# THE LOCAL PRODUCTION OF HANDPUMPS FOR DRINKING WATER IN DEVELOPING COUNTRIES

Buren, december 1984

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## Preface.

If the local government in a developing country choses for handpumps for drinking water supply, there remains the question to be answered whether they can be produced locally, and if so,

- with what production technology,
- in what kind of a workshop,
- how many pumps can be produced monthly,
- what are they going to cost.

This report describes the various possibilities, with their advantages and disadvantages in different circumstances.
It has been written on request of the "International Reference Centre" of the "World Health Organisation", Rijswijk, the Netherlands,=) and is based on studies and experiences in this field in Tanzania and Peru during the period 1978 - 1984.
I wish to thank all who have contributed, especially the local workshop managers and labourers with whom I had the opportunity to cooperate

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=) (II.1)

## I. LOCAL PRODUCTION.

For the drinkwater supply in developing countries, handpumps are used in increasing numbers. They present a good and relatively cheap solution. It is very important that they are produced locally, that means: in the developing country itself. This offers the following advantages:
1) spare parts will always be obtainable;
2) it saves foreign exchange;
3) it stimulates local industry;
4) it contributes to local employment;
5) the pump can be adapted to local circumstances.

There is a distinction between production and assembling. The latter means that the parts are imported into the developing country and are built together locally. Only if the majority of the parts are produced in the developing country the term local production is appropriate. It will be clear that the arguments for local production as mentioned above are only partially valid for assembling.
Another important distinction is the one between regular import and special import. When parts or materials are imported especially for our handpump because they are not available on the local market, this is called special import. If this import does not come through, the pumps fabrication stands still. When the for the pumps fabrication required parts are regularly imported and are normally available from stock on the local market, this is a regular import. In the latter case the availability of the material is more certain.

~~As a conclusion,~~ It is recommended that local production is chosen instead of assembling, and normally available materials are used instead of especially imported parts.

## II. THE CHOICE OF ~~THE~~ PUMP DESIGN;

A number of factors have to be considered in order to find an appropriate pump design.

1) The pump head.
(Fig. 1)

The so called suction pumps have the piston located in the pumpbody. At sea level these pumps can reach suction heads of about 6 m. =) When the pump has not been used recently, it may require "priming" (i.e. some water is poored in from above).

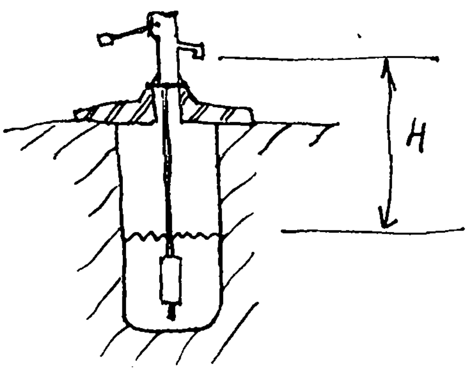



Fig. 1. The pump head, H.

=) At higher altitudes above sea -level, the maximum suction head is less; the difference is 1 meter for each 1000 m of altitude.

This may cause contamination of the water. Though suction pumps are cheaper, they are not very satisfactory for village drinking water supply. The so called deep-well pumps have their piston located down the well. In some cases they are used for pump heads over 80 m ! When the pump head is high like that, the water yield has to be low ($\approx$ 0,1 - 0,2 liter/stroke) because if not, the pump will be too heavy to use. The water yield per stroke depends on the cilinder diameter and the piston stroke. Therefore most pumps are produced with an ajustable stroke or with cilinders in various sizes, in order to adapt the pump to the head. For a low head a larger diameter cilinder and/or a longer stroke is chosen and so more water is pumped than for a high head.

2 The water quality.

The waters chemical composition and the type of material determine whether and at what rate metal parts will be subject to corrosion. In case of very aggressive water only plastics and stainless steel are used. The water aggressiveness depends mainly on its acidity, that is measured by the so called PH-value. If the PH-value is below 7 the water can be aggressive and metal parts may oxidyze (see page 18). The amount and type of abrasive materials in the water, such as sand, affect the rate of wear of the piston seal and the cilinder lining. Special modern plastics are used to obtain the best abrasive resistance.

3 The way technology is used in the society.

In some countries and regions, ~~the~~ people handle their technical machinery more carefully than elsewhere, for instance because they are more used to it, or, because there is more "social control". If the pump is subject to rough treatment, a sturdy type has to be chosen.

4 Maintenance and repair.

If maintenance and repair occur only sporadically, a pump should be chosen that does not require preventive maintenance and only seldom breaks down. But anyway it is important that maintenance and repair are easy to carry out, with simple tods only. If possible, it should be so simple that it can be done by the villagers themselves. If this is the case, the pump is called a "VLOM"-pump: Village Level Operation and Maintenance. +)

5 The number of pumps required.

Some kinds of production technologies are especially suited for mass production, for instance cast iron. This limits the choice of the pump design, because a pump not designed for production in cast iron can not be built that way.

+) More information on the VLOM concept can be obtained from JTDG (II.2.)

Based on its suitability for the local conditions, the pump design is chosen. Generally spoken, a pump that performs well on all items mentioned (high pump head, aggressive water, rough treatment, little maintenance) will be more expensive.
This does, of course, not mean that all expensive pumps are good. Valuable information on pump performance can be found in the test reports published by the World Bank (I.1.). When selecting a proper pump design, it has to be condidered that the producing factory may not be interested in any production outside its own workshop. Other designs are free, or a license can be bought.

## III. THE WORKSHOP.

The next problem is to find a suitable workshop for local production.

It is not recommended to establish a completely new workshop for the purpose of pump production, nor to create a production unit in the local government car repair shop. These workshops will lack the necessary organizational skill and experience.
An especially established pump production workshop will also be very vulnerable: if some day the money supply for pumps stops, the workshop will go bankrupt immediately. It is better to look for an existing workshop that can be expanded with a pump production unit.

Quite often workshops can be found that do have the equipement and the technical skills to produce the pump, but that lack the organizational capabilities. The shop floor is an mess, parts are lost in an abundance of scrap, it is not clear which worker is responsable for which job, nobody knows how much time a certain job takes, etc.. Such workshops may be able to produce good quality pumps, but the delivery time will not be met, or a part of a first series of pumps may not fit in a pump of a second series, or something like that. Best is to look for a workshop of good reputation that has experience in series production of machinery that require the same kind of materials, machining and precision, as our handpump does.

In the capitals in many developing countries one will often find industries with a technical and organizational level far higher than necessary for handpumps production. Besides, more simple workshops can be found, for instance in the departmental capitals, that just could handle the job. If this is the case, there are <u>good arguments in favor of the simpler workshops</u> in the departments.
These are the same arguments that support the production in the developing country instead of production in a developed country (see page 1), because the relation between the province in the developing country and its capital is similar to the relation between the developing country and a developed country. Besides, the simple workshop usually applies less imported machines and works more labour intensive, so it saves more foreign capital, and supplies more of the (scarce) lowskilled labour. In some cases it may even be possible te start pump production at <u>village level</u>, by the local carpenter and/or blacksmith.

It should be realised however that the simpler the workshop, the more difficult it will be to guarantee the products quality. The simpler shop may not be able to work from technical drawings or to perform the operations with sufficient precision, and it may lack the organizational experience. In order to establish a satisfactory production quality the simple workshop needs the intensive assistance of an experienced expert, while the modern industry is quite able to proceed on its own. Therefore, production in low or intermediate level workshops should only be considerd if sufficient assistance can be guaranteed.

The costs of the pump depend on its design, on the local price level, and on the workshop that builds it. Often the local government is afraid that the workshop is unreasonably expensive. It should be realised however that even a relatively simple workshop is an expensive thing. A workshop equiped with a drilling machine, a small lathe machine, welding equipment and the usual selection of hand tools, will cost some U.S. $ 5 per "man + machine" hour. As an example, a pump that takes 30 hours in series production will cost about $ 150 for its fabrication only, that is without calculating materials, transport, etc..
The larger, more modern industries are usually cheaper when producing large series (several hundreds or thousands) but more expensive when the number is only a couple of dozens or less. much

## IV. THE PRODUCTION PLAN

The production plan is made te prepare for production. Between other things it serves to calculate the production time and costs. Usually, small workshops don't have such a plan when starting to produce an article. In such case, the accompanying expert should do it. It includes the next steps:

1) Technical drawings of each part should be made, with all written comments in the local language, with measures in the locally applied units, and adapted to the available material sizes. For instance, a bolt specified as M10 (mm) may be better available as 3/8" (inch), which is almost the same. Make sure that the drawings are made according to the locally used (American or European) standards and that each measure of each part is shown.
   The workers may not be familiar with such technical drawings and may need a lot of explanation. Yet such drawings are the only way to define exactly what should be constructed.

2) Based on the technical drawings, a list of materials is made, where the total amount of materials for one pump is specified.

3) Now a prototype can be built, in order to make sure that no unexpected problems will arise in the production, and to test those details that have been adapted to suit the locally available materials. It is not necessary to wait until the prototype has been built and tested, before completing the rest of the production plan.

4) The next step is the fabrication programm : this shows the sequence of operations for each part to be constructed.

5) The fabrication time can be approximated, calculating from the in the fabrication programm specified operations and the experience with similar products in the same workshop. If no ~~experimental~~ actual data are available, the fabrication time for series production in small machine workshops can be estimated, calculating

0,15 (man+machine) hour/operation

Here "one operation" means : drilling a hole, or cutting a plate, or turning one surface on a lathe machine, etc..
Of course, each operation is different and so are the machines and the workers. Yet the mentioned operation time is a good average. It includes material handling, sharpening tools, cleaning machines, etc.. The fabrication time will decrease as the workers experience grows; it can also be reduced with help of well made "jigs and fixtures". These are helping devices that enable quick positioning of both the tool and the part to be machined.
Their construction is quite a lot of work but definitely worth it if the amount of pumps is sufficiently large (i.e. over 1 - 2 hundred).

6) The workshop lay-out follows from the fabrication programme: the part batches should pass the machines along the simplest possible routes. The workload per machine has to be calculated, in order to judge whether the machines are sufficiently loaded to pay off and to avoid bottlenecks. If the workload of an expensive machine turns out to be too low, that job can be done somewhere else.

7) The production costs can be calculated from
- the machine costs (rent, depreciation),
- the workers wages,
- administration workshop rent, insurance, etc.

These contributions are called fixed costs, as they have to be paid no matter the number of pumps produced.
If the pump production is carried out in a workshop that makes all kinds of other things as well, the fixed costs should not be calculated for just the time it takes to produce the pumps, because at times the workshop will be

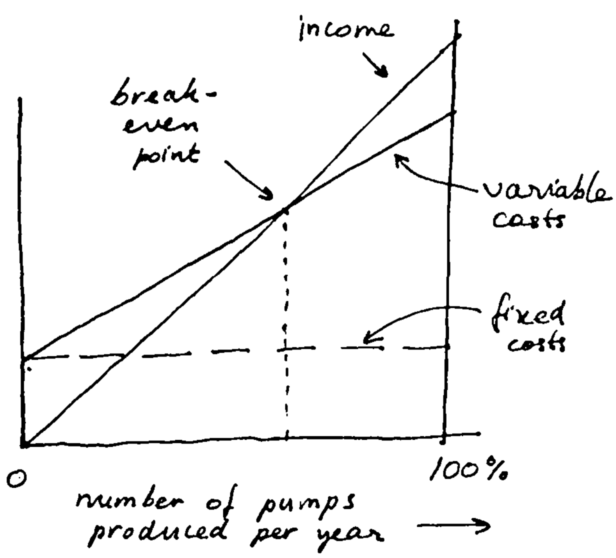
short of work, and strikes and electricity cuts may stop the production now and then. To make up for these idle hours the fixed costs of handpump production have to be adjusted. Other cost contributions are

- materials,
- tools (saw blades, drill-bits, chisels, etc.),
- machine repairs,
- energy (electricity for the welding equipment, etc.).

These costs increase in proportion to the number of pumps produced and are called variable costs.

8) In a workshop that is not restricted to handpump production only, the fixed costs and the variable costs except materials are usually calculated into some constant hour-tariff. In a simple workshop this will be about U.S. $ 5 per man+machine hour. The pump price is found by multiplying this tariff by the production time, and by adding tax and a compensation for the entrepreneurs risk. In a specialised production unit (either a part of an existing workshop or completely on its own), the workshops income depends exclusively on the handpumps, and costs and benefits are therefore calculated as a function of year production in a so called break-even analysis. (See fig. 2.)

Fig. 2. A break-even diagramm.




The figure shows that a small amount of pumps produced during a year gives a loss, and a high number results into a profit. The point where costs and income are equal is called the "break-even-point". The pump price (before tax) is calculated in such a way that the break-even-point lies a bit below the nominal year production, for instance at 2/3.

The production plan being established, the client (=the expert or the local government) has a good base for negociations with the local entrepreneurs. Usually the local workshops can estimate the pumps production time and price only roughly. It happens that the client is able to negociate a price that is in fact too low to allow any profit. At first sight, this looks favourable for the client, but it will defenitely give al lot of trouble later on. The workshop owner, seeing that he is to lose money, will insist in a price increase, while the local government will argue that it has an agreement. The entrepreneur may then refuse to deliver and look for other customers, or he may try to save money by fabricating poor quality pumps. Both parties will be dissatisfied in the end.

These and other problems will always accompany the production set-up of a pump. To reduce the problems, one should consider the possibility to start with assembling instead of production. It offers the workshop more time to grow familiar with the new product. It supposes of course that, there exists a workshop able and willing to send up parts. Later on the assembling can evaluate into production.

## V. MATERIALS AND PUMP PRODUCTION.

### Introduction.

One way to discriminate between various types of pumps is: according to its dominating construction material. The material characteristics affect the design, and on the other hand the material requires a special kind of production technology. The next materials will be discussed here:

- wood
- pipe components
- steel
- cast iron
- plastic

Of each material the most important characteristics will be mentioned, and a pump design based on this material and an abstract of its production plan will be presented, including the workshop lay-out, a cost estimation, etc..
Note that the same pump produced in two different countries will in fact give two different production costs, as the relevant factors vary. =)

=) For instance, in a country like India the production costs seem to be relatively low.

## V. 1. WOOD

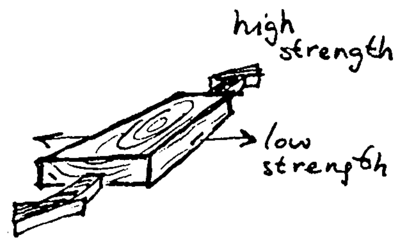
### Availability

Nature provides an enormeous variety of wood sorts, and wood suitable as a construction material is available in nearly every country, though in some it is growing more and more scare. Wood prices vary from region to region but are usually about ≈U.S. $ 0,25/kg. (sawed, not scraped).

### Characteristics

Wood is a relatively light (500 - 1000 kg/$m^3$) and strong, elastic construction material. It is not homogeneous, i.e. its characteristics, for instance strength, depend on its orientation. (See fig.3)

Fig.3. Wood characteristics depend on its orientation.

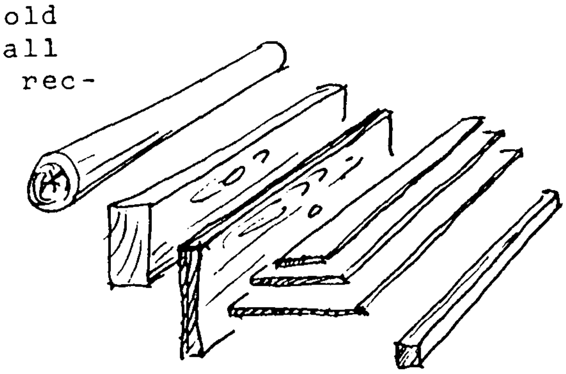



Sometimes it contains knots and fissures that reduce its strength Wood "works", i.e. it changes its shape slowly under the influence of humidity, temperature differences and mechanical loads. It is not possible to machine it very precisely. Many sorts rot when subject to high or varying humidity, while other sorts do not, or can be protected, for instance with kerosene.

### Raw material

Wood is sold commercially in all kinds of usually rectangular shapes (See fig.4.).

Fig.4. Wood is sold commercially in all kinds of usually rectangular shapes.

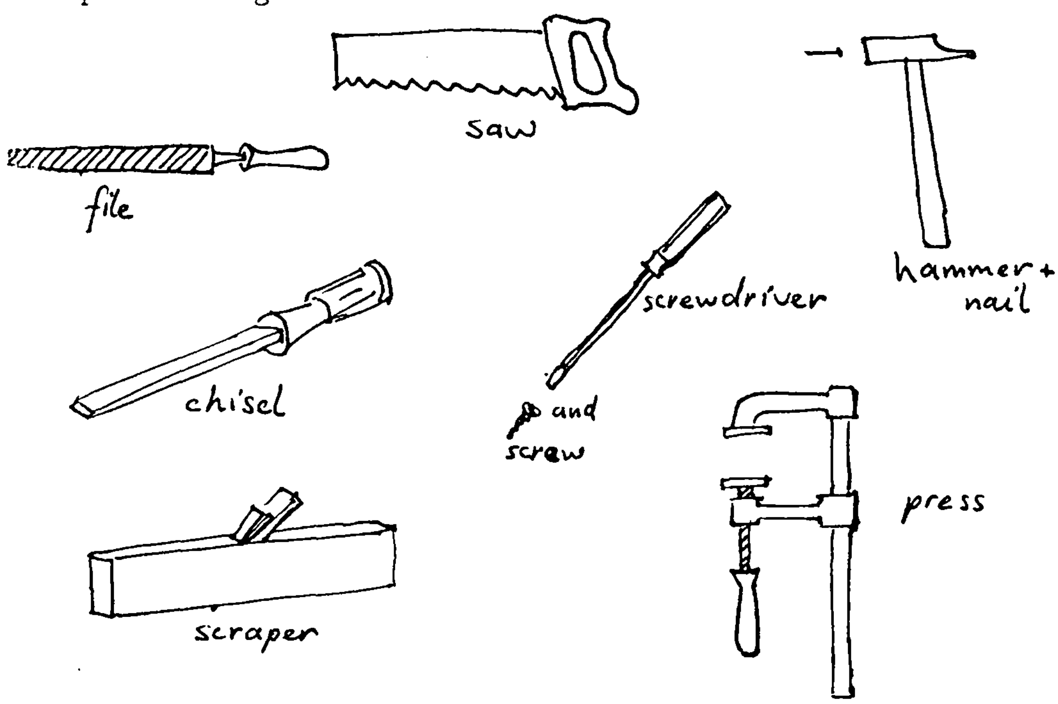


Another form is the so called "multiplex", plates of thin layers of wood glued together under high pressure. Multiplex plates are sold in sizes of about 1x2 meters, in various thicknesses. They are not available in all countries.

Processing

Wood can be machined with both hand and motor driven tools. Small simple carpenter shops can be found even in remote areas, because the required hand tools are relatively cheap. (See fig.5.)

Fig.5. Hand tools for woodprocessing




Before processing the wood it has to dry a couple of months; if not it does not keep its shape afterwards. Note that usually, the local carpenter workshops are of a very low technical and organizational level, and they are not able to produce pumps without very intensive assistance. Besides, if the pump contains steel parts, these can not be processed by the local carpenter.

Wooden pumps

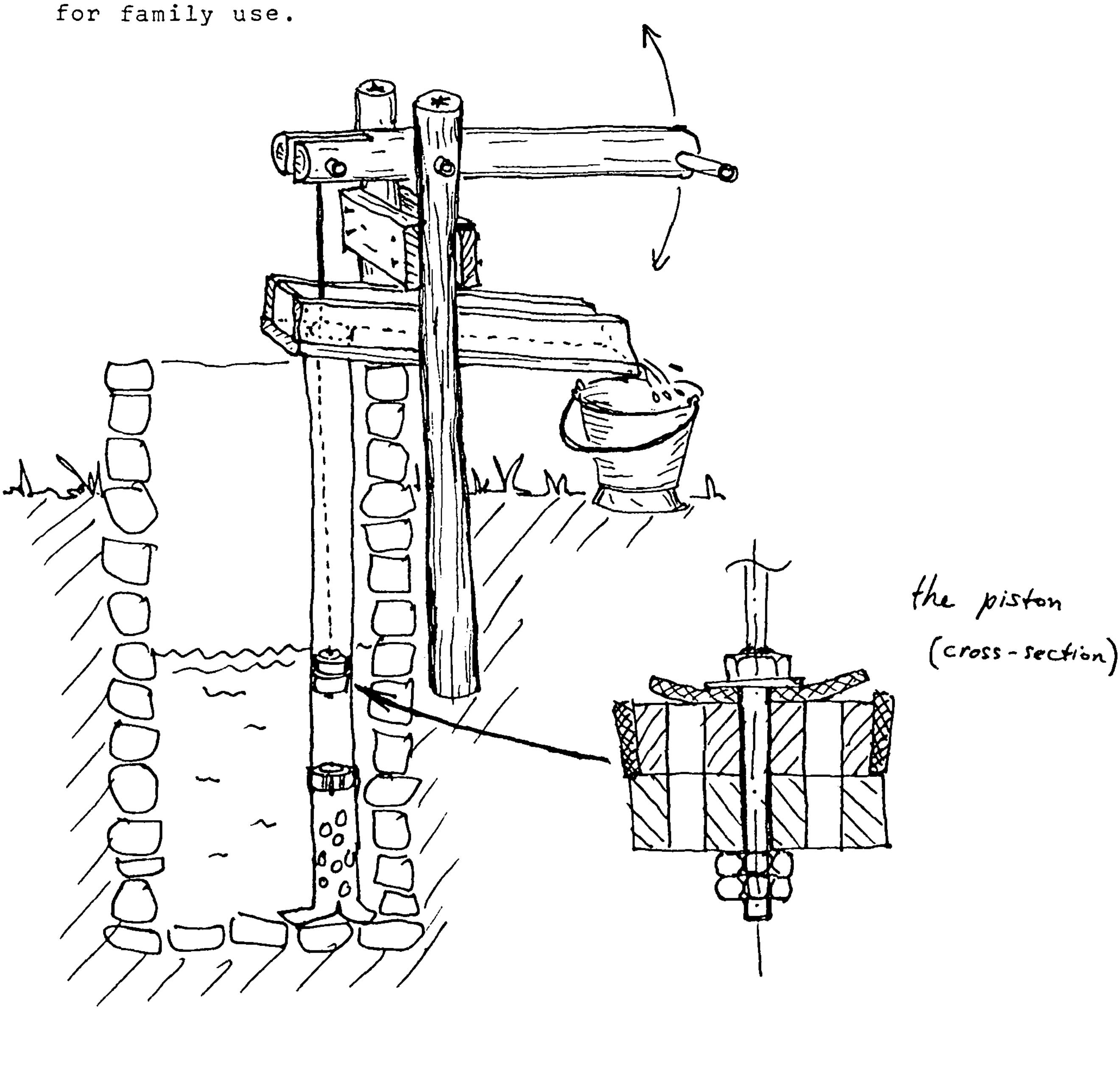
Wood is very suitable for the pump handle and its support, and can be used also for the pump rod, the spout, the piston and the valve seats. It is not a suitable material for the cilinder, the rising main, or the bearing pins.
Wooden pumps do not resist vandalism very well. Especially when the pump is out of order its wooden parts are often stolen for fire wood. Repair and maintenance will be required more frequent than steel pumps do, but simple to carry out. Wooden pumps are especially suitable for family or small community water supply, where the social control is high and where the maintenance and repair are carried out bij the users themselves.

An example of a wooden pump is the Ayaviri pump. An overall view is presented in Fig. 6. It has an open top so its water is not very well protected from contamination, and stones thrown in can damage the piston. It is therefore restricted to family-use. It has a high yield (~ $1\frac{1}{2}$ l/stroke) so it is well suited to irrigation.

The production plan

Its drawings can be obtained from WOT (II.3.). They include a list of materials. The prototype construction will take one or two weeks.

Fig. 6. The Ayaviri pump, a wooden pump for family use.



As an example the fabrication programm is presented in fig. 7. Some seperate operations can be combined into a single one, for instance drilling the holes into the two discs of the pisten. The production time is calculated to be 119 operations/pump multiplied bij 0,15 hours/operation = 18 hours/pump, in series production. In practice (Ayaviri, Puno, Peru 1983) this proofed to be a good approximation. After some training the productivity was 2 man-days per pump.

Fig. 7. The fabrication programm for the Ayaviri pump.

| Part | Sequence of operations =) |
|---|---|
| 2 standposts | sa 2, dr 2, fi 2 |
| handle | sa 3, dr 3, ch 1, fi 1 |
| spout,stroke limits | sc 2, sa 6, dr 6, ch 1, fi 1, gl 3 |
| check valve | wa 1, sa 6, dr 7, fi 2, wa 1, fi 1 |
| wooden bushes | sa 2, dr 2, fi 2 |
| PVC inlet | sa 2, dr 10, he 1, be 1 |
| PVC raising main | fi 2 |
| 3 hinge pipes | sa 3, dr 1, fi 1 |
| 2 wooden piston discs | wa 1, sa 8, dr 7, fi 16 |
| 2 leather discs | cu 6 |
| leather cup seal | cu 1, bo |
| pump rod | sa 1, we 2 |

| | | | | | |
|---|---|---|---|---|---|
| =) sc | scrape, total | 2 | cu | cut | 7 |
| sa | saw | 33 | he | heat | 1 |
| dr | drill | 38 | be | bend | 1 |
| fi | file | 28 | bo | boil infat | 1 |
| ch | chisel | 2 | | | |
| wa | moisten in water | 3 | | | |
| gl | glue | 3 | | | + |
| | | | Total no. | | 119 |

Note: we (welding), 3, is done elsewhere. Its building together is done during installation.

A year in Puno will count some 200 working days, and yearly some 200 pumps can be produced by a 2 man factory.
From the fabrication programm (Fig. 7.) the dominating operation sequence can be found, see fig 8.

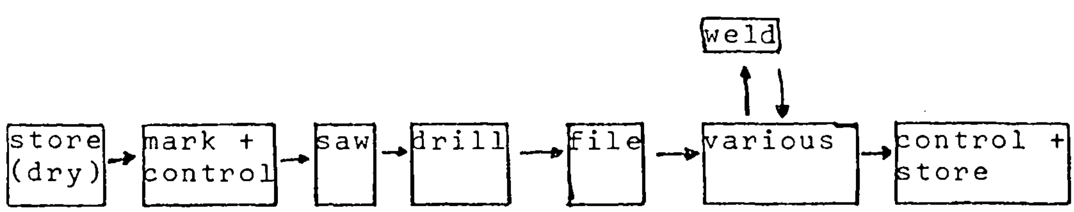



Fig. 8. The dominating operation sequence.

A convenient workshop lay-out is presented in fig. 9.

Note:
table I=sawing
scraping
drilling

table II:others

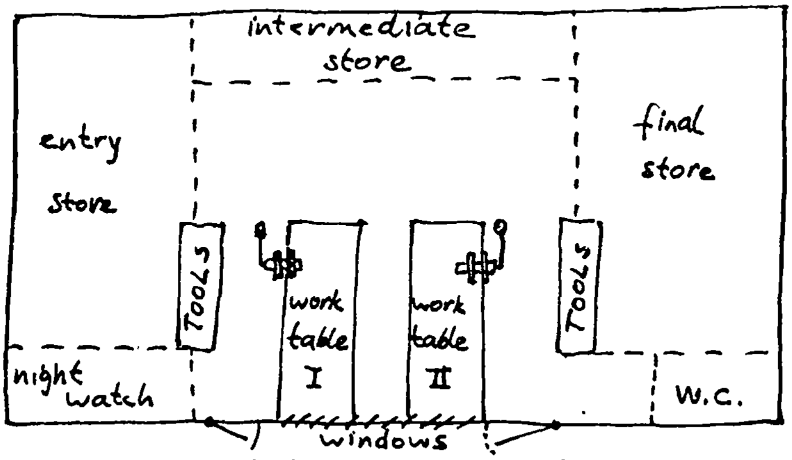


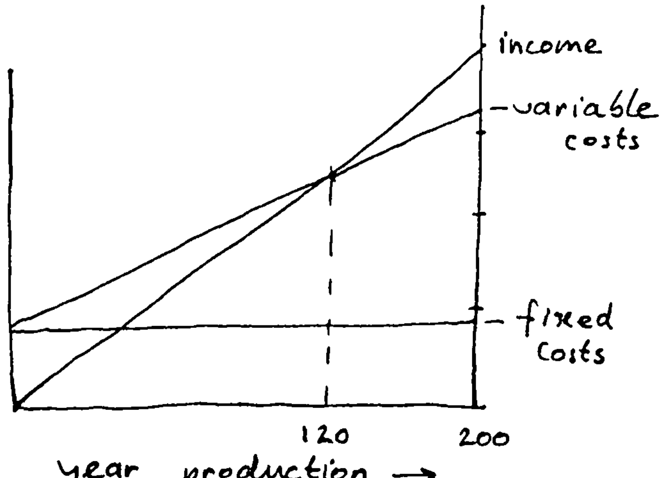

Fig. 9. Lay-out for the Ayaviri pump production workshop

The estimated production costs are:

| | | |
|---|---|---|
| - fixed cotst : | rent on investment | \$ 100 /yr |
| | depreciation of tools | \$ 800 |
| | wages: 200 days \$ 1½ and 200 days \$ 1 | \$ 600 |
| | various | \$ 300 + |
| | Total | \$ 1800 /yr |
| - variable costs : | materials (head=5m) | \$ 23/pump |
| | tool bits and energy | \$ 2 + |
| | Total | \$ 25/pump |

Fig. 10. shows the break-even diagramm (pump price is \$ 40.)

Fig. 10. break-even diagramm for the Ayaviri pump production, if its price is \$ 40.



The break-even-point is 120 pumps a year. Note that the here presented numbers and costs are an approximation only; their exact value depends on the local circumstances.

## V. 2. Pipe components

"Pipe components" means all kinds of sockets, elbows, nippels, etc., that can be coupled to pipes. They have threaded ends to allow an easy connexion to a next component or pipe piece.

### Availability

Pipe components can usually be found in the larger cities in most developing countries, either imported or locally made, usually from cast iron. They are rather expensive: from one or two dollars for the simpler and smaller ones up to tenths of dollars for the larger and more complex ones.

### Characteristics

The main advantage of this kind of parts is the fast and easy coupling and discoupling. The cast iron can be machined like other metals; note that cast iron can only be welded with special electrodes and that the weld will still be very weak. Steel components (nipples for instance are often from steel) don't have this problem. (For the corrosion properties see 'steel and other metals', 'Cast iron')

### "Raw material"

Pipe components are commercially available in standard inch measures like $\frac{1}{2}$", $\frac{3}{4}$", 1", $1\frac{1}{4}$", $1\frac{1}{2}$", 2", etc. =)
Locally produced pipes and components may vary from their nominal measure which may cause problems in their further application. If for instance a too large inner diameter pipe end is threaded, it looses so much of its wall thickness that it is weakened severely. Examples of common component types are presented in Fig. 11.

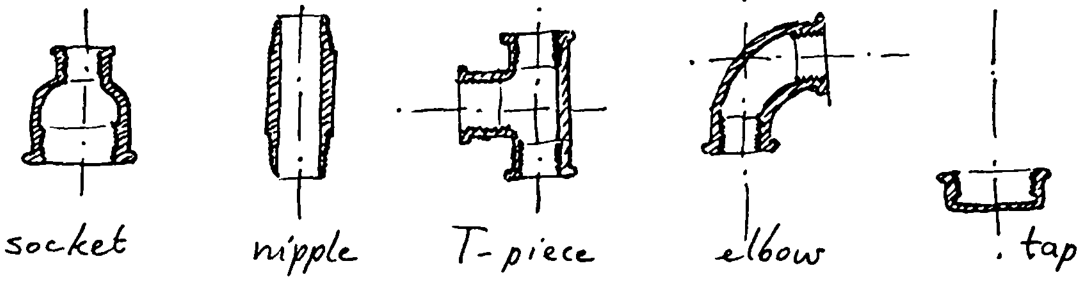



Fig. 11 common pipe components

=) The inch indication resembles the inner diameter of the belonging pipe piece.

The ends may be threaded on the inside or on the outside ("female" and "male").

Processing

Pipe ends are threaded with a cutting device or a lathe-machine. The components are connected with a stilson wrench (see fig. 12b.) For a watertight connexion between the components, so called "teflon tape" is applied, or paint with hennep.

Pipe-component pumps

The pumps are easily installed but parts are easily stolen as well.

Fig. 12. Tools for pipe components

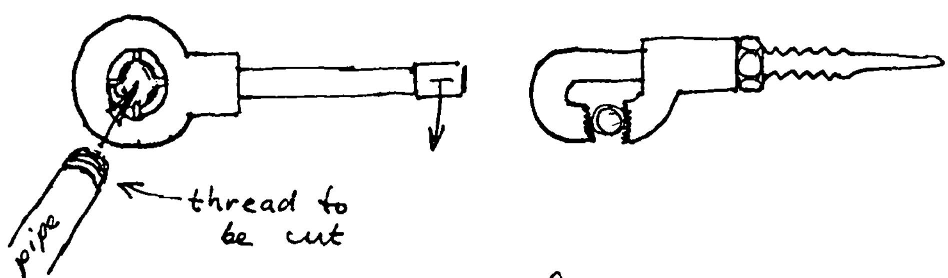
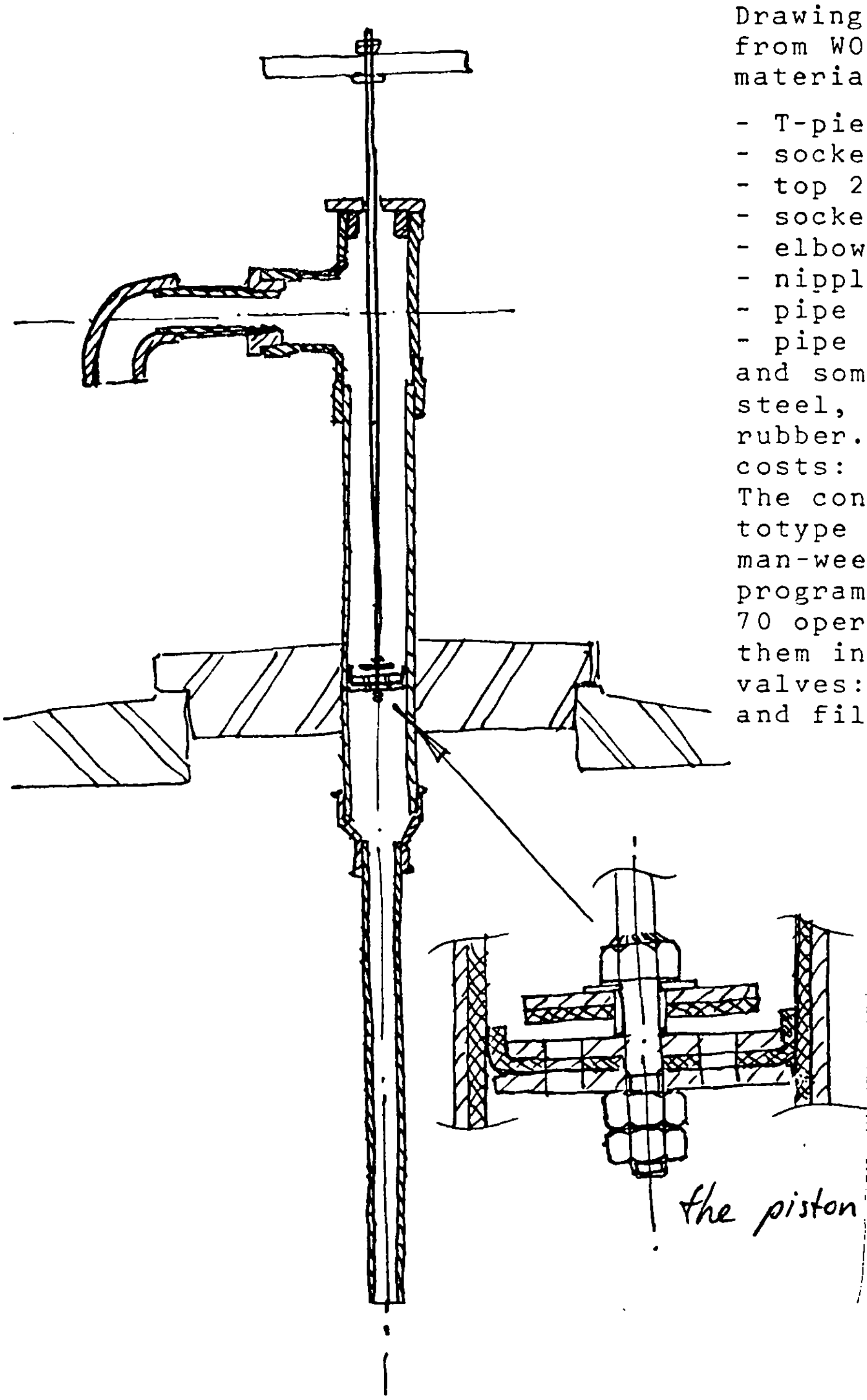



fig.12a thread cutting device

fig.12b stilson wrench

A steel or cast iron pipe piece is not suitable as a cilinder because its surface, even after polishing, remains too rough. A piece of PVC tube should be installed as a cilinder lining. Pipe components are especially suitable for use in the spout outlet, and in the raising main and cilinder connexions.

An example of a pump from pipe components is the (unnamed) one in fig. 13. It is a suction pump, without a handle. It has a relatively low yield ( 0,3 liter/stroke) and its use is restricted to shallow wells ( 6m head). The water is well protected from contamination, and children cannot throw stones in. It is suitable for small communities. It is not very corrosion resistant (see "steel and other metals"+"cast iron")




The production plan.

Drawings can be obtained from WOT (II.3.). The material list consists of:

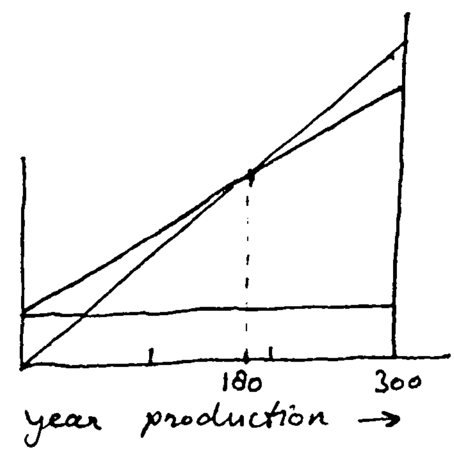
- T-piese 2" female
- socket 2"-1" female
- top 2" male
- socket 2" male- 1" female
- elbow 1" female
- nipple 1"-1" male
- pipe piece 2"
- pipe piece 1"

and some small pieces of steel, PVC, leather and rubber. Total material costs: about $ 40.
The construction of a prototype will cost about one man-week. The fabrication programm consists of some 70 operations, most of them in the piston and the valves: sawing, drilling and filing these parts.

An expensive operation is the threadening of the two inch pipe piece. When producing in series, a lathe machine for this operation only will not pay off, so the threadening should be done outdoors.

The approximated production time in series production is 70 operations x 0,15 hours/operation ≅ 10,5 hours per pump, ≅ 1½ man-day. A two man workshop, with 200 effective working days a year, can produce some 300 pumps yearly. The dominating operation sequence, the workshop lay-out and the fixed costs will be like those of the Ayaviri pump. The variable costs are estimated to be ≈ $ 45/pump. With a pump price of $ 55 the break even diagramm is as shown in fig. 14. The break-even production is 180 pumps a year.

Fig. 14. The break-even diagramm for the pipe component pump as shown in fig. 13.




It should be noted that instead of the threaded connexions welded connexions could be used. The advantage of fast mounting and dismounting would be lost, but the costs would dropp.

## V. 3. Steel and other metals.

### 3.a. Steel.

Availability.

~~Apart from steel factories in the developed world,~~ Many developing countries have their own steel plants nowadays.
In all other countries, steel parts are regularly imported, and the most common forms and sizes are available from stock.
Ordinary construction steel prices vary between U.S. $ 0,5 and 1,5/kg.

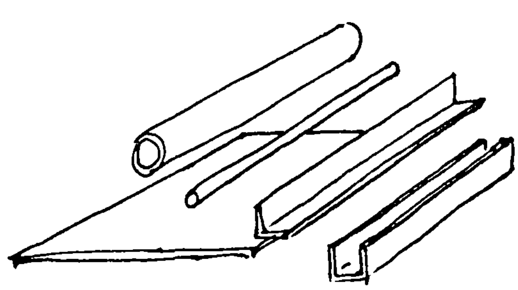
Characterictics

Steel is a relatively strong material, i.e. it is highly resistant against tension, compression and bendig forces, the load being either constant or varying. It is heavy: 7,8 kg/dm$^3$. It can be plastically deformed, especially when heated. Most steel varieties are subject to corrosion. Special types of steel exist, that are better corrosion resistant or stronger than ordinary construction steel. These types are more expensive and more difficult to machine, and in many countries they are not available (see 3b).

The raw material

The raw material is usually commercially available in many sizes of plates, pipes and profiles like angular ones, round ones, etc. (see fig. 15.)

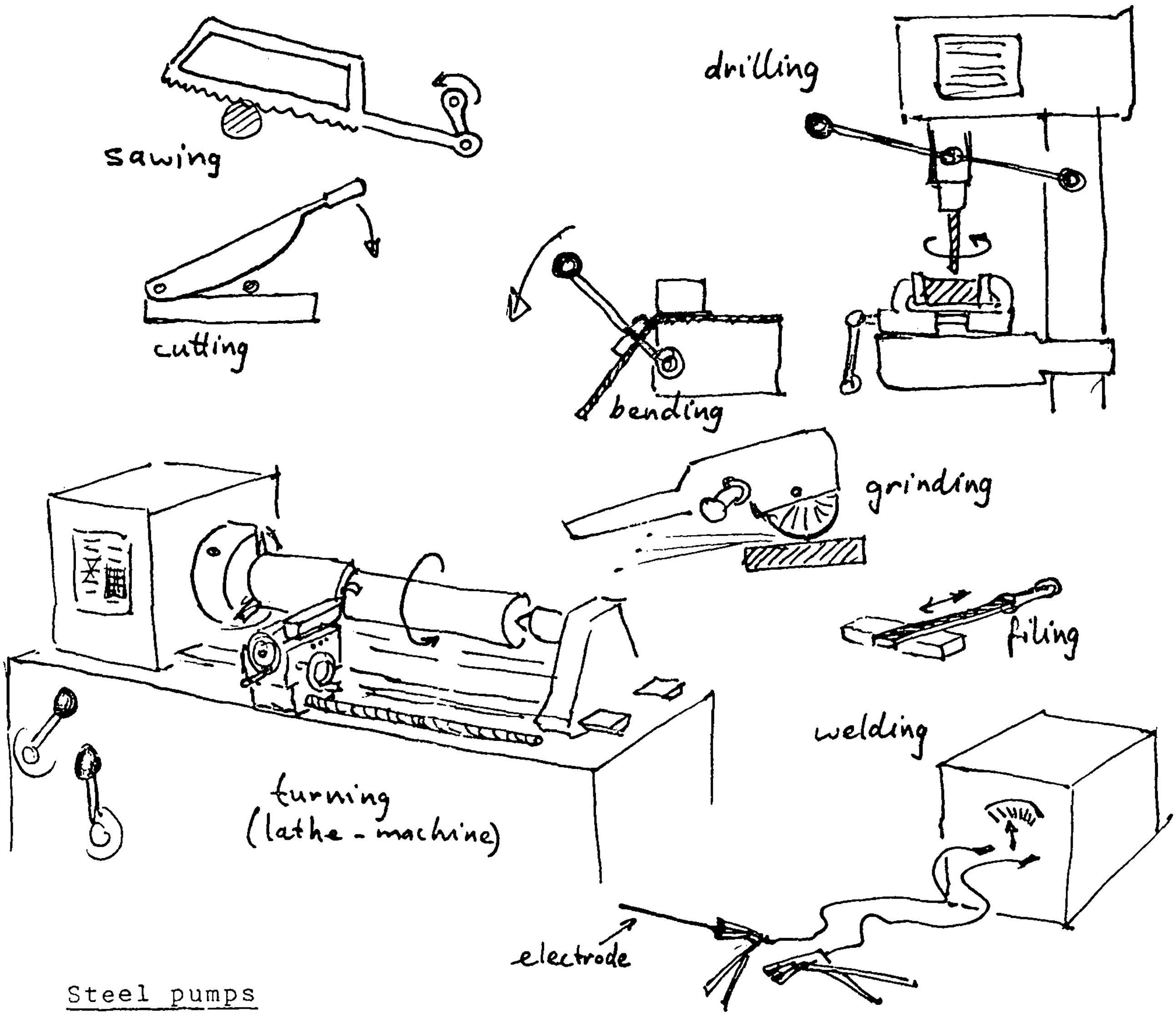
Fig. 15. commercially available forms of steel.



Processing

The most common operations are sawing, cutting, bending, drilling, turning, filing, grinding, welding and threadening, and in larger machine shops fraising and various kinds of cold deformation. (see fig. 16.) These variety of processing possibilities allows a flexible construction design.

Fig. 16. Some common workshop machines




## Steel pumps

These pumps are usually suitable for intensive use and rough treatment, and the water is well protected against contamination. When the water is aggressive, corrosion becomes a problem. The most important characteristic that determines the aggressiveness of the ground water is its P.H.-value, a measure of its acidity. Usually, if the P.H.-value is over 7 normal anticorrosive paint will do. For P.H.-values between 6 and 7, steel parts are galvanised (that is: covered with zinc). For lower P.H.-values ordinary steel is not recommanded, especially not for those parts down the well. Steel is a suitable material for the pump body, the handle, the rising main, the pump rod, the piston, the valves, and the cilinder.

It is defenitely not suited for bearing bushes, nor for the cilinder lining. The repair of steel pumps may be a difficult job for low skilled labourers. Often, the pump will have to be dismounted and repaired in the production workshop, instead of in the field.

3.b. Other metals

For some parts, other metals are also used:

1) Bronze and other copper alloys are used for the bearing bushes and for the cilinder linig. It is important to make sure that the selected alloy is a true bearing material if used for the bushes, and that it is well corrosion resistant if used for the cilinder lining. Prices vary about $ 3/kg.

2) Alluminium alloys are applied for castings for instance for the piston assembly. Its corrosion properties are better than cast irons and its volume-price is between bronze and steel.

3) Stainless steel is used for parts down the well in case of aggressive ground water. Prices: over $ 10/kg.

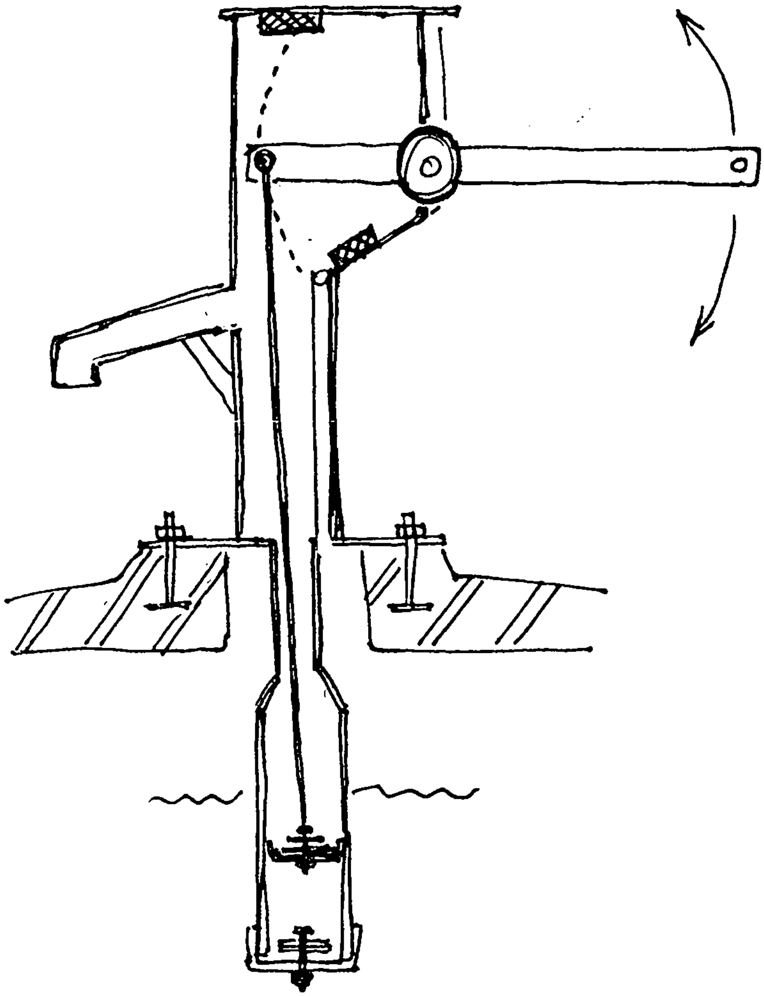
4) Special steel alloys are used for the production of ball bearings. These are especially recommanded as hinge points for intensively used pumps.

Example of a steel pump

The majority of the commercially available pumps are made from steel, for instance the "India mark II", that has been produced in large quantities in India, and the strong "SWN" =), a Dutch product, recently adopted by Unicef for installation in Afrika, and many others.
For local production in a small, simple workshop, the Puno-pump is recommanded. (See fig. 17.). The list of materials consist of steel parts like $1\frac{1}{4}$" pipe, 1/8" and $\frac{1}{4}$" plate, 3/8" rod, and some pieces of rubber and leather, 3" PVC waste water pipe and 3 bronze bearing bushes. Total costs about $ 70. The construction of a prototype takes some 15 man-days. The fabrication programm shows cutting operations, sawing, bending, drilling, turning, threadening and welding, and some operations with hand tools. The total amount is $\simeq$ 150 operations. The fabrications in series will take 150 operations x 0,15 hours/operations = 22,5 hours/pump. The most expensive machines are a lathe machine, a column-drilling-machine and welding equipment. In order to have sufficient work load for the welding equipment and the lathe machine, the minimum number of labourers is four, one of them being continuously engaged by the welding and one almost continuously by turning.

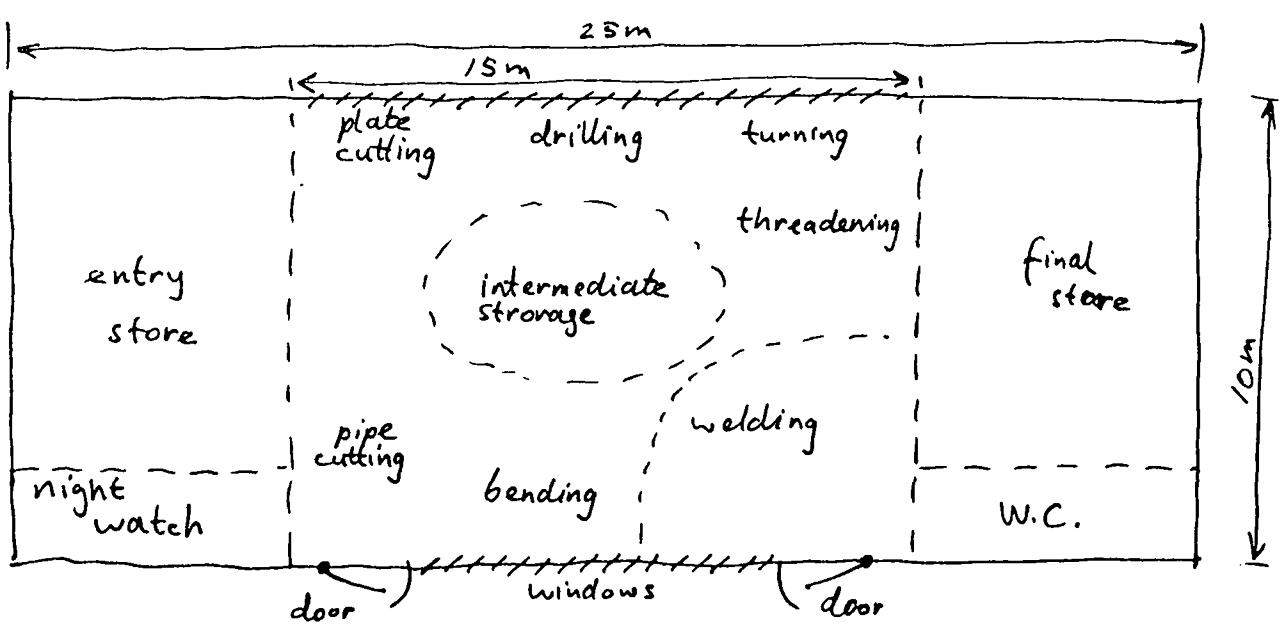
=) (I.2.)

Fig. 17. The Puno pump



A suitable lay out is presented in Fig. 18.

Fig. 18. A convenient lay-out for the production of the Puno pump.



With four labourers the year production will be some 285 pumps. The total of fixed costs will be some $ 30000 /yr. the variable costs some $ 80/pump. The pump price will be some $ 225. Prices of steel pumps vary considerably, the majority being between $ 100 and $ 800 (see I.1.).

## V.4. Cast Iron

### Availability

Cast iron foundries can be found in most cities in developing countries, since they do not require such high investments as steel plants do. Prices of cast iron products vary considerably, especially with the number of identical parts produced and with the amount of machining that is required after the casting in order to obtain more precise dimensions.

### Characteristics

Cast iron is hard and strong, though not as strong as steel. Besides it has little resistance against shock loads. Its corrosion properties are slightly better than those of steel, and so is its suitability as a bearing material. Like steel, it is not used as a cilinder linig because its surface, even when polished, can never match the smoothness of for instance PVC. The casting process is especially suitable for production in large series (hundreds or thousands monthly).

### The raw material

The raw material for cast iron is a mixture of so called pig iron (that comes from a steel factory) and scrap.
Besides, the production requires materials for the patterns (models of the parts to be made), sand for the moulds and clay for the cores, and cokes and limestone for the furnace. The fabrication includes the next steps:

1) Pattern making.

   For each part, a wooden, cast iron or alluminium model is made, scale 1:1.

2) The pattern is pressed into a container with especially prepared sand, in such a way that a negative is formed, the so called mould. Usually two moulds are made for each part, an upper one and a lower one. To make a hole in the part, a core is placed inside the mould, see fig. 19.

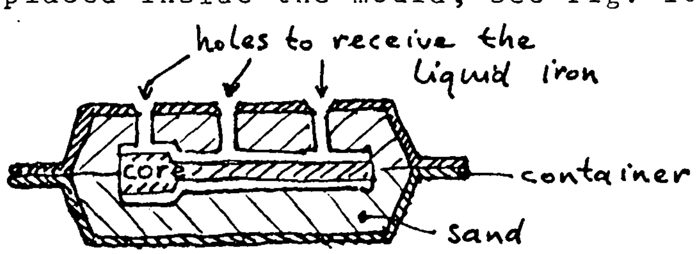



Fig. 19. mould and core

3) In a special furnace the raw material is heated until it melts. The liquid iron is poured into the moulds, where it is allowed to cool during 5 to 10 hours.

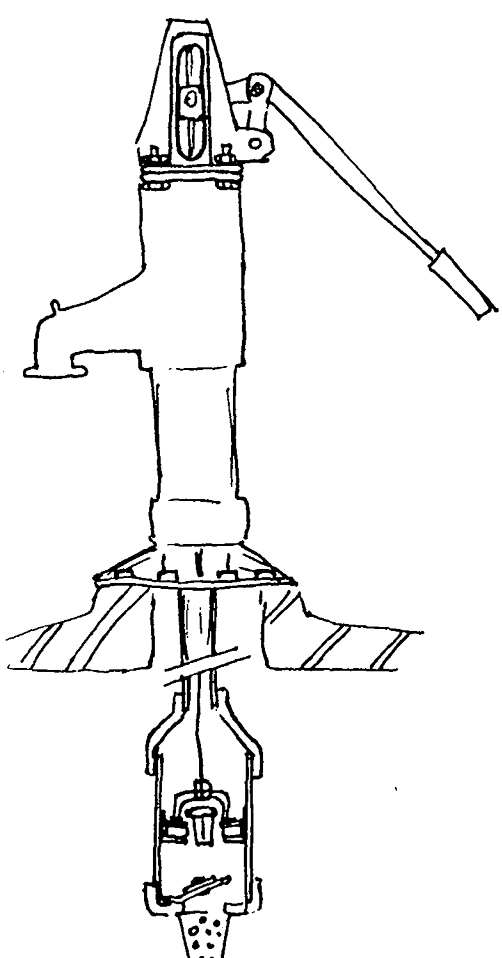
4) The casting are removed from the moulds in order to be inspected and cleaned and the cores are taken away.

5) Next, the castings are machined at those places that require more precise dimensions. Cast iron can be machined like steel except for welding. A weld in cast iron will be weak and brittle.

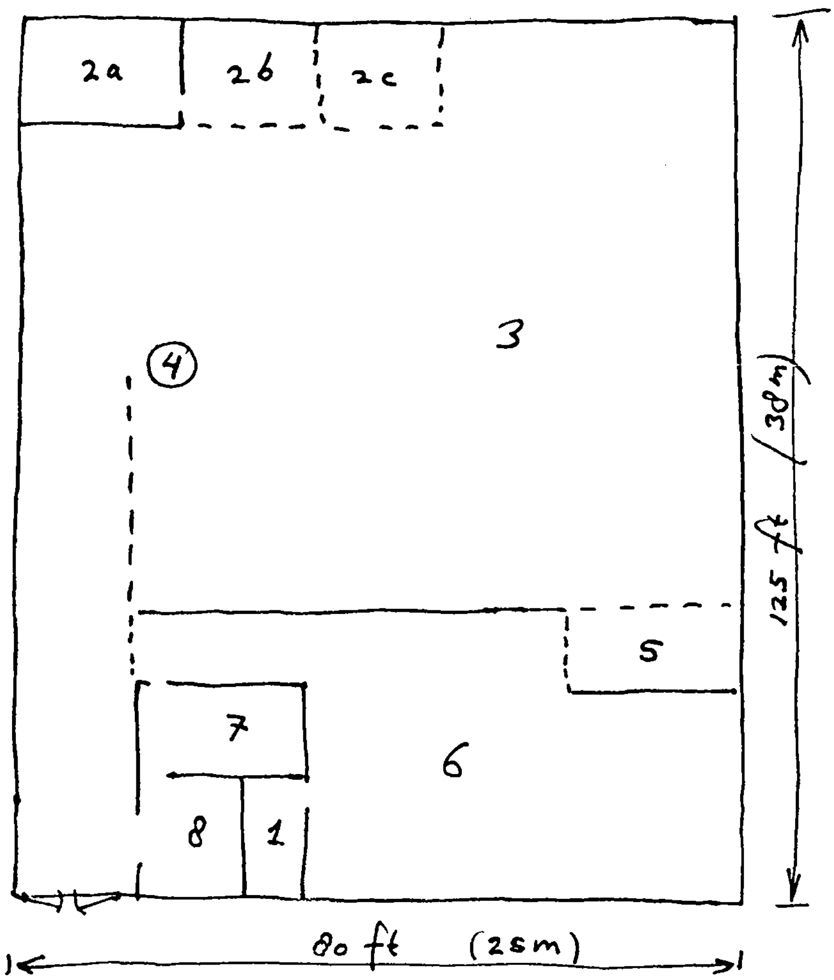
Cast iron pumps are suitable for village water supply though they don't withstand vandalism or rough threatment (playing children) as most steel pumps do, and repairs may be a bit more frequent. In order to improve their durability, many cast iron pumps have steel handles. In the cilinder, a bronze or PVC lining is usually inserted. The advantage of cast iron pumps lies in their low price ( ≃ $ 100) and relatively easy mass production process.

An example of a cast iron village pump is the "AID" pump, see fig. 20. The presented version is a deep well pump. The water is well protected from contamination. Pumps like this are produced in many countries, like Indonesia, Bangladesh, Honduras, etc. It is worth noting that the pump price in the Asian countries lies a bit lower than in the Central American ones, in all varying between $ 50 and $ 150.

Fig. 20 The "AID" pump



The pumps drawings can be obtained from U.S. AID, to be contacted via the local Embassy. The materials required include some 35 kg of pig iron and scrap per pump. Besides, there are the materials for those parts not made from cast iron, like the pump rod, bolts and nuts, etc. The fabrication programm consists of the steps 1-5 as described on page 22. However, productivity data as presented for small machine shops are not available for foundries. Karim c.s. (I.3.) describe a foundry in Bangladesh producing ≈ 1600-2000 pumps monthly, at a rate of 8-10 pouring days per month, that (according to Karim) could be increased to ~3000 pumps/month. The foundry lay-out is presented in fig. 21.




| | | | |
|---|---|---|---|
| 1 | pattern shop | 4 | melting |
| 2a | core room | 5 | cleaning |
| 2b | core making | 6 | machining |
| 2c | sand preparation | 7 | store |
| 3 | moulding | 8 | office |

Fig. 21. Foundry lay-out for the production of max. ~ 3000 pumps monthly (Karim)

## V. 5. Plastic

### Availability

Plastic is the common denominator of an enormeous amount of artificially made materials, their characteristics varying over a wide range. Most common are PVC (Polyvinylchloride) and PE (Polyethyleen), widely used for waterpipes, plastic bags, etc. These two types are made locally in many developing countries. They cost some $ 3/kg. Other types may be more expensive ($ 30/kg or more).

### Characteristics

Most types are highly corrosion resistant, also in aggressive surroundings. Their specific weight is relatively low (1,00-1,4 kg/dm$^3$). Strength and elasticity vary but are usually more like wood than like steel.

### Raw material

Plastics are made from natural resources like coal, oil, gas, etc. and from these the plastic is composed by chemical industries, often in the form of "grains", small cilindrical parts, a couple of mm in size. These grains serve as a starting point for further processing, often "dye-casting". =) Not all plastics can be dye casted however, only those that are so called "thermoplastics".

### Processing

Dye-casting means that the grains are geated so they grow more or less liquid, like paint. Then the plastic is pressed into a mould, it cools, and becomes solid again. When producing pipes and laminates, etc., the process is carried out continuously, but for other products it is done part by part, like cast iron.

### Machinery

The process can only be carried out by specialised workshops that have the dye-casting machine and the know-how. For pump production, a higher quality plastic than the local industry provides may be necessary. Usually, the casting de not require further machining.

### Plastic pumps

Most pumps include some plastic parts; designs that are made exclusively in plastic do exist but are not widely used. For a number of parts plastics are suitable.

| | |
|---|---|
| raising main, pump rod | - PVC, PE, ABS |
| cilinder lining (or complete cilinder) piston assembly | - PVC, glass fiber reinforced composites, PE, ABS |

=) also called injection moulding.

| (part) | - | (plastic type) |
|---|---|---|
| bearing bushes | - | nylon, PTFE composites, .... |
| piston seal | - | PE, polyacetaal, neoprene, .... |
| valve seal | - | neoprene, polyurethane, .... |

This list is not exhaustive. Plastic parts are not very resistant to vandalism, and are therefore not much used as a material for the pump stand and the handle.

An example of a pump that has quite a lot of plastic in its design is the India mark II*) Its pumpstand and handle are made from steel but the rest is mainly plastic.
On the production of this pump, information can be obtained from the nearest Unicef agent or from IRC (see II. 1.). Its costs, in mass production in India are reported te be $ 65 without pumprod and raising main. Note that its costs will be considerably higher in countries with a higher price level, like South American countries. IRC has also information about pumps exclusively made from plastic.

*) Also the "Vulanta" and the "SWN"

## VI.-I Literature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I.2. "Shallow wells", DHV Consulting Engineers, Amersfoort, The Netherlands, '81

I.3. Karim, R, c.s. "Foundry Manual", Bangladesh Agricultural Development Corporation, Dhaha, Bangladesh, '82


## VI.-II. Adresses

II.1. "International Reference Centre for Community Water Supply and Sanitation"
Postbus 5500
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II.2. "Intermediate Technology Development Group"
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WC2E 8HW, ENGLAND

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7500 AE ENSCHEDE, The NETHERLANDS