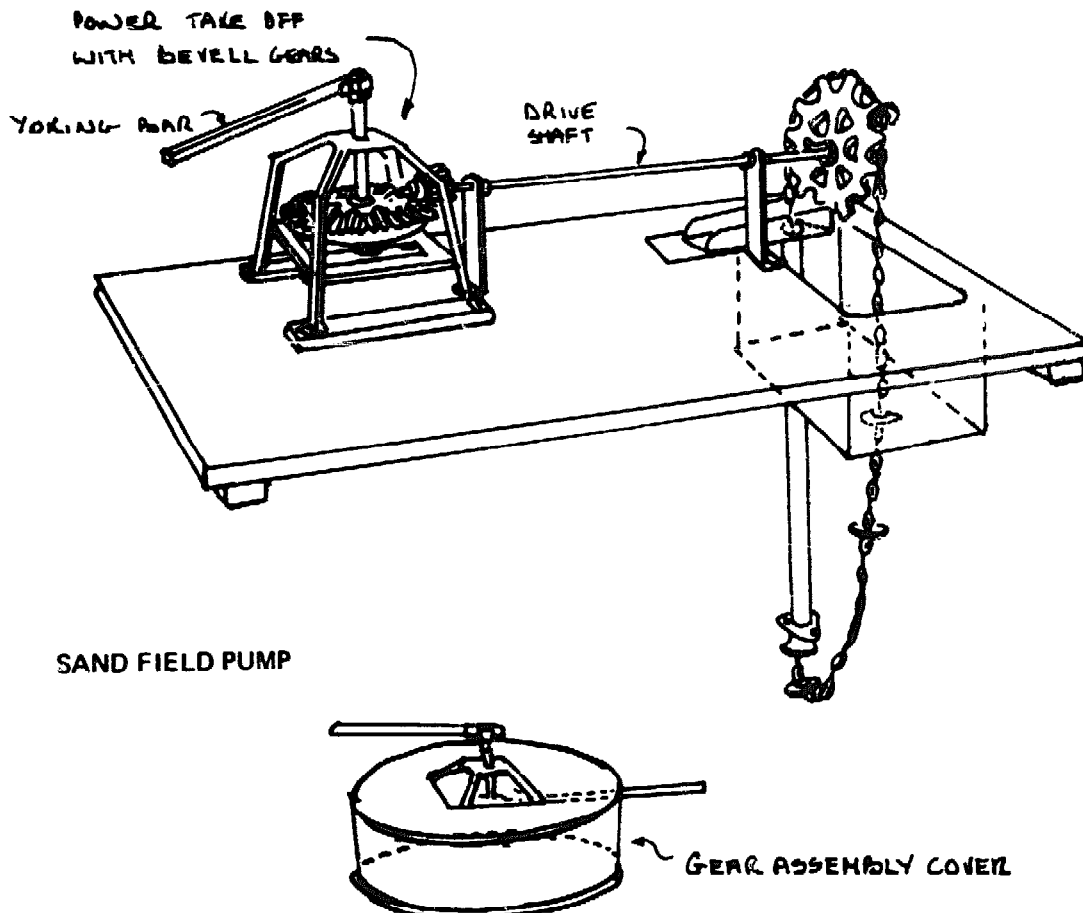
More efficient than the 'Liberation' type, one man, one ox can irrigate 0.3 hectares of land a day.

Construction:

The chain wheel, chain, bevelled cog wheel and pinion, are the same as those used in the 'Liberation type pump, only that the drive shaft is longer. A protective cover is placed over the cogs to prevent accidents to the ox or attendants. The bar pulled by the ox is connected to the verticle axle on which the bevelled cog wheel is mounted.

NOTE:

The main advantage of this device is that the ox can be kept clear of the well: the animal steps over the drive shaft to the pump. It also allows the gear mechanism to be firmly secured to the ground away from the well. If the well is small in diameter, there would be no great advantage using this device, - the power take off gears could be taken away to be used on some other activity.



No. 19.

## MODIFIED 'TWO PIPES' WATER PUMP

Rate of Pumping:

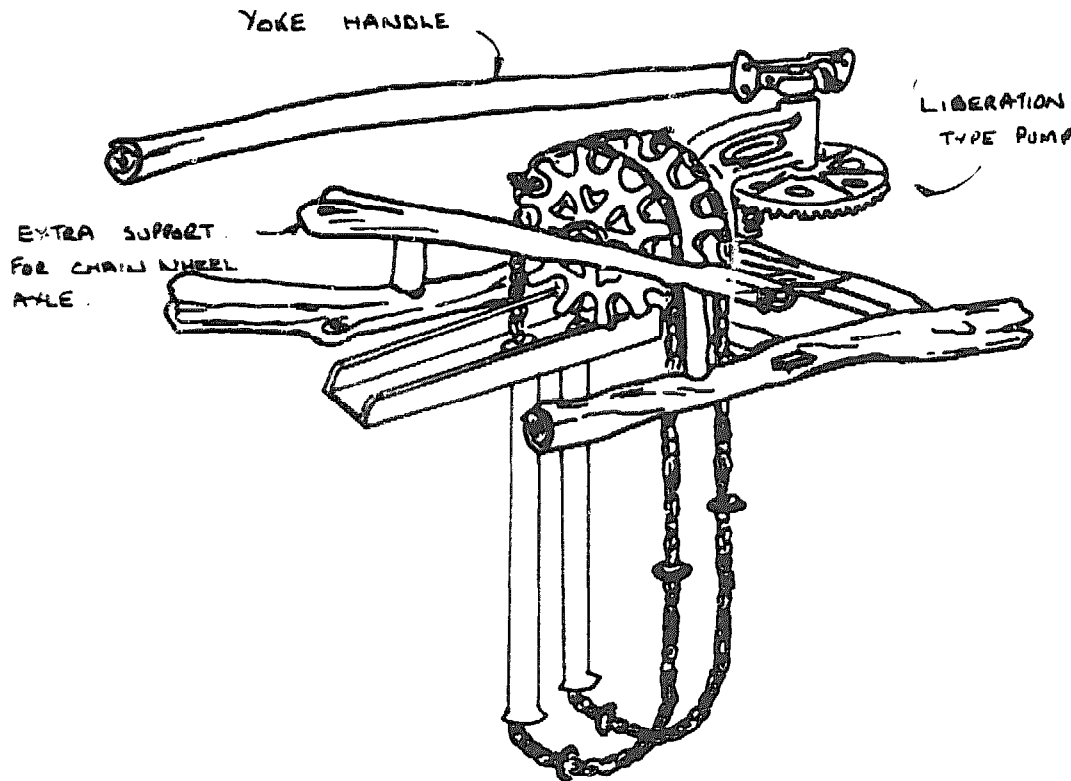
Suitable for wells over 7m deep, using one ox, 0.4 hectares of land can be irrigated each day, that is twice as much as the 'Liberation' pump can manage.

Construction:

This pump is a modified version of the 'Liberation' type water pump. The main difference is that the chain wheel axle is extended, and two chain wheels equipped with water chains and pipes are used.

NOTE:

The longer chain wheel axle is supported on the outside end by a timber frame. The ox harnessed to the draw bar walks around the equipment and the well.



MODIFIED 'TWO PIPES' PUMP



No.20 .

## WINDMILL AND HAND OPERATED PUMP

Rate of  
Pumping:

With suitable wind speed, the device can irrigate  
1.0 hectares/night.

Construction:

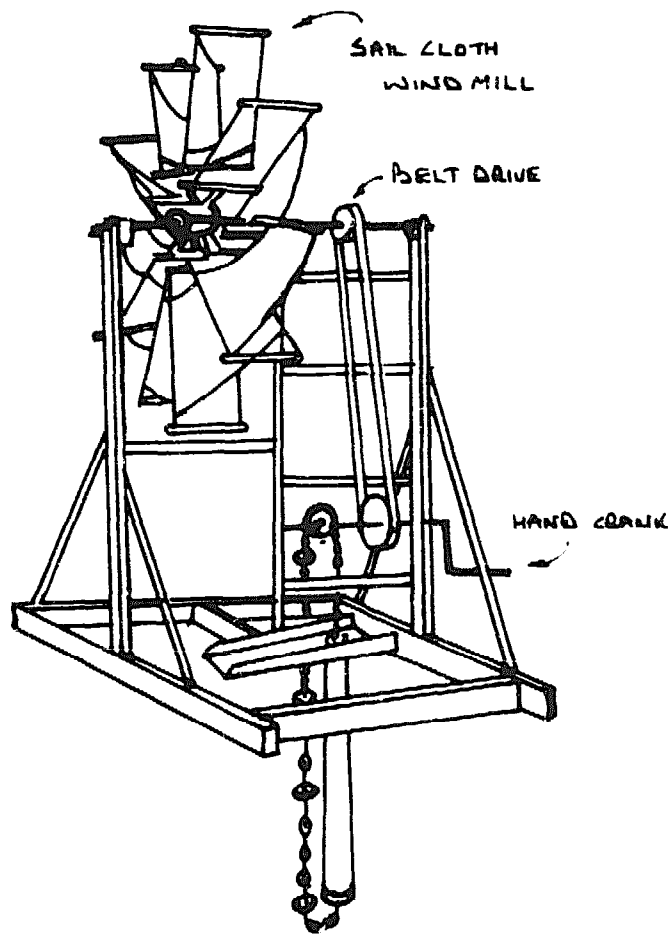
This kind of water pump is driven by wind force or hand cranking. Its structure consists of a wooden frame work, 250cm long, 230cm wide and 330cm high. On the top of the frame work is located an iron axle with square cross section and 230cm in length. At one end of the axle a wind mill is secured and at the other end a belt wheel is positioned.

The windmill is formed by ten blades made of canvas. At about 100cm above the base another iron axle, 160cm long and 3.5cm in diameter is positioned on the frame work and is parallel to the top one. A belt wheel is affixed on the axle. It is connected to the wheel on the upper axle by a leather belt.

On the lower axle 24cm apart from the belt wheel a chain wheel is located, connected to the water lifting mechanism. An iron crank handle is also secured at one end of the lower axle which can be used when the wind has dropped.

NOTE:

This device uses the power from the wind when it is available, and hand cranking when the wind falls. The device would have to be turned around into the wind whenever the wind direction changes.



WINDMILL AND HAND OPERATED PUMP

No.21.

**MOTOR OPERATED PUMP**

Rate of Pumping:

Motor power 3.5-5 h.p. diesel engine. Speed 135-180 revs/min. Water lift more than 15m. Can irrigate 0.1-0.2 hectares/hour

Construction:

This type of water pump is driven by a motor. The construction is as follows:

A rectangular iron frame 76cm long and 48cm wide fixed on two 200cm long, 10cm high and 8.5 cm wide, wooden beams.

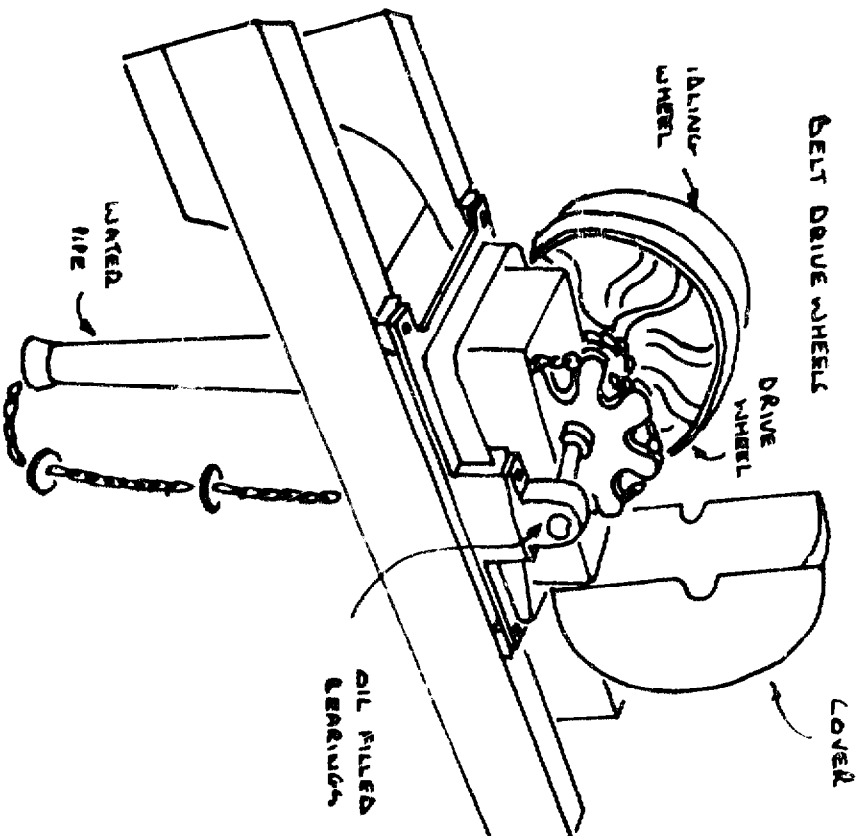
Across the iron frame is an iron axle supported by two oil-filled bearings. In the middle of the axle is a chain wheel made of iron.

The water pipe is tapered with a narrower cross-section at the bottom end so as to reduce friction. The top of the pipe opens to a water chute which together with the chain wheel and a protection cover forms a box.

On the other end of the axle are two belt wheels of 52cm diameter. The outer one is an idling wheel which is only used for emergency stop. On the side of the belt-wheels is a ratchet and pawl.

NOTE:

This pump is one of the few in the Exhibition that was powered by a diesel motor. It is constructed almost completely of cast iron and is therefore relatively expensive and difficult to make. The device pumps from depths greater than 15m, which means that it can be used in deep wells or where a conventional centrifugal pump would be difficult to use.



MOTOR OPERATED PUMP

## 7. WHERE TO GO FOR FURTHER INFORMATION

### 7.1 On China.

It is not possible to fully understand the success of the programme of self-reliance in rural development, symbolised by the equipment shown in Section 6, unless the history and philosophy of China is taken into account. Valuable and useful information about China can be obtained from:-

The Society for Anglo-Chinese Understanding,  
152 Camden High St.,  
LONDON NW1  
United Kingdom.

### 7.2 Pumping Devices.

a) 'Chad Chain Pump' T. Corcaran.

Peace Corps Technical Notes. August 1969. Washington DC 20525  
U.S.A.

A short description of a chain pump constructed in Chad, West Africa, to be powered by a camel, using an automobile back axle as a power transmission.

b) 'Chad Chain Pump' - Working drawings and instructions.

VITA Publications. 3706 Rhode Island Avenue, Mt. Rainier,  
Maryland, USA 20822.

Full detailed drawings and instructions on the method of constructing an animal powered chain pump from steel strips. The components are cut and bolted into place, - no welding is needed. The chain and washers are also made from steel strip; the washers have rubber seals bolted to them. The chain wheel is attached directly to the back axle of an automobile, and the animal on the driving yoke walks around the well. The pumping assembly is mounted on wooden joists directly over the mouth of the well.

- c)'The Hydrostatic Pump and Other Water Lifting Devices in the Context of the Intermediate Technology Approach'  
R. Ohlemutz, 1975. 147pp. Phd Thesis, University of California, Berkeley. USA.

The Thesis is in several parts, an introduction to low cost water pumping, a description of traditional techniques, and the research carried out on the hydrostatic pump. The section on traditional techniques gives a useful comparison of pumping rates.

- d)'Cost and Performance Analysis for A Range of Simple Pumps'  
J.S.Richardson, 1972. Student Thesis. Dept. Mech. Engineering, UMIST. Manchester, U.K. 40pp.

A range of traditional and commercial pump designs are compared for initial and running costs. The initial costs are broken down to show the cost of each component - these costs will, of course, vary widely in different parts of the world. The running costs include depreciation and power costs; the chain and washer pump was considered to be the best choice for a farmer without access to cheap finance or maintenance facilities. For periods of over ten years, the commercial centrifugal pump powered by main grid electricity, proved to be the cheapest.

- e)'Simple Water Raising Devices'. D.Farrer. Student Thesis. Dept. of History of Science and Technology, UMIST. Manchester U.K. 25pp 1969.

A description and classification of a range of traditional water lifting devices, with emphasis on their potential for use in rural areas.

- f)'Water Lifting Devices for Irrigation' M.A.Molenaar, FAO Paper No.60. 1956 75pp. Food and Agricultural Organisation, Rome, Italy.

A comprehensive description of most of the traditional and more modern water lifting devices in use around the world, including the chain and washer pump. The paper makes some assessment of the relative performance of each pump. This publication is at present being updated by FAO for re-printing.

### 7.3 Power Sources.

- a) 'The Employment of Draught Animals in Agriculture'.  
FAO, Rome 1972.

A detailed account of the use of draught animals in agriculture, including their use in water pumping. This is perhaps the most useful publication available on animal power, and describes not only the power output from various types of animals, but also the care and attention that they need.

- b) 'Feasibility Study of Pedal Power Applications in Developing Countries'. D. Weightman, Industrial Design Dept., Lanchester Polytechnic, Coventry, U.K. 1974. 12pp.

A description of the best ways of using pedal power for a variety of tasks including water pumping, and the power output possible.

- c) 'Windmills for Water Lifting....' E.W.Golding. FAO Informal Working Bulletin No.17. 60pp.

A review of the possibilities of using wind power in agriculture, with a description of the devices that can be employed to pump water. Many of the slow speed, high torque devices described could drive a chain and washer pump.

- d) 'The Design of an Animal Gin'. R.E.A.Day. Student Thesis Dept. Mech. Engineering, UMIST. 1970 22pp.

This thesis deals with the application of animal power, using the rotary action of a gin. Methods of harnessing the animals are described, and a detailed account is given of the various gear assemblies that can be used to take the power from the animals. This thesis is of great value.

## APPENDIX

This section shows two examples of present-day commercially available pumps from India, one proposal for a rope pump variation, and finally a foam belt pump made in France. Also included is a design for a ship's pump obtained through the kind offices of the Maritime Museum, Greenwich. The pump was used on ships of the British Navy in the eighteenth century.



## HAND CHAIN PUMP

**Rate of Pumping:**

Operated by two persons, the pump is capable of lifting water from a depth of 3 to 4 metres. It has a capacity of 18 to 20 cubic metres per hour.

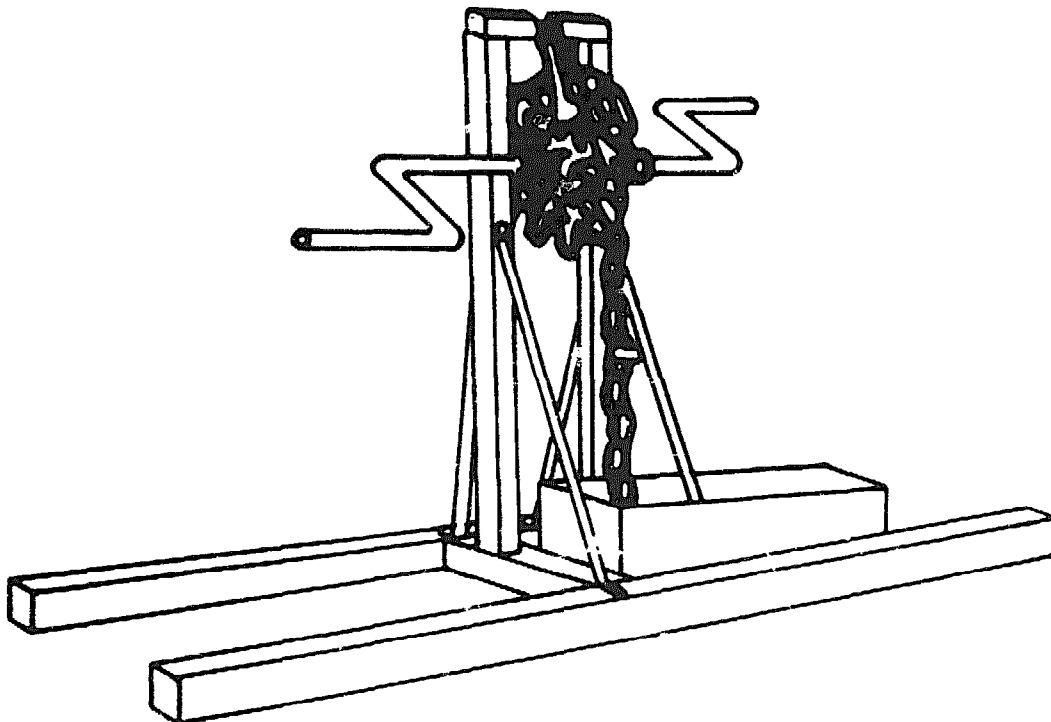
**Construction:**

The wood and metal framework carries the chain wheel axle, mounted on two heavy-duty ball-bearings. The axle is fitted with hand-cranks at each end.

The rising main pipe is made of sheet metal, and the rubber washers are easily replaceable. The pump weighs 125 kg.

**NOTES:**

A simple device with no flywheel. The upright members are braced to give additional strength and rigidity. The ball bearings reduce the frictional resistance of the pump provided they are maintained in good condition.



HAND CHAIN PUMP

## ANIMAL-DRAWN CHAIN PUMP

Rate of Pumping:

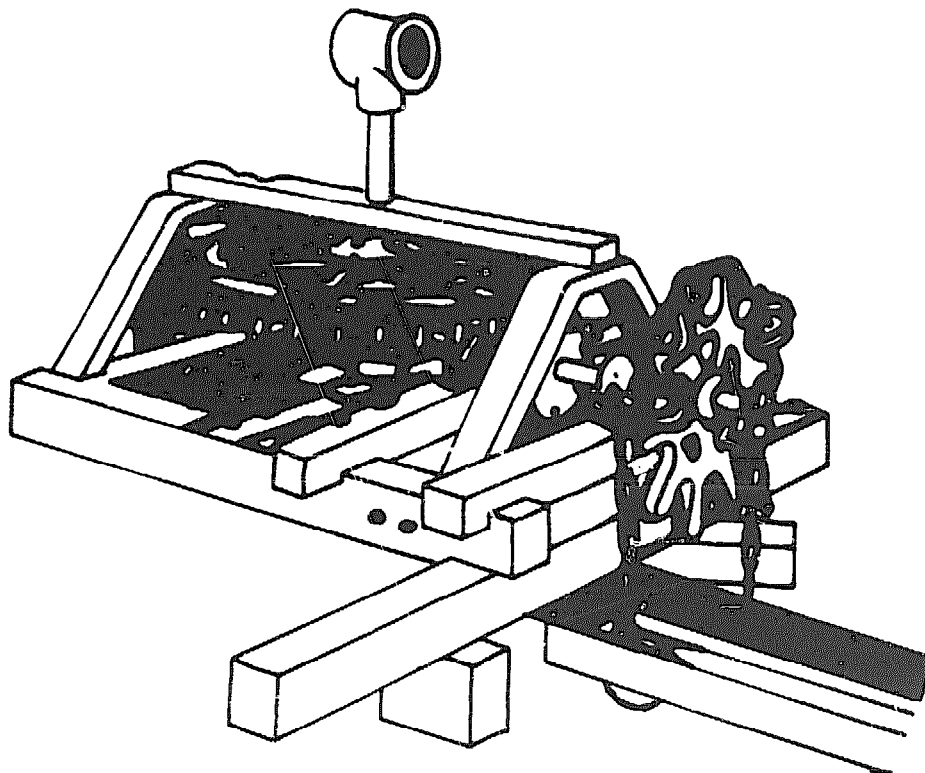
Operated by animal power, the pump is capable of lifting water from a depth of 13 metres. It has a capacity of 13.5 to 18 cubic metres per hour.

Construction:

The wooden framework supports both the large horizontal gear and the chainwheel which is cantilevered on a two bearing axle. The pole drive from the vertical axle of the main gear can be taken direct to the animal which walks around the well head. The chain is fitted with rubber washers which are easily replaceable. The pump weighs 380 kg.

NOTES:

The chain wheel has a small diameter making the pump suitable for installation in wells whose diameter is as small as 1 metre. The device is robust and the gearing low.



ANIMAL-DRAWN CHAIN PUMP

## ROPE PUMP

Rate of Pumping:

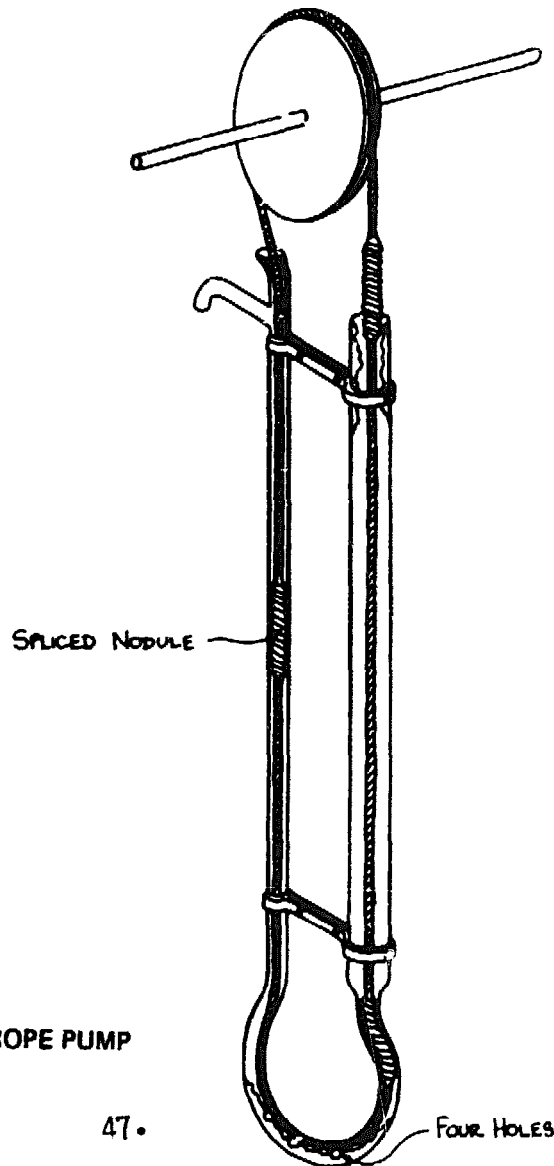
As this is only a proposed variation on the chain pump principle no performance figures are available.

Construction:

The chain and washer mechanism is substituted by an endless rope which is spliced at intervals to form "nodules" of an enlarged diameter, these nodules acting as pistons within a plastic rising main pipe. The rope would either be driven by a large wooden pulley operated by a windlass handle at ground level, or would pass over an overhead pulley and be operated by a direct downward pull on the return side.

NOTES:

Experiments and field trials under working conditions are necessary to evaluate the performance of this pump. There may be a problem of rapid wear and rotting of the rope and slipping on the pulley.



## FOAM BELT PUMP

Rate of

Pumping:

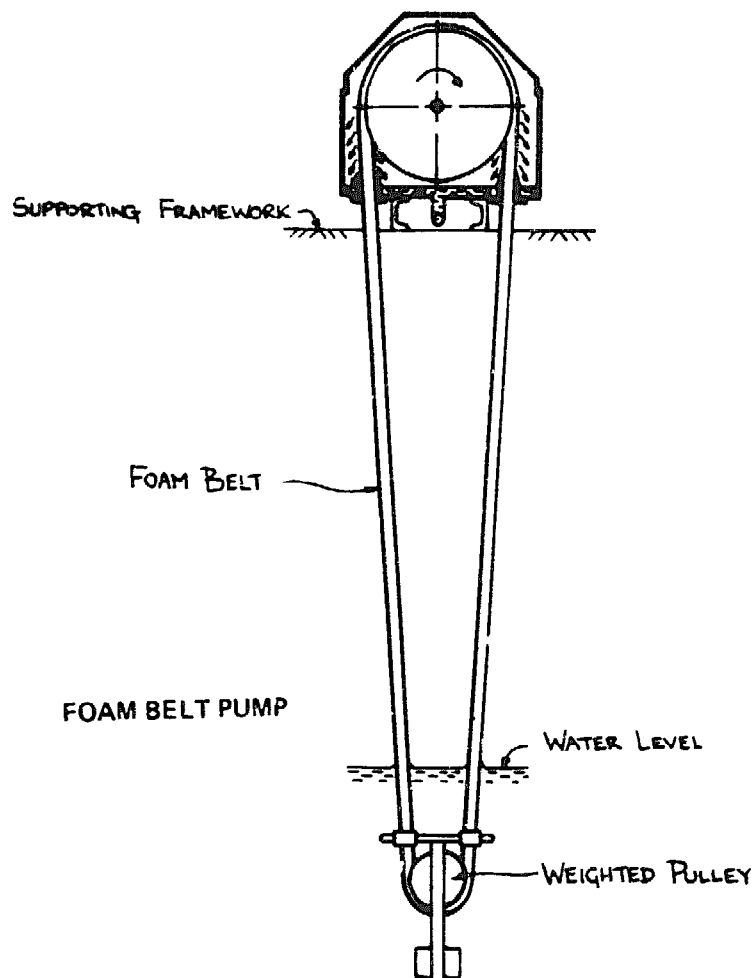
This device deviates considerably from the chain pump principle. It is operated by one or two persons and is adaptable for being driven by animal power. It has a capacity of 3 to 6 cubic metres per hour.

Construction:

The rising main is dispensed with, and the chain of links and washers is substituted by a continuous flexible belt made from a foam material which absorbs water. The body of the pump which houses the drive pulley is mounted on a metal framework, and the belt is kept tight by a weighted pulley submerged in the well. The axle of the drive pulley is fitted with hand cranks at each end. In the pump body the belt is squeezed as it passes through two constrictions so that the water it has soaked up is removed.

NOTES:

It is important to calculate the correct length of foam belt so that the weight on the lower pulley clears the bottom of the well by about 50 cm.



## EIGHTEENTH CENTURY SHIP'S CHAIN PUMP

### Rate of Pumping:

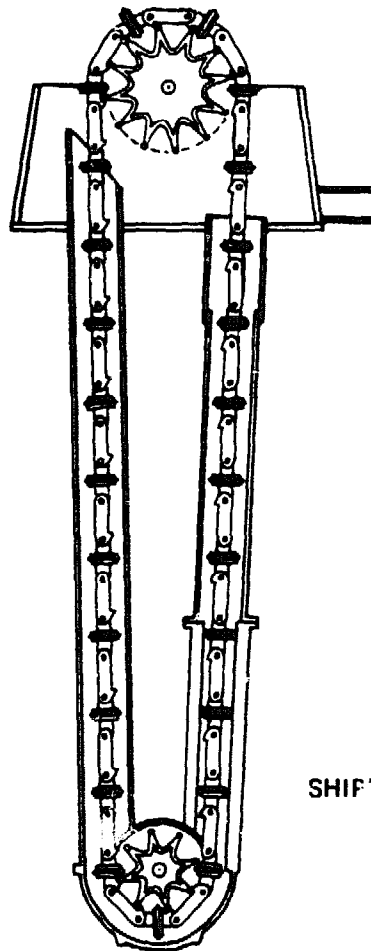
Capable of raising "one hogshead of water in one minute to the height of ten feet" - that is to say, 17 cubic metres per hour from a depth of 3 metres.

### Construction:

The chain is made from iron plates linked together with bolts. The plates are shaped to fit the sprockets so that movement takes place with minimal jerking and slipping. The leather washers are held between two circular brass plates. The two pipes are made from wood, the lower part of the ascending pipe being lined with brass. The axle of the drive sprocket is fitted with detachable cranks which are long enough for thirty men to work at once.

### NOTES:

Ships of war normally carried four chain pumps for emergency pumping. They were chosen for reliability and ability to withstand strenuous treatment. In later models, the lower sprocket was omitted and the ascending and descending pipes were joined by a curved metal tube.



SHIP'S CHAIN PUMP