The rope pump

The challenge of popular technology

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The rope pump:

The challenge of popular technology

Errata

Unfortunately, in the english edition of the book, some problems occured in the lay-out, especially in relation to the mathematical symbols and the indices. If you are just interested in the plain text, you should not encounter mayor problems. However, if you are interested en the details of the calculations and formulas, you will have to use this errata list. For the apendix F (Calculating pulley wheel and raising main diameters) and the list of symbols, the corrections needed were so numerous that I decided to present these paragraphs integrally.

As mentiones in the book, we remain interested in hearing any comments on the book, as well as your experiences with the rope pump.

Arnhem, december 1992
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- **Page 48** first paragraph line 2-3: "and of greater depth" should read: "even at greater depths".
- **Page 99** first paragraph line 5: "photo #" should read: "photo 16".
- **Page 110** and following: the terms "stabilizing rock" and stabilizing stone" are used indifferently: they are indeed interchangeable.
- **Page 124** last paragraph last line: "called" should read: "called ∂".
- **Page 127** figure 7.2: "valid for = 0.4 mm" should read: "valid for ∂ = 0.4 mm".
- **Page 128** figure 7.6: "valid for = 0.4 mm" should read: "valid for ∂ = 0.4 mm".
- **Page 130** line 3: "the 1/4" protection tube" should read: "the 3/4" protection tube".
- **Page 154** last paragraph line 3: "with a # 10" should read: "with a spanner 10".
- **Page 155** first paragraph line 2: "photos # and #" should read: "photos 23 and 24".
- **Page 155** first paragraph line 7: "# 10"should read: "spanner 10".
- **Page 210** figure A.9 line 3: "values: = 0.2 mm" should read: "values: ∂ = 0.2 mm".
- **Page 210** first paragraph line 5: "water up (+)" should read: "water up (↑ +)".
- **Page 210** first paragraph line 5: "water downwards (+)" should read: "water downwards (↓ +)".
- **Page 211** equation 4 should read:
  $(P_0 - P_2) = (P_0 - P_1) + (P_1 - P_2) = 0 \times g \times H_{pis}$ (N/m^2) (4)
- **Page 213** first paragraph line 6: Vpis 2 m/s y 0.65 mm., or Vpis 1.4 m/s and 1.1 mm." should read: "$V_{pis} \approx$ 2 m/s and $\partial \approx$ 0.65 mm, or $V_{pis} \approx$ 1.4 m/s and $\partial \approx$ 1.1 mm."

- **Page 213** paragraph 2 line 3: "(hyd, model/hyd, real)" should read: " "$\eta_{hyd, model}$ / $\eta_{hyd, real}$".
- **Page 213** paragraph 3 line 3: "-tub = 71 mm, - pis= 69 mm" should read: $\varnothing_{tub}$ = 71 mm, $\varnothing_{pis}$ = 69 mm".

Page 225 paragraph 2 line 6: "Oude Velperweg 506824 HE Arnhem" should read:
"Oude Velperweg 50
6824 HE Arnhem".

List of Symbols (page 217)

f	s^{-1}	Frecuency of axis revolutions	0.5 - 1
F_{handle}	N	Real force on pump handle	($F_{handle, teor}$ * η_{mec})
$F_{handle,teor}$	N	Force on pump handle if there were no friction	
g	m/s^2	Gravity acceleration	9.81
H_{head}	m	Pumping head	
H_{pis}	m	Distance between pistons	2 - 4
$\varnothing$	mm	Diameter	
$\varnothing_{handle}$	mm	Pump handle diameter	500
$\varnothing_{rope}$	mm	Rope diameter	5
$\varnothing_{pis}$	mm	Piston diameter	18 - 44
$\varnothing_{pul}$	mm	Pulley diameter	350 - 540
$\varnothing_{tub}$	mm	Raising main diameter	18.2 - 44.5
P_{in}	W	Input power, developed by user	30 - 150
P_{out}	W	Output power, resulting in pumped water	
Q_{drag}	m^3/s	Component of loss flow due to drag by piston	
Q_{loss}	m^3/s	Loss flow (= Q_{pres} - Q_{drag})	
Q_{pres}	m^3/s	Component of loss flow due to pressure	
Q_{real}	m^3/s	Real flow	
Q_{teor}	m^3/s	Theoretical flow	
V_{pis}	m/s	Piston speed	1 - 2
VOL_{rev}	Ltr	Theoretical volume per rotation	
∂	mm	Play between piston and tube (= $\varnothing_{tub}$ - $\varnothing_{pis}$)	0.2 - 1

η		Pump total efficiency ($= \eta_{hyd} * \eta_{mec}$)	
η_{hyd}		Hydraulic efficiency ($= Q_{real} / Q_{teor}$)	80 - 95%
η_{mec}		Mechanical efficiency, defined as loss factor due to friction ($= F_{handle, teor} / F_{handle}$	80 - 90%
Π	Pi		3.1416
o	Kg /m³	Specific weight of water	1,000
v	m²/s	Kinematic viscosity of water	$1 * 10^{-6}$

Appendix F
Calculating pulley and raising main diameters
(page 204)

In paragraph 7.2 we discussed the selection of the pulley and raising main diameters so that the demand of force and power be adjusted to the optical offer medium (defined by the ergonomic parameters of the users). In this appendix, we deepen the discussion of the calculations regarding this topic.

Four categories of parameters enter into play in these calculations:

- the ergonomic parameters;
- the invariable parameters;
- the variable factor that we cannot influence (the pumping head) and thus;
- the two variable parameters that we have at our disposition for optimizing the system: the pulley and raising main diameters.

The ergonomic parameters are fixed ranges that we cannot influence.

They are the following:

- $\varnothing_{handle}$	Pump wheel **handle** diameter (500 mm.)
- F_{handle}	Force on the pump handle, between 50 N and 120 N.
- P_{in}	Input power developed by user; varies from 40 W to 150 W.
-f	Frequency of axis revolution of the pump handle with a range of 0.7 - 1 revolution per second.

The **invariable parameters** that influence the calculation of forces are:

- g	Acceleration of gravity (9.81 m/s2)
- η_{mec}	Mechanical efficiency (estimated at 0.8)
- O_{rope}	Rope diameter (5 mm)
- Π	(3.1416)
-o	Specific weight of water (1,000 kg/m3)

The variable factor that we cannot influence but which does guide the selection of the diameters is:

- H_{head} Pumping head (m)

The two parameters that we can vary tooptimize the system are:

- $\varnothing_{pul}$ Effective diameter of the pulley (mm) and:
- $\varnothing_{tub}$ Real interior diameter of the raising main (mm)

In working with these formulas, we must respect the units used in this list. The formula that defines the torque on the pump handle is:

$$F_{handle} = 1/\eta_{mec} \times \frac{\varnothing_{pul}}{\varnothing_{handle}} \times \Pi/4 \times (O_{tub}^2 - O_{rope}^2) \times \varrho \times g \times H_{head} \quad (1)$$

This formula can be simplified by introducing two combined variables:

C	a constant (N/(m*Ltr)), and
VOL_{rev}	Volume per revolution (Ltr)

$$C = \frac{\rho \times g \times 10^{-3}}{\eta_{rope} \times \Pi \times O_{handle}} = 7.8 \qquad N/(m x Ltr)) \qquad (2)$$

$$VOL_{rev} = \emptyset_{pul} \times \Pi^2/4 \times (\emptyset_{tub}^2 - \emptyset_{rope}^2) \times 10^{-6} \qquad (Ltr) \qquad (3)$$

We note the the volume per revolution VOL_{rev} combines the only two variable parameters that define the force over the lever: O_{tub} and O_{pul}. In other words: the volume per revolution is a measure of the forces acting on the lever.

Now, we must take into consideration that the speed of the piston influences the hydraulic efficiency (see appendix G). The rotating frequency of the pump handle f assumed as optimum for the user in the range of 0.7 - 1 s-1 defines V_{pis} (speed of the piston), varying between 1 and 1.5 m/s, while the optimum speed estimated at 1.5 to 2 m/s. It thus implies attempting to maintain O_{pul} maximum (540 mm, which corresponds to a rim of 20"), and varying the diameter of the raising main O_{tub}.

Let's return to the calculations. Introducing C and VOL_{rev} (equations 2 and 3) in equation 1 gives us:

$$F_{handle} = VOL_{rev} \times C \times H_{head} \; (N) \qquad (4)$$

and also

$$P_{in} = F_{handle} \times O_{handle} \times \Pi \times f \; (W) \qquad (5)$$

With these formulas (4) and (5) we can calculate with ease the torque on the pump handle and the input power required in the different cases. Figure A.8 (not included in this errata, see book) gives the force on the pump handle as a function of the pumping head, for a range of five volumes per revolution used by the Region V DAR as reflected in Table A.3.

Table A.3: Recommended diameters of the pulley and raising main depending on the pumping head (The ranges in bold are the most common).

Range of pumping heads (m)	0-6	0-10	10-20	20-30	30-40
Tire for pulley (")	20	20	20	20	12
Raising main (")	1 1/2"	1"	3/4"	1/2"	1/2"
Pulley diameter Øpul (mm)	540	540	540	540	350
Raising main diameter Øtub (mm)	44.5	30.4	23.3	18.2	18.2
Volume per revolution VOL_{rev} (Ltr)	2.6	1.2	0.7	0.4	0.25

As we have defined VOL_{rev}, we can take advantage of this entity to easily calculate the flow Q_{real}:

$$Q_{real} = \eta_{hyd} \times VOL_{rev} \times f \text{ (Ltr/s)} \quad (6)$$

With the calculation method presented in this appendix, the force on the pump handle F_{handle} and the entry power P_{in}, can be easily calculated and thus the optimum values for the raising main $\varnothing_{tub}$ and the pulley diameter $\varnothing_{pul}$ may also be determined. We can also see how to calculate the pump flow Q_{real}.

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We would appreciate it if copies of any material using part of this book could be sent to us at the following address:

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The challenge of popular technology

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participated in this book's production, as well as all of those who offered information, suggestions, criticisms, corrections and photos.

The development and distribution of the rope pump in Nicaragua has taken many years, with various organizations and many people participating in the process. The combination of these efforts has made the rope pump what it is today.

Although it fell to me to gather all the experiences and reflect them in this book, I in no way claim to be the "author" of the pump. On the contrary ...

I therefore dedicate this book to all those who contributed and continue contributing in their own way and anonymously:

to the children who treat the pump like a toy and thereby submit it to excellent tests of force;

to the mothers, who as the primary users make comments, criticisms and suggestions coming out of daily use;

to the innovators who continually change components and add accessories to their own pump;

to the promoters and installers who share all of the "quirks" of installation in any kind of well;

and finally to the technicians, students and engineers who with their calculations, models and designs contribute towards a better understanding of this technology.

I hope that this book will be one more step in the development and distribution process of this fabulous popular technology that is the rope pump.

Juigalpa, November 25, 1991
Bernard van Hemert

Summary

The initiatives of many people and institutions have developed and promoted the rope pump in Nicaragua over the last eight years. The initiatives include different concepts, designs and approaches. Development has been primarily directed towards the drinking water supply from hand–dug wells with depths from 5 to 30 meters.

The development and implementation of the pumps has been within the concepts of "appropriate technology:"
–all implementation activity begins with a felt need by the beneficiaries; this also influenced the pump's design;
–to impact health, it is considered more important to guarantee large quantities of water in a decentralized form than relatively small quantities in centralized wells, although this can have a negative impact on water quality control;
–self–sufficiency in materials and knowledge both at the national level and at the user level when possible;
–certain social control over the pump is necessary, but this is not considered a limitation; rather it guarantees interest and care by the users;
–village level operation and management (VLOM);
–local production when possible; and at the least national production;
–a transfer of technology both to the producer and to the user to guarantee a foundation of technology in society and its continuous development, even without outside intervention.

1,500 pumps have been installed in total in both private and community wells under different implementation approaches:
–self–construction is considered a necessary phase in the pump's introduction for initial development and assimilation into the community;
–sales at both the artisan level and the semi–industrial level are responsible for the majority of installed pumps;

–institutional rural water supply and sanitation projects have developed and implemented the pump in excavated and drilled wells with good results.

The rope pump is inexpensive, efficient and simple. It has a high efficiency rate and pumps large quantities: from 2 liters per second at five meters to 0.3 liters per second at 40 meters. The pump is appropriate for intensive use: it can pump up to 32 barrels daily (8 m^3). But even more important than this data is the fact that the pump is easy to construct, operate and maintain.

One central characteristic of the rope pump is that it can be easily adapted to different types of construction: in Nicaragua we know of pumps made only of wood and rubber (materials cost: US$13) and of models using iron, injected polyethylene pieces andglazed ceramic (total cost: US$45). In terms of water quality protection, there is a theoretical possibility of contamination, but practical data thus far have demonstrated that contamination is no greater than in wells equipped with other pumps.

The pump can be adapted to different conditions: there are special models for drilled wells; to pump water above ground level (pump on a post) for large volumes (irrigation, cattle watering); and with movements for a motor or a simple windmill. The last two models are in the development phase, while the others can be used without any risk.

New research and development of the pump are not being carried out in a structured manner for lack of resources directed specifically to research, but it does take place in an ad–hoc manner. Research is currently concentrated on drilled pumps and on the special models already mentioned.

In addition to covering what has been mentioned above, the book details the design, construction, installation and maintenance of the pump, taking into account all the known options.

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Introduction

This book, just like the rope pump, is imperfect. And, just like the rope pump, it is too important to wait for its perfection.

We have just left the decade which took on the challenge to resolve at the very least the problem of water for human consumption, supposedly combining efforts of all the nations of the world with their technologies. But despite good intentions and million–dollar investments, the majority of the world's population continues to face an infant mortality rate and a series of illnesses which, if it had sufficient water available, would not exist in such quantities. Even more: in absolute numbers, there are more people who do not have access to basic water and sanitation services than at the beginning of the decade. The search for appropriate technologies continues to be an urgent challenge: available to all; inexpensive but efficient; easily built, operated and maintained.

Many individual and institutional initiatives over the last eight years have developed and promoted the rope pump in Nicaragua under different concepts, designs and implementation approaches as one alternative technology. Development has been primarily directed towards the drinking water supply from hand–dug wells from 5 to 20 meters. The pump has been so successful at the national level that we believe the moment has arrived to put the Nicaraguan experiences in writing. The initiative and the coordination of this book's production comes from the team of the Rural Aqueduct Directive (DAR) in Region V in Nicaragua. This team has been developing the rope pump for four years and has been implementing it in rural water supply and sanitation projects. Many more people and institutions, however, collaborated and gave their opinions on the content and form of the book.

Although the information presented covers different areas of interest and is directed towards different impact groups, we decided (for practical reasons) to edit it in a single book. It is likely that you will only be interested in one or two of the four parts of the book.

In the **first part** we deal with the pump **in general terms**; its history, its fundamentals and its characteristics. We also present the different implementation approaches and production aspects. The section is directed towards those with general interest; project managers, policy makers, but also for interested users.

The **second part** is primarily directed towards technicians and engineers, and deals with **construction** aspects. The pump is described piece by piece with its construction alternatives. Themechanical and hydraulic characteristics are discussed. If at times we go into a lot of detail, it is with the goal of being thorough, but for the great majority of the pump's applications the theory we present is not necessary.

The **third part** deals with practical and operating issues like the pump **installation** and **maintenance**, as well as problems which can arise in the field.

The **fourth part** finally describes the **special models** that have been developed in Nicaragua: pumps in drilled wells, those for high discharge rates, post–mounted pumps, pumps with motors and with windmills. We deal both with general aspects as well as some aspects of construction and installation.

We have tried to be as objective as possible, but in order to reflect some of the enthusiasm which motivates many of the people involved we have included a series of **interviews**. The language in the interviews is inevitably very "Nicaraguan", and it may be difficult to understand in other countries. We decided, however, to maintain the local flavor of the language.

Although this book contains all the information necessary for installers and users of the rope pump, it can probably not be directly understood by them. We recommend in many cases the development of a pamphlet explicitly directed towards them based on their educational levels, cultural customs, and in the specific characteristics of the pump in their region (ground water tables, well designs, available technologies and materials, etc.).

It is important to keep in mind while reading this book that there **is not just one type of rope pump**. In each region, in each situation the pump can have a different design or different materials. Nor **is there one implementation approach** for the rope pump. Each initiative has its philosophy and pursues its objectives. Although we try to focus on the essential characteristics that all rope pumps have in common and reflect the **different** concepts, designs and approachies, references will inevitably be defined by the Nicaraguan experience and conditions in general and DAR–Region V in particular. Therefore we don't discuss only the known alternatives with their advantages and disadvantages, we also try to present the logic that exists behind each option, so that the reader can decide which solution is the most appropriate for the specific case, or if there are conditions which favor other alternatives not covered here.

To conclude, it is important to emphasize that we in no way consider the rope pump a "finished product." We are aware that development continues, and we hope that this book—in a short time—will be outdated by other improvements in the pump and in implementation approachies. Perhaps you, reader, can contributeto this process...

We wish you enjoyable reading, and request that you send us not only your comments on the book but also your experiences with the rope pump. (See addresses at the end of the book.)

Bernard van Hemert
Jan Haemhouts
Osmundo Solís Orozco
Orlando Amador Galiz

1

The challenge of popular technology

**If you want to know what a wolf is capable of,
ask the sheep.
If you want to know what technology is capable of,
ask the poor.**

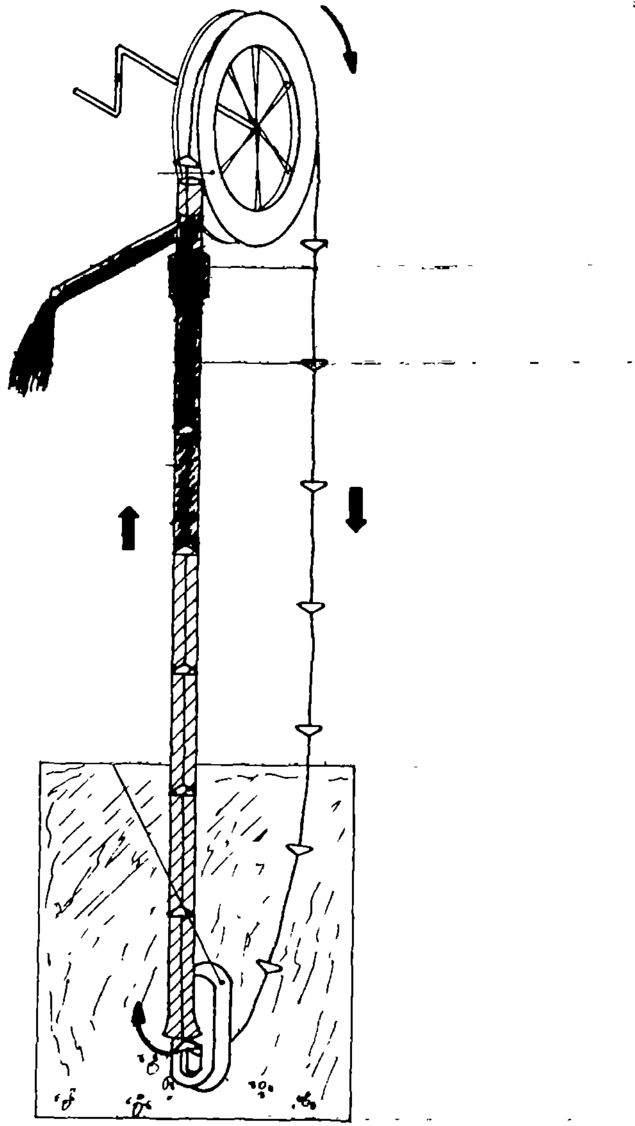


Figure 1.0: Global sketch of the rope pump

Chapter 1:
A developing technology

When discussing possible solutions to the problem of "underdevelopment" through cooperation programs, the deceptive image continues that these solutions can only be found in **following the example and imitating the history of industrialized countries**, based on the transfer of technology. The effects of implementation of technology, however, coincide with what those who develop the technology seek, but do not necessarily equally benefit the others. In certain cases the implementation of an outside technology can negatively affect the development of communities who have not participated in the formulation of that technology.

We have worked in Nicaragua based on these beliefs, developing and implementing the rope pump that we will now describe. Before describing the pump's implementation approaches in sections 1.2 to 1.4, we present in section 1.1 a concrete description of the pump.

1.1 General description

The rope pump is inexpensive, efficient and simple. Figure 1.1 demonstrates the pump set up. The heart of the pump is a never–ending **rope** with **pistons**. This rope is raised through a **raising main**, passes through a **pulley wheel** and falls free into the well. Under the water, a **guide** assures the smooth entrance of the rope and the pistons into the raising main.

Turning the pulley wheel makes the rope move. The pistons give minimum play in the raising main and suction the water up. You could say that the whole raising main serves as a long cylinder in which the pistons only move in one direction. When it gets to the top, the pumped water is diverted to the user's bucket.

The basic principle of the rope pump is that simple. In chapter 6 we describe the pump with all its details.

The rope pump is highly efficient and pumps great quantities: from 2 liters per second at a depth of 5 meters to 0.3 liters per second at a depth of 40 meters. The pump is appropriate for intensive use: it has pumped up to 32 barrels daily (8 m^3). Even more important than this data is the fact that the pump is easy to build, operate and maintain.

The pump can be adapted to different conditions: in the fourth part we describe special models for drilled wells, to pump water above ground level (pump on a post), for pumping large quantities (irrigation) and run by a motor or a simple windmill.

Now that we know more or less what a rope pump is and what it can do, we present a brief historical review and describe different implementation approachies currently in Nicaragua.

1.2 Some notes on the history of pumping technology.

This book does not aim to present the rope pump technology as something finished. On the contrary, it presents this alternative as one step in the generation of always more adequate solutions. In this sense we feel it is important to present some historic elements which help to see the logic and the limitations of the development of this technology.

Since the discovery long ago of water's influence on plant growth, to today, when man is able to program genetic changes in those same plants, the problem of controlling and bringing this vital liquid to necessary level has motivated a combination of the most varied experiences, abilities and knowledge over thousands of years.

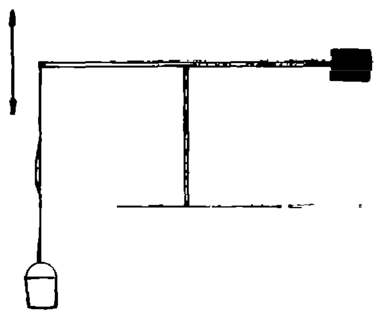


Figure 1.1: Shaduf

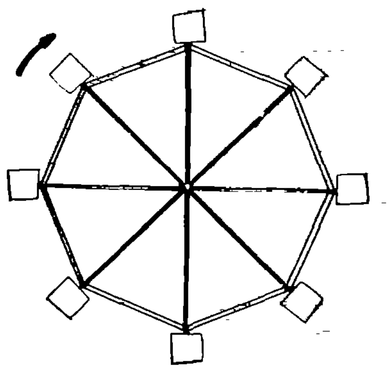


Figure 1.2: Noria

The first water pumping technique is considered to be the **shaduf**, developed some 3,500 years ago, and still used today. Figure 1.2 illustrates that the shaduf is like a lever supported by a post in the middle. On one end there is a recipient to hold water, and on the other a counterweight, equal to half the weight of the water and the recipient. This way the operator has to use the same force to raise the water as to lower the empty recipient. By dividing the required pumping between a series of shadufs, each one raising the water one level higher, water can be raised considerable heights with surprising efficiency.

The second basic step in this line of pumping technology is seen in the development of the **noria** (translated from Arab: "the whiner"—for the sound produced by the wood materials). This pump consisted in a series of recipients put around a wheel (figure 1.3), which can be considered a compound of a series of levers distributed over a single axle. The lower part is submerged in water. The wheel turns so that the recipients leave the water upright, staying full until they reach the top. As

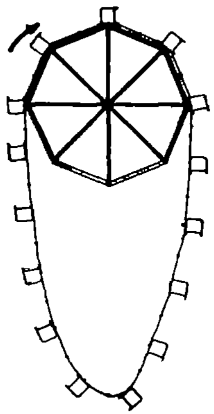


Figure 1.3:
Noria with chain

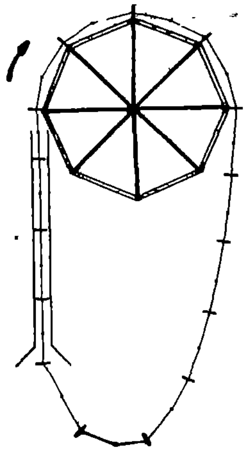


Figure 1.4:
Chain pump

they go down the water falls out into a receiving canal. Compared with the earlier system the noria has the great advantage of allowing continuous movement with no dead time. Just like the shaduf, the noria continues to be a common mode of water extraction for many communities, in particular combined with the tradition of animal traction.

The constructive logic is perfected with a variant of the same **noria, in which the wheel functions as a pulley which moves the recipients on a chain** (figure 1.4). Given that the height of the pumping no longer depends on the wheel's diameter but rather onthe length of the chain, the wheel's design is reduced to a pulley wheel which sustains the chain and transfers the motor force. This implies a major reduction in its diameter and the necessary materials, and increases the possibility of

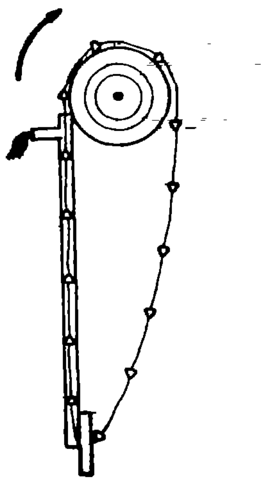


Figure 1.5:
Rope pump

Figure 1.6:
The next step?

pumping from narrower and deeper wells. As the wheel's diameter is reduced, the height between the position where the recipient begins and finishes emptying is also reduced. That is to say, there is less water lifted uselessly above the discharge level, which logically results in greater efficiency.

The next step in the noria's transformation was the substitution of the recipients on the chain by walls around the rising chain, with plates located within these walls, set at equal distances along the whole chain, making the noria into a **chain pump**. This description is similar to still existing models, like irrigation canal pumping, which moves large quantities of water at minimal heights. In this case the pump walls form a canal where the plates move along the chain. Two pulleys sustain the chain, with the upper one transferring the motor force to the chain.

The best–known and developed model of the chain pump, illustrated in figure 1.5, is made up of a tube instead of walls and discs or washers instead of "plates." In this form the chain pump had a huge impact from the 16th century to the 19th. In the middle of the last century one of various uses of these pumps was as emergency pumps in transatlantic ships, one application which indicates the level of efficiency and reliability.

With the emergence of large–scale industry, and therefore its preponderance over artesanal production, there was more selective development of technologies, logically in function of criteria which favored industry growth. The following are characteristics which promote large–scale industrial growth:
–**minimum weight and volume in relation to potential**, which is achieved using minimum force at high speeds.
–**standardization in production and universal use**, which permits centralized, massive and therefore inexpensive production.
–a certain **complexity and limited durability**, which limits massive plagiarism and maintains demand by avoiding market saturation.

The concept which most closely matches these criteria, among the broad array of existing pumps, is the **centrifugal pump**, based on the creation of centrifugal force, using blades on rotors turned by high–velocity motors. Despite relatively low efficiency, this allows high power transmission at very low volumes.

The concept of pumping with a chain actually contradicts the above–mentioned characteristics:
–it is relatively large and heavy, and uses great force at limited speed;
–it can be easily adapted to local craftsperson production;
–it is not as universal as the centrifugal pump, which automatically adapts volume to pumping height;
–it only raises water to the pulley level.

Clearly the chain pump cannot compete with industrial pumping equipment, and since it does not coincide with interests that directed development of industrialized countries, its application remained limited to those countries where it formed part of the cultural heritage and where craftsperson production still predominates.

With third world movements, which since the sixties have promoted a re–thinking of the concept of technological development promoted by industrialized countries, a process of rescue, experimentation and implementation of technology has begun which has as its first criteria social–economic utility. Given its high efficiency and its nature as craftsperson technology, the chain pump formed part of this technological regeneration, which is currently more commonly known as **"Appropriate Technology"** and in Latin America as **"Popular Technology."**

Old chain pump models were changed with the introduction of modern materials, at the same time overcoming limitations in the technology. Beginning in the seventies the pump became known according to different languages as the **bomba de cuerda; rope pump; pompe #a corde.** In Latin America the name was adapted to use the common words for rope; **mecate** in Nicaragua, **lazo** in Guatemala, **soga** in Peru, etc. The modernized version of the chain pump appeared in the majority of third world countries, but generally with little success. Its introduction in Nicaragua, on the contrary, initiated a dynamic process of creative alternative models which continues broadening.

1.3 The rope pump in Nicaragua.

The rope pump's history in Nicaragua demonstrates that those typically considered to be the agents of technology transfer as not as important in this process as is commonly believed. On the other hand it confirms the importance of social participation

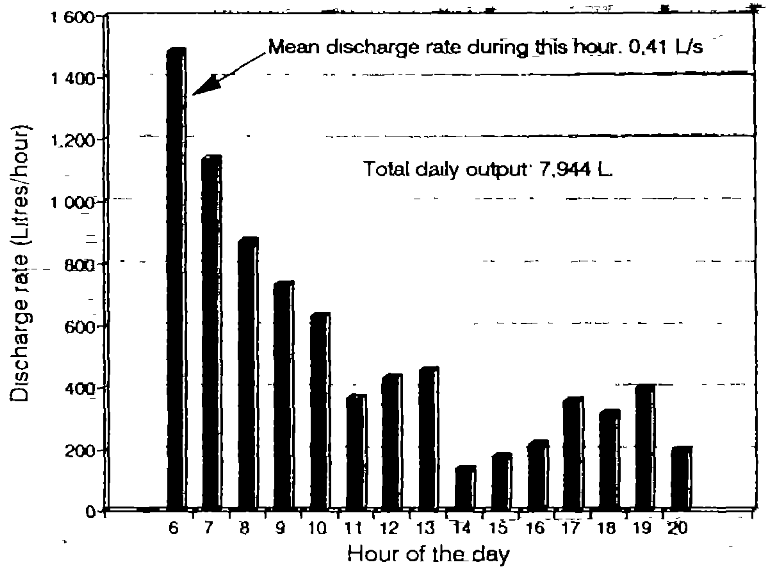


Figure 1.8:Hourly discharge rate en the "El Pochote" hand-drilled well.

both in the definition of criteria in the technological development process and in the actual processes of innovation and transfer. It also demonstrates the necessity of combining the process of transfer and generation at the community level with some sort of institutional support. Preliminary studies and experimentation accelerate the development and transfer of technology.

Rope pump technology was introduced for the first time in Nicaragua in 1983 in the Santa Cruz community (outside of Estel1), with the installation of a prototype in an 18–meter well. The pump was made at the Center for the Investigation of Appropriate Technology (CITA–INRA) of the Agrarian ReformMinistry. This version was based on previous experiences in Haiti, which were adapted to what was estimated to be the area's economical and technical level. There was no criteria developed about

Photo 2: Little girls working the pump
This pump is installed over a drilled well with a 35 meter pumping head. It yields 32 barrels (8 cubic meters) a day (El Pochote).

possible long term transfer and development, leaving the initiative to those who knew the area best; the local population.

In less than a month spontaneous self–construction and innovation projects began in the community. CITA's participation consisted of promoting the organization of the community into two collectives in order to satisfy the need for pumps in the community and to enrich the innovation process, encouraging interaction and solidarity among the peasant–inventors. There was also institutional support with the supply at cost of PVC tubes, the experimental distribution of prefabricated rubber pistons, and the training of peasant–inventors in theoretical aspects of technology.

Nemesio Porras Mendieta

What, in your opinion, might be the rope pump's formula for success?

"In analyzing its objectives, the uses it fulfills and its implications for the rural sector, there are direct and indirect benefits. As of now, the opinions regarding this point vary in the extreme; either overwhelming enthusiasm or attributing its achievements to the devil. The enthusiasts are clear about its popular nature: its revolutionary undertones as a result of the organization it requires; its promoting the participation of women, the resulting social changes, and the rejection of technological dependence. The detractors accuse it of demagoguery, of being populist and strengthening negative paternalism. And finally, the calmest of these maintain that it is economically impractical. One positive aspect of these discussions is that they have contributed to the distribution of the rope pumps."

"I think that it has had some technological success in the manner in which it was introduced, and I believe that it has promoted modernization, but not socio–economic development in terms of rural well–being, nutrition, community and national integration, and no notable changes stemming from its innovative style have come about. The pump, as with any other technology based on inanimate objects, does not have the ability to succeed or fail in and of itself. It requires the stimulus, support and enthusiasm of individuals to give it life. It has been demonstrated in practical terms that any form of rope pump construction is successful if itis accompanied by a program of self–generated organization within the communities."

"The success of the rope pump relies on the manner in which it is introduced into a marginalized community, with the only resource being the community's desire to participate within a group project, because the process must involve a program based on the community's social organization and self–management. The only methodology that results in the successful transfer of technology is that which takes into account the subjects of development, providing for their collective participation and unlimited creativity."

The introduction of glazed ceramic isolators in the wood guide was one of the most important results of this first phase of construction. This allows the least wear on the rope and the pistons, overcoming the pump's most obvious weakness. After about a year of pumping experience with various models and innovations, the user–innovators decided that **the rope pump is the most economical way to "get water out of a well, cheaper even than taking out water with rope and bucket."**

Although not all changes in the pump's construction by the peasants were improvements, it was very important to let the process develop at the community level. The usefulness of the pump was proved by the way in which the communities **appropriated the technology**, and slowly **initiated the transfer** towards a large part of northwestern Nicaragua, including the urban area.

This experience generated enough confidence at the institutional level to program a directed and massive transfer, supporting the community organization and education processes, promoting latent creativity and intellectual potential around a huge problem: water.

The first step was to produce a community–oriented flyer (Orozco, E. 1984), as well as to organize various training workshops for promoters from the central Rural Aqueduct Office (DAR) of INAA, as well as community representatives.

Despite CITA's efforts to bring INAA into the project, and the presence of several high–level staff members who were convinced of its importance, no significant advance was made. During the first years professional and institutional representatives, in contrast to the community acceptance, regarded the rope pump's technology with little interest. This resulted in an incongruency between the appearance of acceptance and an undeclared rejection.

Given the success of the rope pump at a seminar on low-cost water supply and sanitation technologies organized in 1987 by INAA–PAHO–UNICEF, a plan was developed to produce a series of pumps, considering the possibility of implementing the technology in popular neighborhoods in Managua.

Photo 3: One of the pioneers:
Don Pompilio with his wife and grandchild
The photo also shows one of the first pumps installed in Nicaragua. Against the left leg: a wooden guide and another guide with an porcelain insulator. Against the right leg: a wooden pulley (Santa Cruz).

Shortly afterwards preparations for pump production began near the capital, with sales/production coordinated with various popular organizations and the Delegate of the President. Priority was given to the project's social aspect. Production took place in the San José Industrial Cooperative with the support of a former CITA advisor.

Don Pompilio

How did you become familiar with the rope pump?

"When the rope pump first came to the CITA–INRA Center, many people were invited to come and learn about the project. There were many projects; with animals, with windmills. But what most attracted my attention was the little pump, it was the easiest to learn."

What conditions are necessary for the construction of this type of pump?

"There is the tube, the rope, the pistons which we might make one by one, but now that they are made in the factories in Managua, we use those instead If the client wants them made of old tires, then they are made of old tires, but if not, then we use the pistons made in Managua."
"This is what I say to the owner 'You are going to supply me with the wood, nails and rope I make nothing except the pulley wheel and the guide.' I tell him to get me a ceramic isolator in order to form the guide, so that the pistons work correctly and won't wear out To date I have constructed 290 pumps, that's all "

What procedures do you follow when they experience problems?

"I explain how to change the pistons and how they have to have the ropes and the pistons ready, how to make the transfer without taking out the tube. You just let it go loose, pull it in reverse and since it doesn't draw water that way, there is less effort in pulling "

Who else participates, or do you make the pumps by yourself?

"I explain to the pump owners that it is important that they pay attention when I install the pump But there are those that must go off to work, leaving behind only the women to help And the women are the more interested, perhaps because they have had to haul buckets with thousands of problems. So the women are the ones who are more interested "

Considering these materials, only the ropes should give you trouble. What about the guides?

"They function but it is not the same because I went about for three years working with that same foot valve which was already too worn out, it isn't the same as with that ceramic isolator You can make them of laurel which is a fine wood, always looking out for wood that lasts long under water. And I explain to themhow it's made in terms of cost, if the person is poor, we help them. If they have family members I explain to them too. If not, I put it together for free "

Do you think that someone with little knowledge, yet familiar with agriculture and cattle raising, could construct and install a pump simply by observing your pump?
"Many have brought pumps here but they couldn't install them. I have been installing the pumps for them They use 9mbaro wood for the guide, and many have used the lever from a plow guide, they tie up the tube and through it passes the rope, and they don't put on any weights. So there are problems. Someone who had read "Enlace" installed a pump but then came later to ask me questions. I suppose he got it installed because he said that if he couldn't do it, he would come get me, but he never came."

What can be said of the companies that install great numbers of pumps?

"For me it is very nice It's good for people who have cattle to have access to water But I do ask myself if these people are training the users of these pumps in case they get damaged. I explain to the people as I am installing: 'This goes here, and this goes there You'll put it together like this when it gets damaged' Who knows if they are explaining to the user so that the pumps won't break down."

Do your procedures work?
"I have had no rejections (of my methods), not a one What happens is, one has to control the little ones who might want to fool around with the equipment So I tell the children, 'No, no, children This is not here to be fooled with '"

Based on your experience, what are the merits of the other pumps?
"I don't like them. I have seen the kind they use to fill the water troughs for cattle. All of the system located down below is difficult to take out, and the water has a bad smell. The rope pumps are more hygienic, and there's nothing to rust. With the rope pump all you need is to have its rope and pistons ready, while with the other, one always has to be looking for the people that know how to install the system. The pistons don't have much life, and with so many people coming to get water, I don't know what kind of system it could use because it has no resistance. And when it stops working the people come, remove the covers and take out the water with buckets, because the system doesn't last long."

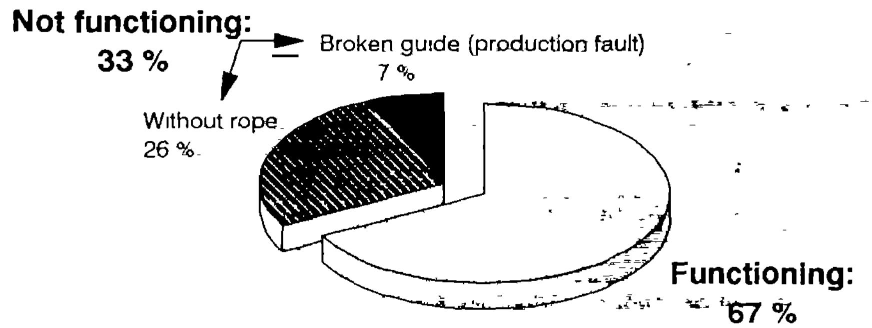


Figure 1.9: Condition of rope pumps installed in Bluefields. An evaluation of 88 rope pumps two years after emergency installations. Source: Sol1s, O., 1990.

The work included the development of various models, including the motorized pump and the double handle for drilled wells up to 70 meters; the serial production of ceramic guides using innovations from the Santa Cruz peasants; the current design of pistons and the organization of low–cost production.

After the disaster caused by Hurricane Joan, INAA decided to install 300 rope pumps in Bluefields as an emergency measure. This was the first large–scale implementation. Its emergency nature it created serious difficulties; technical problems given that the product was not well–tested, and lack of quality control and social problems because of lack of training and community participation. Even with these weaknesses, it is interesting to observe that an evaluative study carried out two years later indicated that **67% of the pumps visited were functioning** (even though there was no maintenance system). 26% of all the pumps were not working due only to problems with the rope, a minor repair. Users were generally content with the pump. Taking these circumstances into account, these results are very positive.

Bit by bit the National Engineering University (UNI) changed its policy. The UNI was sponsoring the project in collaboration with the San José Cooperative, and it prioritized commercial and academic aspects. The cooperative lost its role as protagonist, stopped producing and limited itself to selling its inventory.

In the same period in 1988, DAR–Region V decided to experiment with the rope pump in one of its institutional rural water supply and sanitation programs. The iron wheel was reinforced and embedded in a concrete slab to protect the well. The bearings and the blocking system were improved. After two years of limited implementation, positive results were seen and the rope pump was adopted as standard in all DAR–Region V projects. A sales system was also established, not only of rope pumps but also of construction materials for improvement of wells, latrines, floors, etc,. all in combination with technical assistance and sanitation education. A credit fund was established for groups without resources. In addition to these project activities, it was decided to promote the pump through a publication, a decision which was made a reality through this document.

As a product of the Bluefields and Region V experience, INAA decided to incorporate the rope pump in a broad study of low–cost rural sanitation technologies carried out by the Engineering University (UNI) in 1989. Although the study had interesting results, it did not go beyond the laboratory phase and had practically no relation with the countryside (See Ballesteros, M., 1991).

Given the great demand generated by the rope pump, in 1990 the "Rope Pump Society" was formed. This private initiative took on its business with great energy: traveling from fair to fair, using radio announcements, and covering the country in trucks full of pumps, looking for clients. They achieved a monthly sale rate of 50 to 60 pumps. The society is not only dedicated to sales, but also invests in pump improvements and in the development of special models, trying to monopolize on innovations.

There are also other projects promoting the rope pump, initiated by organizations like CEPAD, Bridges of Peace and COOPINIC. Although they do not currently produce great quantities, they accumulate experience and develop different implementation approaches.

For an idea of the number of pumps installed over the last ten years, see figure 1.10.

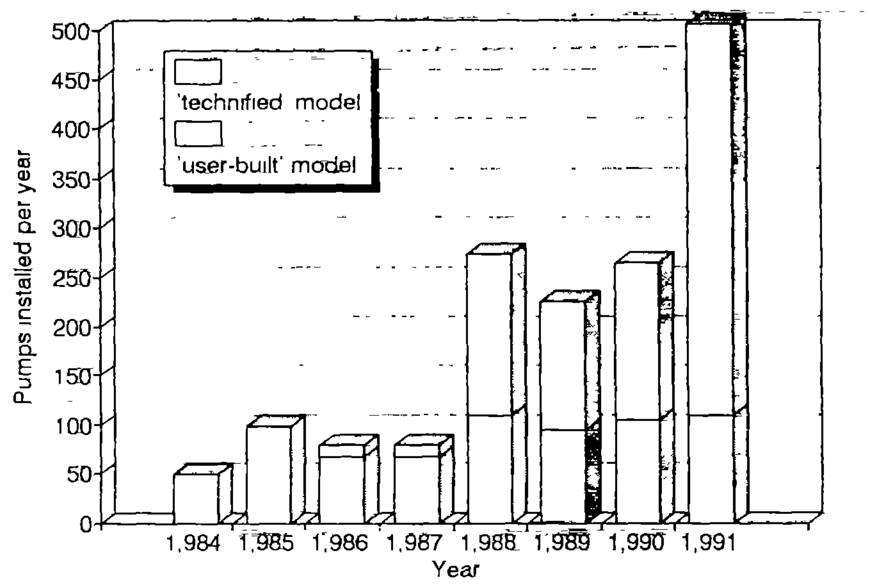


Figure 1.10: Rope pumps installed in Nicaragua.

1.4 Implementation approaches

After this short historical review, we now analyze three prototypes of rope pump implementation methodology with which we have experience in Nicaragua: user–building, sales and institutional water supply projects. These prototypes are clearly rudimentary, and each initiative contains elements of all three. Even so, they are useful to analyze the achievements and limitations of the different possibilities for technology implementation. In each one, we refer to the fundamentals that we detail in chapter 2.

User–built pumps

The idea of user–built pumps is that the beneficiaries themselves build their own pump with available resources, in some cases with institutional support. This approach responds to the reality of many peasants who are not only farmers, but are also carpenters, masons, etc. In addition, in the countryside there is often not cash available (to buy a pump), yet tools, construction materials, knowledge and time are available. Wilian, a promoter of user–built pumps, comments, "...The most necessary tools for pump construction are a hammer, a saw, a square, a machete is very important, a hand–drill to make some holes and a rasp. The leather punch is necessary to make pistons, but working carefully they can be made perfectly well with a sharp knife. That is to say it isn't totally necessary, but we use it to do the work faster. You don't need lots of things if you want to do it simply."

The pumps built in this way are usually rustic and simple, but represent the effort of the users themselves. The felt need of the beneficiaries, self–sufficiency and the transfer of technology are important advantages of this approach.

One discrepancy between those who have worked with this approachy is related to the manner of communication and promotion: if thisis done through construction–training workshops or

Ramón Jimenez Mendoza
self–builder

How did you first hear about rope pumps?

"Well, quite simply, we participated in the Farmer to Farmer Project, and through it we were able to obtain a copy of the magazine "Enlace", in which there was an article that explained about rope pumps. We needed the pump because with this rope pump my problems could be solved and it could be constructed very economically. No, I have never seen a pump, other than the one that I have made. No, I haven't seen one."

What does one need to construct a pump, in terms of both knowledge and finances?

"In terms of money, I didn't spend much because I already had the tube. I did have to buy the t–joint, and two lengths of rope that I bought for diez cordobas per rope. That was it. It took us three and a half days to make it. Sometimes things went wrong and that set us back somewhat; maybe we made the pulley wheel frame incorrectly and then had to make it over again."

"In the magazine they explained how to make the washers with a knife. We made a punch from galvanized tube, and sharpened it. We put the tire on a block and hit the punch with a mallet, and in this way we cut the washers. What you need is to have at least some idea of what you are doing and where there is a will, there is a way. Just a little idea, nothing more; an idea of how it might function better and not malfunction."

What do you have to say regarding purchasing a pump made in a workshop?

"Well, sure, a pump made of iron is going to last longer because we are dealing with iron, but it is also going to cost more. I prefer the one I make myself for economic reasons, because I try to do it in the least expensive way possible with whatever I have at hand. With the pumps made in the workshop, the builder includes all his/her expenses, and can't charge one peso less. But not with mine; I look around to see if I might not make it with a little piece of old rope until I have enough money to buy a new one. That's the way I made the pump and now I have water."

"Water is the most important thing needed in the home, in order for one to feel comfortable when going out to do a job or conduct business. One . now knows that water can be easily obtained in thehome, and the important thing is that there be an abundance of water, easily obtained and economical. With this pump you don't need electricity. You don't need anything, except maybe a little food to give you strength."

Photo 10: "I prefer the one I make myself..." Don Ramon Jimenez with his home-made wooden pump Note that he didn't use the central rim of the tires, but only the tread and walls. The outlet spout is a folded sheet of galvanized roofing. (San Patricio).

Photo 4: Will it really work?
The whole family participates in the construction of the pump, whether is be as carpenter or observer. User–builder workshop given by Wilian, in the white shirt, promoter from 'Puente de Paz' (El Brasil).

through promoters, or if it is enough to just see a sample pump or read an article or flyer (written communication). Another difference is how many and which parts and/or tools are bought or produced by the users themselves. The tubing is always bought, but there are variations in pistons and guides.

Another related aspect is that there are not only grass–roots innovations, but there are also mistakes. For this it would be interesting to do follow–up which promotes precise communication to accumulate experiences and avoid repitition of errors.

The great advantage of this approach is that the user understands the technology, and at any time can repair, adapt or change the pump. Therefore we can really talk about a **popular technology**, and guarantee that there is real interest and confidence in the new technology. The technology is not limited to the apparatus, but rather forms part of a broader training and development process, reinforcing confidence in one's own creative efforts.

A disadvantage is the limited impact (not everyone has the skill to build their own pump) and the technical limitations which prevent building pumps for deeper wells. Another problem for large-scale growth is the lack of a materials distribution network outside of the regional capitals, especially in terms of small quantities of tubing and accessories. Institutional projects could help in this aspect.

Sales

The sale of pumps emerged closely related to the previous approachy. A peasant—after having participated in a pump construction workshop—begins to build and install pumps for other residents. He develops skills and special tools, without giving up his previous job. This phenomenon is found frequently.
There are also broader initiatives, where various people work full-time and have made significant investments to accumulate pumps, secure transportation, put out publicity, etc.
Both cases demonstrate that the pump is viable: "free-market" mechanisms show that both builders/installers and clients are interested in the pump. This is the best guarantee that the technology will survive without outside interference.

The greatest emphasis of this approachy is in the felt need of the beneficiaries (of course) and in local production.
The advantage of this approach is that it is both agile and flexi ble, and offers accumulated experience (many installed pumps) which permits innovations not only in the pump itself but also in its production and installation. If there is not a closerelationship with the user, there is a danger that the seller forgets the

Alfonso Aragón Amador
" Palo de Hule" Promoter

What exactly is the "Palo de Hule" and how does it function?

"Well, the "Palo de Hule" is a foundation just beginning to function. We've been operating for a year and in addition to the assistance we receive from the Dutch, we receive support from the Juan XXIII Institute with our work here in the store. People with extremely limited resources make their requests, and in some cases we provide them with discounts of 30% or 50%, and they can pay over a period of three months, or simply according to their ability. There is a short form that they must fill out with their full name, address, the type of material they are buying, and their signature. There is also a section in which they state whether they have the ability to pay the full price, or whether they need credit or a discount."

"In the store we have everything, at least in terms of tubes of all diameters, wrenchs, everything related to potable water. We also have chlorine, sand, cement, cement blocks in case one has to make a rim for their well, or an apron, all those things. We have everything. We've also poured concrete floors in the houses of some poor people."

"In the majority of the wells in which we have installed pumps, (about 60%), we have done all of the work necessary, including the rim, the apron – all the work, even the storage tank for collecting the water. That's something that we include in the installation and sell in the store. When people saw the first pump installed and functioning, the rest of the people began to arrive at the store to see how they could get their own pump."

How do you train people in the use of the pump?

"The training of the users is 100% complete. It only takes a short time to install the pump – about an hour and a half. But in some cases, for example, when I have to install two pumps in one day, I dedicate all my time in order that the people learn well. When possible, we install the pump once, see how it functions, and then sometimes I take it out again, and tell the users to install it

themselves, so they begin with the first steps and finish the job well."
"In four months I have installed 64 pumps, and they are still functioning. During my first month of work I installed 11 pumps. And honestly, I did the rest in just these four months of work. There are 200 requests pending."

Is it necessary to visit the sites to see how the pumps are functioning?

"At least at the end of each month, or sometimes every 22 days I go visit the pumps. But it's a lot of work for me, and I am just a promoter, nothing more. I visit a lot of communities. In addition, there are communities such as those in Serrano, in which I have 6 pumps to install during the next month. For me alone, it's a lot of work, but every 22 days I make a run through at least Jerusalen. In El Almendro I checked out the pumps we installed for the bank and all are functioning."

Is there satisfaction in this kind of work?

"In my opinion, the most unpleasant aspect is that we are a tiny business, but, we are not part of the government, and it isn't up to us to go around looking for and talking to the people about bettering their health conditions, and making latrines. It isn't our job. All of that is the State institutions' responsibility. But in reality, from what I have seen, the institutions are not interested. Well, I've seen that and it makes me truly sad."
"My greatest satisfaction is that with the use of the pumps I have seen an improvement in health. That is the principal factor for me; that all the children are drinking clean water because the well is kept sealed, chlorinated, and they will no longer have the problem of putting a dirty bucket or dirty hands in the well – they simply turn the crank and draw up water. When we first arrive at the site, there are cases in which one finds cockroaches in the well. So when we do the installation, when we make the apron and the rim, etc, if the old rim is made of wood, we take out the wood and make sure that the owner or the user clean out the well. I consider it super important that we eliminate all the creatures living inside the well and the existent dirty water, leaving everything new, including the water."

Photo 5: Water to drink, to wash, to bathe...
For health reasons, the pump should be included as an element within an integrated sanitation system; a well, a cement floor, a bathing area, a drainage pipe for the laundry. Some of these improvements were financed by "Palo de Hule". (Jerusalén).

medium and long term needs. This can affect not only the durability of the pump, but also the training of users in maintenance and repair.

This approach is ideal for private wells, especially when there are economic benefits from the water (cattle, irrigation). One problem is the sector with scarce resources, which should be covered by a special program of subsidies and/or credits.

Institutional Projects

What we call "institutional projects" are projects (generally with international funding sources) which work with an integrated package of water supply, basic sanitation, health education and at times many more elements. The rope pump is just one part of this combination of activities. Generally there are communal wells, and emphasis is put on the pump's force rather than on its cost. Water quality protection is also prioritized. Within this approachy, impacts on health, local operation and maintenance and national production are prioritized.

It is worth referring to a combination of institutional projects with private sales; the DAR–Region V initiative offers the sale of construction materials, rope pumps, technical assistance and sanitary education at a reasonable price. This initiative was described in the above paragraph and in the interview with Alfonso Arag;n.

One of the advantages of this method is the greater possibility of impacting the living conditions of the community because of the **integration** of the activities. There are usually resources and willingness to contribute to the study of the pump and the production of information and documentation. The greatest danger is that of working too schematically, and not responding to the specific needs of the beneficiaries, which results in lack of interest on their part. Another limitation is that these projects are limited to specific areas, and many times to specific groups within those areas.

Up to here we have the description of the three most–developed implementation approaches in Nicaragua. As can be observed, each one has strong and weak points, and the reader will have to decide which is most convenient for each situation and objective. In chapter 2 we pull from these practical experiences various fundamentals which are at the base of the rope pump.

Chapter 2: Basic rope pump concepts

Different ways of analyzing a problem result in different technological solutions. Behind every technology exists (or existed originally) certain basic concepts. There was some vision (whether conscious or unconscious), although it may have been lost during the technology's evolution.
In this chapter we try to make concrete some of the **concepts** which are at the base of the rope pump as a low–cost popular technology:

–a felt need by the beneficiaries;
–health impacts;
–self–sufficiency;
–social control;
–village level operation and mangement;
–local manufacture;
–technology transfer;
–technical–theoretical concepts.

In the above section, where we described different **approaches** for implementing the rope pump, we implicitly knew these basic concepts.

The basic concepts do not only refer to the **approach** of the introduction of the pump but also to the **apparatus** itself. The aspects are two sides of the same coin; the introduction of a technology with community benefits. They are inseparable.
The basic concept of the rope pump is known as **"appropriate technology."** In literature about technological development of so–called "third world" countries, the concept of "appropriate technology" has played a fundamental and increasingly important role.

However, definitions of the concept vary so much that we prefer not to dwell on this term. Many central elements in definitions of "appropriate technology" are the same as those described in this chapter. We can confirm that the rope pump technology is an appropriate technology.
We now discuss each of the concepts that form the base of the rope pump as it has been developed and promoted in Nicaragua.

2.1 A felt need by the beneficiaries

One fundamental concept in all development activity (and therefore in all drinking water supply projects), is that it should begin from the interests and reality of those benefitting. We must then first define **who** are the beneficiaries and the users of drinking water wells.

The digging and cleaning of a well is considered man's work. Wehave experiences in which women participated actively in digging and masonry work but they are exceptions. In this sense, it appears logical to organize construction of new water works with the men. However, women are the most involved in everything which refers to the **supply and management** of drinking water in the house. In this sense, they are the primary beneficiaries. In terms of **pumping** water, the situation is more diverse. We can make a general observation that throughout Nicaragua in the case of communal pumps, women and children are usually the ones who gather the water. On the contrary, in the case of individual family wells with storage tanks, it is usually the man or oldest son who fills the storage tank various times during the day. There is thus not a clearly–defined impact group in terms of the pump's use. Usually men take charge of mainte-

Photo 6: Women are the principal users of the pump
Pregnant woman staying at the 'Birthing Center' drawing the daily wash water. (Nueva Guinea)

nance, although there are many cases in which women repair pumps. At any rate, **women should always be explicitly involved in all decisions, activities and trainings** around any drinking water project. We will thus use the feminine form when referring to users, beneficiaries, etc, although we are clearly not excluding men. If we ask any peasant woman for a list of criteria to choose a source for drinking water, she will respond with a list something like this:

1.– the distance and the topography of the trajectory;
2.– the cost per bucket of water;
3.– the flavor, color and smell of the water;
4.– the social climate around the well;

5.– the ease with which water is drawn;

7.– and only maybe at the end would she mention the bacterial quality of the water.

We may disagree with these priorities, but **we have to accept them as the basis for our activities.** It is true that through health education it could be possible to change these priorities, but for now this is the basis for action. And if we want the beneficiaries themselves to plan, carry out and maintain their own water supply system, we have to offer them something that is important to them and not grasp on to some established plan (for example PAHO norms, INAA standards, etc).

Once the improvements have been made and enjoyed, the beneficiaries will modify their criteria, and see the importance of other improvements. **We propose a process of step–by–step improvements, assimilated one by one by the users, instead of imposing a pre–designed sanitation system.**

Let's keep these considerations in mind while we analyze the drinking water situation in rural areas. It is relatively easy to dig wells in many zones; water depth ranges between 5 and 30 meters and the soil is not very rocky. There are villages where half the houses have wells, and the other half buy their water from these wells. In these cases, it is ridiculous to tell acommunity to build one or two community wells, because the people will not be interested. (We have to remember their list of priorities.)

Another typical situation in rural areas is very dispersed communities extending for kilometers, with micro–nuclei of 4 or 5 houses. A single central well would also not be much use because it does not fit in with their priorities.

In situations like these, it makes more sense **to improve the existing wells**: to build the well's apron, a drainage trough, slab, and to install a pump which facilitates withdrawing water and protects the well. Since there are many wells, there is a need for many pumps; therefore the pump should be inexpensive (and since there are few users for each pump, it doesn't need to

be made so strong). Many wells are private, and so a sales policy must be developed to impact these families (whether with subsidies or not), which once again implies an inexpensive pump both in construction and in maintenance.
The rope pump fulfills these requirements of price and simplicity, and is an ideal pump for such situations.

2.2 Health Impacts

There can be objections to the above approach by arguing that a drinking water source should guarantee 100% pure water (the PAHO philosophy), and that this cannot be achieved by improving existing wells with their faulty construction and poor locations.Various studies have demonstrated that the **quantity** of water available has more effects on health than its **quality**. An abundance of water stimulates its use to wash hands, food, diapers, the bathroom, to clean the house, etc. Apparently, these are more important sources of contamination than a certain degree of contaminated water being consumed. We don't want to say that one doesn't have to worry about drinking water quality, but you do have to take into account that the quantity is more important. The same studies indicate that the quantity of water used increases significantly when the source is closer.
An area with many dug wells should be taken advantage of, even when their hygienic conditions or physical characteristics are not optimal. It costs the same to install a robust and "hermetical" pump in a new central well as it does to install 15 or 20 rope pumps in various private or communal wells, improving the wells (with slabs, rims, linings, drainage troughs). It must be decided which will be preferred by the community.
In terms of water quality, there is no confusion. When we talk about limitations in protecting the source, we refer primarily tothe wells (bad location, proximity of latrines, with no sanitary seal), and not to the rope pump. As we will see in section 3.4,

Photo 7: The pump in the parlor
Studies have shown that decreasing the distance to the water source increases water consumption. This has a positive effect on health. (Nueva Guinea)

the rope pump appears to give the same water protection as "traditional" pumps. It is interesting to mention here a related aspect, that high water consumption has an unexpected positive effect; water spends less time sitting in the well, which prevents excessive bacteria growth in the water.

To conclude this section on health impact, it is important to emphasize the need to accompany the introduction of improved wells and rope pumps with **a thorough health education campaign which should especially emphasize the adequate transport, storage and use of drinking water.** If this does not take place, the impact on health—which is the final objective of any drinking water project—will never be achieved.

2.3 Self–sufficiency

Another taking–off point in any development activity should be that outside support not be perpetual, but only serve as the impetus to developing viable alternatives. Many times projects come to an end, donors leave, and only leave behind a limited number of wells with pumps. Rather than multiply, sooner or later they break down for lack of maintenance. This is not development. The projects should develop an alternative which is a realistic option for the benefitting population, even without the intervention of a donor; an option that can be produced, bought, installed and repaired. A pump for rural areas should be inexpensive and easy to produce nationally, preferably at the local level. The rope pump is one of the few technologies known today which fulfills these prerequisites.

Photo 8: "...Our commission is composed solely of women.."
Women from a potable water committee together at their pump which is well protected by a box and a fence (urban area, Nueva Guinea)

2.4 Social control

Logically, a piece of equipment like a manual pump that receives intense use requires certain strength. There will always be inadequate use, careless users, unruly children, etc., and any pump should be designed to resist such situations.

Many producers have tried to make pumps which resist any kind of abuse or vandalism. We think the importance of this should be put in perspective, because if the users don't care about the pump, if they don't take care of it, clean it, maintain it, or use it properly for drinking water, it will have no impact on health. (And why install pumps under these conditions? Only to achieve higher coverage rates?) If a user values the pump she will automatically care for it, repair it, etc. The rope pump is based on the principle that the owners/users should take care of it. If there is no social control, the rope pump will not work (as it is currently designed), since it is susceptible to any robbery of parts or injury.

In the case of community wells, a Drinking Water and Sanitation Committee of three to four members is usually formed, preferably women, to take charge of organizing care, cleaning, administration and maintenance of the well and the pump. Another successful alternative is the "private–public" well; one family makes its well available to a defined list of other families, and the pump is installed. This way, the well is for public use but receives private care.

2.5 Village Level Operation and Management

One concept which has received growing attention by drinking water and sanitation project leaders is Village Level Operation and Management(VLOM). Although there are many different manifestations of this basic concept, all share various essentials: the community members themselves are able to decide on all the aspects of pump operation and maintenance; they organize and carry out all activities. Normally there is a drinking water committee and various people trained to make repairs.

The rope pump has all the characteristics of a good VLOM pump. But it isn't only the technical characteristics of a pump that make it appropriate for VLOM. The whole working method for developing the water system should work toward a VLOM situation. There should be support for the formation of a water supply committee, training of various villagers in pump maintenance, access to necessary tools, spare parts and supplies, etc. In short; once the system is set up, the community alone should be able to keep it functioning.

In Nicaragua, the majority of rope pumps have no institutional maintenance system. One exception is the rope pumps installed by DAR–Region V, where there is an institutional operation and maintenance system that primarily limits itself to water quality control. Repair work is minimal. In the majority of cases there is training of users around all aspects of pump maintenance, both organizational and technical. There is also a limited network of pump parts sales. Even with these conditions, the majority of the pumps are in good condition, illustrating that the rope pump can be maintained perfectly well by the users as long as they have been given adequate training.

2.6 Local manufacture

Literature mentions advantages of local production of hand pumps which include: saving money, greater probability of parts availability, knowledge to make repairs, and finally, stimulation of local industry. Disadvantages mentioned in these studies are: design limitations because of low technological levels and problems of quality control.

Photo 9: Local production
The iron worker, Rafael Castilla, with a supply of structural supports in his workshop where he makes, among other things, pulley wheels for the rope pumps (Juigalpa).

Clearly the rope pump concept is one of local production as much as possible. The arguments are generally the same as those mentioned above, but it is worth going into detail in some areas:

Self–sufficiency: In order to reach the above–mentioned goal of self–sufficiency, existing local production structures should be involved. This small local industry can be supported in its growth by introducing new techniques and tools; this is part of the development process.

Local innovation:
The experience and creativity of artisans are essential to the adaptation and development of the rope pump. Their experience gives them a very different and many times more innovative vision than that of professionals.

Adaptation to local conditions:
When the artisan produces and installs the pumps and understands the technology, he can then adapt the design to changes in production conditions (for example; availability of materials, introduction of new tools, etc).

User–maker relationship:
Local production guarantees a certain closeness between the maker and the user which facilitates spare parts supplies, repairs, adaptations and even the development of special models adapted to the specific user's situation. This closeness is a guarantee of quality, since the maker is continually subject to quality control in practice by the users.

An extreme case of local production is **user–built** as it was described in section 1.4. In that case the future owner makes her own pump. The great advantage is that the owner understands the technology and at any moment is able to repair it, adapt it and change it.

2.7 Technology transfer

A technology which sets out to be "popular and democratic" must be understood as much as possible both by the makers and the users. This is necessary to guarantee adequate operation and maintenance, but even more it is the greatest fruit for the users, for its continued development and for its adaptation to particular cases. The transparency of its workings and structure invites owners and users to experiment with the pump, exploring all of its parts. One can see many pumps with innovated "improvements" made by the users themselves; rubber here, anextra lever there, more pistons, homemade wooden guides. They don't always mean substantial improvements, and are often based on an incorrect analysis of the problem. At any rate, it indicates that the users have incorporated the technology and are not afraid of exploring and examining their pump.

The true understanding of a technology therefore implies more than the handing over of the pump with a supply of spare parts and a "user's manual." It implies the need for users together with makers to explore the pump with the goal of experimenting, analyzing and testing new ideas.

We think that this has been the basis of much of the rope pump's success in Nicaragua. We can affirm that artisans and users have supported much of the rope pump's development. They have actually played a much larger role than the technicians and engineers.

As we saw in chapter 1, in Nicaragua we have many ways to promote the technology, ranging from open sales with no training to construction by the users themselves. The latter concept obviously fits in much better with the philosophy of the rope pump as described here, but it has its limitations; it demands a high social and technological level on the part of the promoters. Even so the technical possibilities are limited, preventing the rope pump's use at depths greater than 20 meters. At any rate, we consider essential discussion and understanding of all aspects of the rope pump by its promoters and makers (artisans).

2.8 Technical–theoretical concepts

Up to this point we have only touched on cultural and socio–economic aspects of the rope pump technology. There are also fundamental technical considerations that favor the basic rope pump concept. To explain these, we make a comparison with reciprocating plunger pumps.

The great majority of hand pumps are of the reciprocating plunger type: They have a cylinder hanging on raising main. A piston moves in the cylinder, driven by the pump rod. The weight of the water column rests one moment on the piston (sustained by the sounding line) and the next moment on the foot valve (sustained by the raising main), in continual alteration. This **dynamic load,** combined with the shock due to the accelerations (2) implies **fatigue and creep** for the sounding line and the raising main, especially in the pipe threads; even more so if these pieces are made of some kind of plastic. These problems occur more in pumping heads of more than 40 meters. Because of the relative elasticity of the plastic materials, the system can easily begin oscillations at a certain depth, increasing the tensions and the effects of wear and tear even more.

In addition to these construction problems, the effects of alter-

(2) Besselink et.al., 1990 has measured and calculated factors of 1.2 to 1.8 with respect to static load.

nate acceleration and deceleration, both of the sounding line and of the water column, limit the pump's mechanic efficiency.

The rope pump, on the contrary, has a great advantage of continous unidirectional circular movement. There are no alternating accelerations of either the complete water column nor of the pieces. This movement implies a **minimizing of accelerations and static load** (at least in the pieces with the greatest concentration of forces; clearly the axle is subject to a dynamic load) with all of its advantages in terms of less load on the parts and fewer mechanical losses. The weight of the water column is uniformly distributed on the rope within the raising main because of the chain of pistons. The raising main never has to support a pressure greater than a few meters of water column (the distance between the pistons), in addition to its own weight. This represents a pressure of only 3% as compared with the raising main in a plunger pump at the same depth of 40 meters. The only element which is subject to considerable stress is the rope, and even so the load is static and much less than the sounding cord due to the lack of acceleration shocks. This situation implies that we can pump from great pumping heads with simple PVC tubes. Only the rope has to be strengthened, which is no technical problem.

The mechanical losses are minimal, which implies much greater efficiency than with the plunger pumps. The circular movement of the rope pump's handle is much easier for the user than the tilt of a lever. **Ergonomics** tells us that one can develop much more potential with a circular movement than with the up and down movement of a lever with which we are familiar from traditional pumps. There are then two reasons why the rope pump pumps more water than the plunger pumps: it is more efficient and it is more ergonomically adapted.

The reduced load on the parts under water and the absence of threads makes possible the use of non–metallic materials, ~~and~~ even ~~of~~ greater depth, without the danger of drag. And since the rope pump does not use any metal parts below water, there is no problem of corrosion is this critical zone.

With these technical–theoretical considerations we conclude this chapter on the different basic concepts of the rope pump.

Chapter 3:
Rope pump characteristics

In this chapter we present the **technical characteristics** of:
-operation and management;
-reliability;
–discharge rates, pumping heads, and efficiency rates;
-water quality control, and;
-costs.
Given that the use of quantitative data cannot be avoided, we use two typical models as an example: the **'technified'** model, which has been implemented by the DAR-Region V and is amply described in the second part, with an iron wheel, concrete slab, polyethylene injected pistons (PE) and a glazed ceramic guide, and the **'user–built'** model, with a wooden wheel, wooden guide with rubber pistons.

3.1 Operation and management

The rope pump is excellent for operation and maintenance at the local level or by the owner. This has been proven in practice. Even in the cases where there has not been much emphasis on maintenance issues during implementation, we have noticed a regular state of maintenance of the pump in the majority of cases: one example is the case of Bluefields, figure 1.8. This is even more true if users have gone through a real transference of technology. It is not surprising that in these cases it takes little for them to carry out adequate pump maintenance.

Basically, maintenance is limited to a weekly oiling of the bearings. Two pieces are continually being worn down and need to be changed once or twice a year: the rope and the pistons.

In Appendix A we estimate the useful life and we calculate the monthly cost given different conditions for use. In table 3.1 we give a summary. Table 3.2 illlustrates the useful life in a typical case.

Table 3.1: Maintenance costs in dollars per month

Technified' Pump				'User-built' Pump			
Discharge (m^3/day)	Depth (m) 10	20	30	Discharge (m^3/day)	Depth (m) 10	20	30
8	1.09	1.93	2.76	8	1.09	-	-
4	0.92	1.09	1.46	4	0.91	1.08	-
1.5	0.85	0.93	1.04	1.5	0.86	1.04	-

The table indicates maintenance costs in dollars per month (factory sale price) for two cases: 'technified' and 'user-built' according to differing conditions for use. Note that the difference in maintenance costs in both cases is minimal.
Calculation: Appendix A.

The **tools** necessary to change the rope, pistons, and guide are limited to a knife and a burning ember. To change the bearings a no. 10 wrench is needed. A saw and PVC glue are required to change the pipes.

As regards **personnel** required for maintenance, the qualifications necessary in order to do upkeep are minimal, and after a half-day of training, anyone can do maintenance. The rope and the pistons can be changed in half an hour (the majority of this time is occupied in fastening the pistons on the rope), while it only takes 15 minutes to take out the pump.

In the case of the 'user-built' pumps, where rubber pistons and wooden guides are used, all the parts can be made in the community. In the case of 'technified' pumps, PE pistons and glazed ceramic guides are used so it is necessary to create a system

Table 3.2: Useful life for pump pieces by month.

Part	'Technified' (glazed ceramic guide; PP or PE pistons)	'User–built' (wooden guide for rubber pistons)
Rope	**10**	**6**
Piston	**20**	**18**
Paint	24	24
Guide	**36**	6
Bearings	36	36
Outlet spout	48	48
Raising main	48	48
Pulley wheel	48	48

The useful life is given in months for the two cases: 'technified' and 'user-built.' Conditions are relatively severe, pumping 4 m3 per day with a pumping head of 24 m. The numbers in **highlights** were determined in the field, the rest are estimates. Calculation: Appendix A.

for **parts distribution.** This creates dependence. Until now our experience has been limited to structures directly linked to projects or small businesses that sell rope pumps. In the majority of cases, this is sufficient, but in the case of institutional projects with determined ending dates, continuityin the distribution of parts must be guaranteed through a network of private stores that guarantee parts at market prices.

Finally, it is important to emphasize that it is preferable to implement a preventive maintenance system rather than a corrective system by strongly encouraging that the caretakers/owners keep control over the pump parts that are subject to wear, and that they change them before they break. This subject will be elaborated upon in the third section.

In both cases ('hand-built' and 'technified') we can conclude with certainty that the rope pump is a pump that completely fills the requisites of a **'VLOM.'**

Humberto Zapata Sánchez and Concepción Mendoza Castro Social Promoters

What is your work related to the issues of potable water and environmental health?

Humberto: "I work in the DAR (Rural Aqueduct Office) in Boaco, and my training to be a promoter took place in 1984. During my early experience as a promoter, I worked with small aqueducts and communal wells which were equipped with Demster, 23F and Monitor pumps. Our work is to see that the communities have access to potable water and that those in the countryside enjoy better health."

Concepción: "I was trained to be a promoter in November 1989. For me, the job of the promoter is to provide more information to the community, broaden their knowledge regarding the social needs that should be taken into account in the rural area, in order to better the standard of living of the people who live in those communities."

Through experience, what opinions have you and the community members formed regarding the use of the various types of pumps?

Humberto: " I am familiar with the Indian, the Demster, the Monitor, and many more. These pumps are very problematic in the rural areas. Beginning with their installation, the pumps require a specialized team that is familiar with that type of pump. And you need a vehicle, a number of tools and a lot of people to help you since the tubes and tools are heavy. One person alone couldn't install a pump. The parts are imported; we don't make them here in Nicaragua. And as Nicaragua is a poor country, the communities have few resources to be going about importing this or that part from abroad in order to keep the pump functioning. The people say that this type of metal pump made from galvanized pipe draws up awful tasting water in the morning, with foul sediment. It takes about half an hour of pumping to clear the water that had remained in the tube, while with the rope pump it even comes out colder."

"There is more acceptance of the rope pump, seeing as how it is easier, simpler, and the accessories are well known. It is so simple that it gets their attention and interests them because they see that they can do the installation and repiars and the costs aren't very high. None of the community members or ranchers have requested those kinds of monstrous pumps. They have shown a great interest in the rope pump, and we have had a big demand for that type of pump, not only from private individuals, but from the communities with wells. They haverejected the Indian or Demster type of pump because they have heard about the experiences of other communities with that kind of pump. In order to not tell them what kind of system they should install, we give them the various options, but everyone has opted for the rope pump because they say that operating the pump is easier."

How well is the rope pump accepted by the users?

Concepción: "There is a saying that goes: one's likes are influenced by what one sees. Perhaps the rural farmworker is not going to understand the technology in depth, such as the technical explanation of the pump, but he sees a pump functioning and it gets his attention: 'Hey, what is this all about, and how does the water come out with the rope?'. He begins to get curious and wants to know more. And then, this doesn't get the attention of just the man or the child, but of the women as well, who say, 'I can see how it is easier, and how it will make it easier for me as a woman, and for my child, to obtain water.' I can see that they view the pump as attractive, simple and more easily operated."

Humberto: "Compared to the other pumps, if you are going to tell a woman what is the first thing to go on a (traditional) pump, you could mention thousands of things that are going to go. First it might be the washers, it might be that the sounding rod falls apart, that the rectangular rod breaks, many things can break. So when you talk about these things with the women, they don't pay attention and they back off, saying, 'This is a subject for the men'."

"When they ask, 'What is it that breaks the fastest with this pump?' and we tell them that it is the rope, and show them how to change that rope and make the washers, then they say, 'Ahhhh, that we can do, no problem.' and so the women feel they have more of a right to participate."

Concepción: "Sure, there are a lot of differences and there exists more acceptance on the part of women. I think that part of this stems from the fact that generally the women participate more in dealing with water; it is the woman who uses the water for all the domestic chores, to drink, to wash dishes, to bathe the children. All of this responsibility falls on the woman, and it is also the woman that is going to be drawing the water. And so she also uses the pump within the communities and tries to make a decision: 'Hey, this is the pump that's right for a woman's strength because it is easier to turn the pulley wheel, more water comes out, my container fills up more quickly, and I am going to be able to manage more water, more efficiently.' So the women can make decisions regarding the type of pump because in making the comparison with another type of pump, they feel that it is more complete. In addition, there are women who haveparticipated in the installation, and it is they who have had the responsibility of repairing the rope pump, because it is easier, the accessories weigh less and everything is easier than the other types of pumps."

Concepción: "It is popular because in the first place, it is made from our own materials. It isn't necessary to bring in parts from somewhere else, and its cost is within reach of people with few economic resources. It is democratic because practically everyone has the right to participate in the installation and reparation, including the women and children. There is nothing difficult as I see it."

Humberto: "In regard to the other pump there is no democracy. We need a technical team, and only this team can do the work so no one else can participate because they don't know the system, they can't do it. It has to be done by the technical team from INAA."

What interests are involved in the marketing of the pump?

Concepción: "For a promoter, his or her particular interest is social, to create conditions which are going to improve the living conditions of the people, of the community, to orient them in how to better their situation. Whereas, an individual, or someone who sells pumps has an economic interest in bettering his or her own situation. In fact, what interests them is filling their own pockets, and they don't give all the recommendations necessary in order to assure that the pump purchased by someone doesn't fall apart all the time. So their's is an economic interest and ours is social."

Humberto: "I have even felt more at ease in my work when I arrive in a community and they say, 'You know, this pump here broke the rope because it got stuck, but we already bought a new one and it's functioning.' I feel as though our work has been a success, I feel that I am developing my work."

What do you think about the issues of water quality control and public supervision in relation to the rope pump?

Concepción: "The degree of contamination is not a function of the pump or the type of pump one installs in the well. It stems from the users, because, no matter how well covered or hermetically sealed a well might be, if the user doesn't know how to manage the pump, or doesn't know how to make proper use or the water, if there has existed no ongoing education regarding sanitation, there tends to be contamination even if they are using a rope pump."

Humberto: "There isn't a need for much public supervision because the community appreciates a pump of this type; it hasbeen noted in the communities that it is as though they have more love for a pump of this type, as though they were seeing it as being weaker. For this reason, they themselves take more care than they would with the other pump, with which they might even see if they could hook it up to an ox. But they feel that it is competent and so they take better care of that little pump, or show it more love, you might say."

Who decides on what type of pump to use and what lies in store for the future?

Humberto: "The communities themselves have shown us that the pump that works for them is the rope pump. We can't install something that tomorrow will leave the community with the same problem as before; they have no way of drawing the water, they begin to put their containers inside the well, and in no time we are back where we started from, except worse off, because now they have water with a higher concentration of microbes, there is no circulation, and we are generating more illnesses in the community with this huge pile of broken pumps accumulated in x number of months."

Concepción: "In reality, that is going to depend on the knowledge that has been acquired regarding improvements to the pump and the problems that it has resolved in the rural sector. It is going to depend on the degree of knowledge on the part of both the financing organizations and the (government) institutions, in order to fully understand that here, in this country, what is needed is a solution brought about by ourselves, with our own resources. The rope pump has a better future because it is more widely accepted due to its low cost and high output, which is something that is of special interest to the private producer."

Humberto: "I think that it is better to make use of this type of pump here because it results better for the communities. I also think that throughout the time that we have been working, the rope pump has been in first place here."

How would you describe your direct participation in this technology?

Concepción: "In fact, we as promoters have immersed ourselves in the development in practical terms. What happens? The engineer can design the pump, or the man who can build it, builds it. But those who have experience in using it and those who transmit that experience are the community and us. And it is as a result of all these experiences, direct or indirect, that all the improvements are made in order to better the technology. So, I feel that we are in fact in midst of the development of this new technology."

3.2 Reliability

In order to elaborate on the subject of reliability, we will begin with its definition. The definition of the "reliability of equipment" used most frequently, is the "Mean Time Before Failure" (MTBF). However, this definition does not take into account the time necessary for repairing the equipment, and consequently it is inadequate for disperse potable water systems. In this case, corrective maintenance is a serious problem, both in financial terms as well as time.

A different definition is used by Arlosoroff e.a., 1988, defining a pump's reliability in the following manner: "Reliability is what mechanical engineers call 'availability:' the probability that the equipment will be functioning on any given day, calculating the functioning time as a percentage of the total time:

$$\text{Reliability} = \frac{\text{Functioning Time}}{\text{Total Time}} \times 100\%$$

In this book we use the second definition. The two definitions are illustrated in figure 3 1. Although pump "B" has a tendency to fail more frequently than pump "A," its reliability according to our definition is greater because repairs can be made more rapidly. it is not necessary to bring tools, parts, or technicians from a long distance, and all repairs can be made locally.

The rope pump is a typical example of pump type "B" it is not very rugged, but repairs are easy and fast. The only aspect to worry about is the transference of technology to users and the distribution of parts

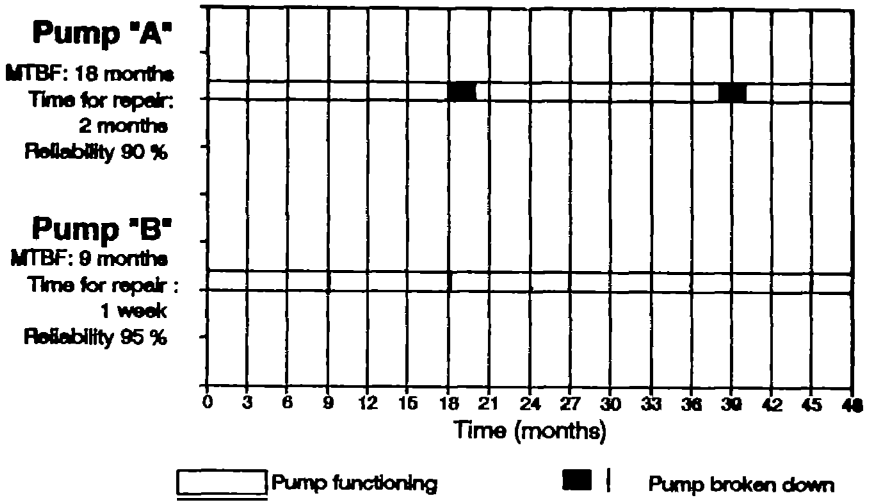


Figure 3.1: Reliability of two pumps
A ficticious chronogram of the functioning of the two pumps. Given the definition used in this book, pump "B" is more reliable than pump "A." The rope pump is a typical example of pump "B."

Reliability, within the definition used here, is not just a technical matter: socio-economic and cultural factors also come into play, for example:

-motivation of users to take action to repair the pump;
-the possibility of taking water out of the well even if the pump is broken;
-availability and quality of alternative water sources;
-complexity of repairs (costs and availability of necessary parts);
-level of training and self-confidence of users. Here it will be demonstrated whether or not training was effective for the principal users (women) to maintain the pump or if it was only effective for those who dug the well (men).

All of these factors are important points that should be considered in institutional rural water supply and sanitation projects as well as for the sale of pumps. The use of the rope pump by itself does not guarantee high reliability, but reliability can potentially be guaranteed when the users have been trained and are willing.

No systematic monitoring in the field has been done using percentages on the pump's reliability, but we can affirm on the basis of our observations that it is reliable:

-Repairs are generally made within a few days. If the process drags, it is due to a lack of resources to buy necessary parts.
-Frequently repairs are made by the owner or caretaker. Sometimes someone is paid, but it is always a community member.
–The lack of tools and technical knowledge is never mentioned as an obstacle to repairing the pump.
Don Emilio Miranda, a member of the water committee of a communal well comments:
"...When the porcelain guide broke, I began to think: Why can't I make this piece out of wood? Why am I going to go all the way to Nueva Guinea to buy a new guide if I can make it here in half a day? And the one that I make will probably function better that the one that they bring from Managua..."

Thus we conclude, on the basis of our observations, that the rope pump is reliable.

3.3 Discharge rates, pumping heads and efficiency rates

For users, high water discharge is almost always of primary importance, more important than ease of movement. Almost everyone prefers working hard for a strong flow of water rather than working less but waiting longer to fill their bucket. On various

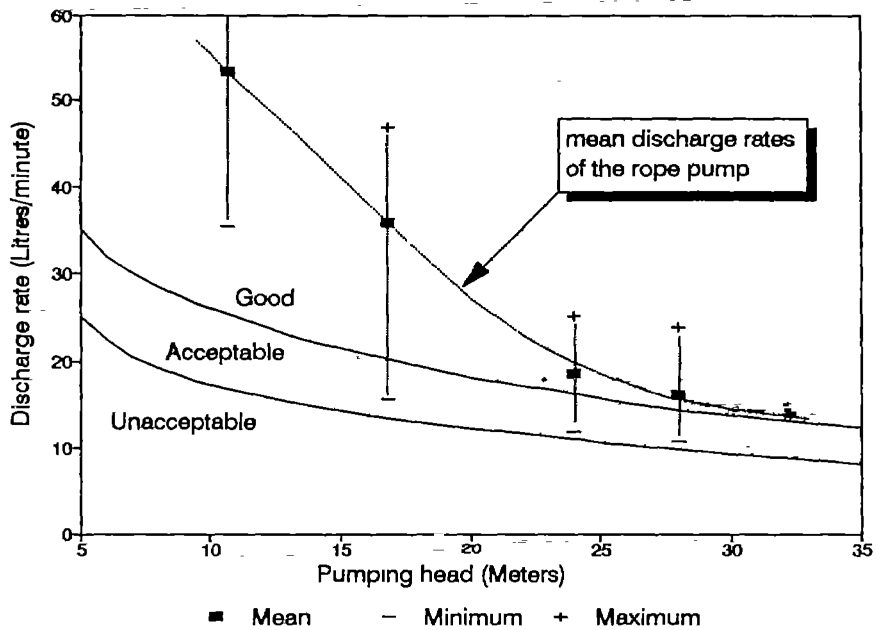


Figure 3.2: Pumping discharge rates

The lines represent the limits between the three zones defined by Arlosoroff e.a., 1988. The symbols summarize 53 tests done in the field executed at four wells with different users, including children. It can be observed that when pumping head increases, the rope pump results come closer to the typical zones. This is due to the following; for cylinder pumps the efficiency increases with the pumping head, while in the case of the rope pump it remains the same (Source: Heuthorst, 1991).

occasions we had temporarily installed pumps with a greater diameter raising main than that advised by the theoretical norms of ergonomics (because of a lack of tubes or pistons with the correct measu rements), but after installing a "better-designed" pump several weeks later, according to the ergonomic parameters, the users wanted to stay with the original pump. In other words, we generally found that users apply a potency much higher than 100 watts. However, we consider that pumps with heavy action should be avoided in order to keep the pump accessible to women and children.

Arlosoroff et.al., 1988, defines good discharge rates in figure 3.2, as well as acceptable and unacceptable rates at different pumping levels. Given that these discharge rates depend directly on strength developed by the user, the graph is not unique: a strong man gets more water with the same pump than a girl. The rope pump complies perfectly with the established norms demonstrated in the graph; particularly for shallow wells, the discharge rates are much higher than required.

Given field experience, among others the case study in El Pochote, we can use table 3.3 for an overall idea of the possibilities of a rope pump's coverage.

Table 3.3: Hours of Daily Pumping

Number of Users	Discharge m3/day	Depth / Discharge	10 m 0.9 l/s	20 m 0.5 l/s	30 m 0.3 l/s
75	1.5		0.5 hrs.	0.9 hrs.	1 4 hrs.
200	4.0		1.2 hrs.	2.7 hrs.	5.0 hrs.
400	8.0		2.5 hrs.	5.0 hrs.	7.8 hrs.

The daily discharge categories are taken from Arlosoroff, 1988.
The quantity of users is estimated based on this data assuming a consumption of 20 liters per person per day.

The pump's efficiency is directly related to daily discharge rates. Although we analyze the subject of efficiency in depth in chapter 7, it is worth mentioning this dilemma briefly.

The **total efficiency** of the pump varies between 60 and 90%, which is high for a manual pump. A high efficiency rate is of particular importance in the case of deep wells where pumping water is serious work. In pumps with a pumping head of 35 - 40 meters (which are the deepest in which we have installed the rope pump), the efficiency is still good.

The total efficiency of a pump is the product of the hydraulic efficiency multiplied by the mechanical efficiency.

Mechanical efficiency consists of the friction losses between the different moving parts of the pump. It is difficult to establish the mechanical efficiency by testing but we can estimate it based on experiences in the field as between 80-90%. (As explained in section 2.8, the mechanical losses of a rope pump are less in principle than those of a reciprocating plunger pump.)

The **hydraulic efficiency rate** consists of the leakage of water through the narrow ring that exists inevitably between the piston and the wall of the raising main. This efficiency rate is easy to measure, and field tests demonstrate that it varies between 80 and 95%. The hydraulic efficiency rate depends on various production factors, principally the play between the piston and the raising main, and the piston's velocity. The dependency of these two factors is demonstrated in figure 3.3.

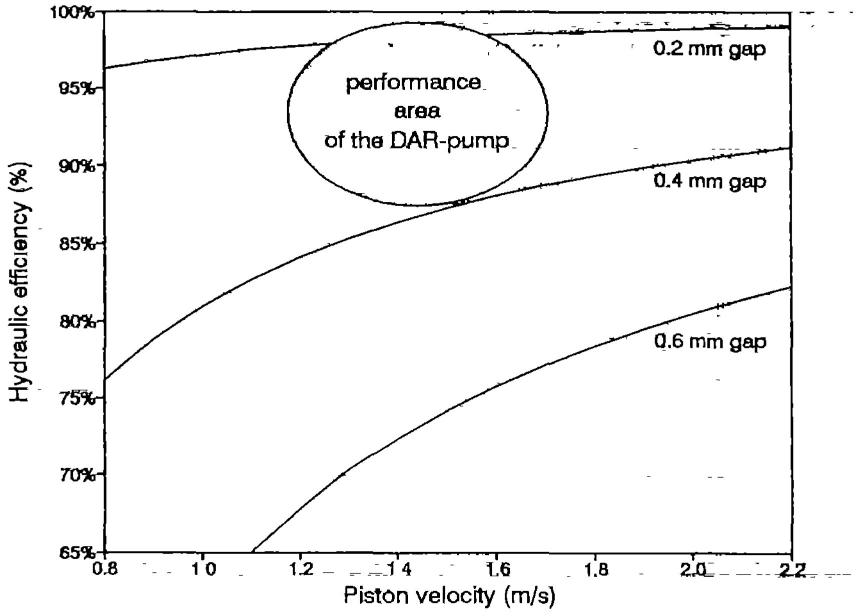


Figure 3.3: Hydraulic efficiency
Curves of the theoretical hydraulic efficiency rate of a rope pump as a function of velocity, for three plays between the piston and the raising main. (1/2" tube, 2m distance between pistons) (Source: Heuthorst, 1991).

When referring to the pump's efficiency rate, the subject of ergonomics must be mentioned; the ease of movement, or the user "efficiency." It is known that an easy movement to drive the pump permits the user to generate more power and become less tired. The uniform circular movement of the pulley wheel handle is in this respect much more favorable than the movement of tilting a lever. These are not just the criteria of users in Nicaragua, but also the conclusions of field and laboratory tests done in Arlosoroff e.a., 1988.

This aspect could be improved somewhat by including a flywheel on the pulley wheel, an element to consider for very deep wells or high discharge rates.

We thus conclude that in terms of efficiency rates, the rope pump complies completely with the requirements.

3.4 Water quality protection

One of the principal reasons for installing manual pumps is to protect the quality of drinking water in the well; the pump seals the well and impedes the infiltration of contaminated water Although it is true that the rope pump does not seal the well hermeticallly (think about the rope and the openings of the protection tubes), it has been proven to give ample protection. The concrete slab with the protective tubes makes the infiltration of contaminated waters that fall on the slab impossible, and the possibilities of contamination by the rope also seem minimal, particularly when a protection for the pulley wheel has been installed

Figure 3.4 demonstrates a comparative study of water quality in sealed wells with a rope pump and with Dempster pumps. It can be observed that there are not great differences between the two categories of wells, and although the sample is small, it can be concluded that other intangible factors are more important to water quality control than these different types of pumps.

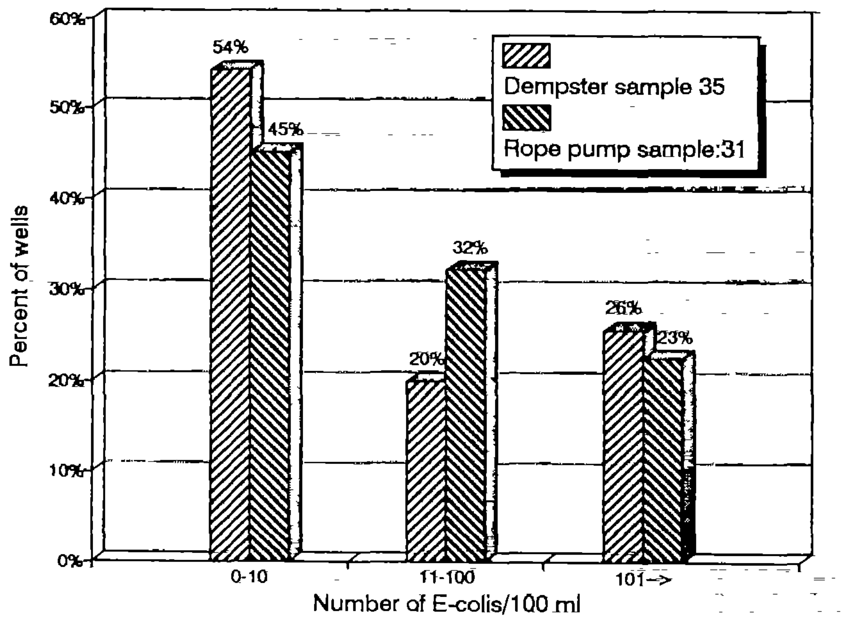


Figure 3.4: Well contamination

The quantity of E-coli per 100 ml in water samples taken from sealed wells with rope pumps and with Dempster pumps. The data comes from 66 samples taken by the UNOM team in Nueva Guinea and in Boaco. Wells were chosen which eliminated possible negative influences like: poor locationof wells because of streams or latrines; poor lining quality of slab or rim, poor sanitary conditions and maintenance of well and apron; if chlorination took place after the last opening. The greater number of samples from Dempster pumps is due to the fact that there are more wells with this type of pump installed in the region. Note: The great majority of these rope pumps did not have any protection for the pulley wheel.

In the discussion regarding the protection of water quality another factor must be taken into account; the reliability of the pump. A pump that provides good water quality protection is of little value if the pump is not reliable; most of the time the users will be taking water from the well with a bucket on a rope. It is also important to keep in mind that every time a well is opened, there is a possibility of contamination, which means that the well needs to be chlorinated before closing it. If this is not done adequately, the water quality could be affected.

Humberto, a coordinator of promoters, does not leave any doubt: *"...We cannot install something with which the community will have the same water problems tomorrow--they will have no way to take out the water, and they begin to drop buckets into the well and in a short time the situation will be the same as before, even worse because the water is more concentrated with microbes, there is no circulation and more illness is generated in the community with all these broken pumps that we will have."*

Another aspect in the study is that we have only looked at the wells in good condition, leaving aside nearly 60% of the wells with imperfections in construction, location, or maintenance. It does not make any sense to install a pump that hermetically seals such wells.

Finally, many rope pumps in Nicaragua are installed in wells without a slab or a wooden cover. Although it is true that in these cases the well's protection is not as good as with a concrete slab, even in these cases the pump's installation means a substantial improvement in the hygenic conditions of the beneficiaries because the ease with which users can take out water encourages them to use greater quantities
(See paragrah 2.2: Impacting health).

3.5 Costs

The rope pump is very inexpensive; the price of the "technified" model varies between $43 to $47 according to depth, while the "user–built" pump costs about $13. This price does not include the cost of the wooden wheel! The market price of this wood would be between $8 to $10, but practice demonstrates that old pieces of wood are almost always used.

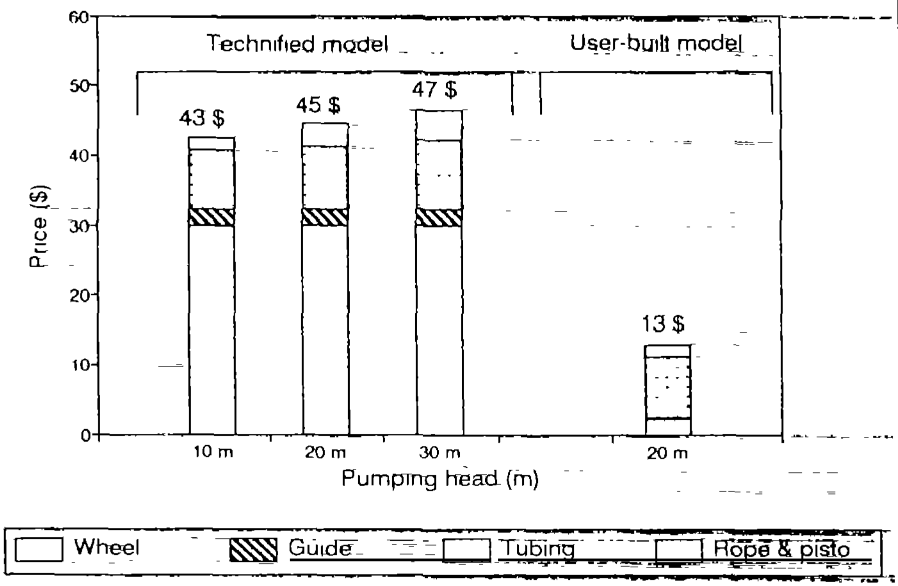


Figure 3.5: Price Structure
The price structure of the 'technified' rope pump and of the 'user–built' according to the pumping head. Source: author and Bargmann, D. 1991

For an investment program for rural water supply and sanitation projects this data is not significant; the pump's cost is a minimum percentage of the total project cost. The other characteristics of the pump are considered more important than the purchase price. For the self–sufficiency of a rural population with little resources, however, the pump's cost is very important. The low cost of the rope pump makes it possible for wide distribution given that many people (family nucleus, or several families), are willing and able of paying this sum for a pump, keeping in mind the low installation and maintenance costs.

Table 3.4: Costs per piece of rope pump in US dollars
(Pumping Head: 24m.)

	Technified Pump		User–built Pump	
Piece	Value $US	%	Value $US	%
Wheel (materials)	12.00	27%	2.50	19%
Wheel (production)	18 00	40%	-	0%
Guide	2.50	6%	-	0%
Discharge tubes	2.23	5%	2.23	17%
Raising Main	6.72	5%	6.72	51%
Rope and pistons	3.28	7%	1.68	13%
TOTALS:	44.73	100%	13.13	100%

Graph 3.5 and table 3.4 demonstrate the costs of the pumps by piece and depth. The following observations can be made:

- The costs increases are relatively small given the depth of the well; much less than with other pumps. This is due primarily to the use of PVC pipes with a small diameter, a relatively inexpensive product. The following phenomenon can also be observed: greater well depth, smaller pipe diameter and therefore lower costs of pipes per meter.

- The cost of the rope and the pistons increases almost lineally with depth; although this cost is relatively low, it does significantly influence the recurring maintenance costs (See section 3.1).

When analyzing the data in the graph and chart, the following conditions must be taken into account:
- The same wholesale prices were used for the 'user-built pump' as the 'technified' pump. In practice, if the user-built pump is not supported by a project, its real cost could double or even triple given the great difference existing between wholesale prices and prices in the departamental tool shops.
- Nicaragua today is an expensive country to produce in; production efficiency is very low and salaries are relatively high. Costs may be lower in other countries.
- The values shown are the sale prices of the suppliers of each piece. The installation and assembling costs are small; in the case of a wooden cover 1-2 working hours, in the case of a concrete slab 8 working hours. But, the collection of the parts from the different small businesses that produce them requires a significant investment, i.e.:
  - the metalworking shop for the wheel;
  - the rope weaving shop for the rope;
  - the injection workshop for the pistons;
  - the ceramic workshop for the guide, and finally
  - the factory for the PVC pipes.

The cost of running around to find all these pieces--although it could be significant--cannot be quantified and cannot be taken into account.
-The cost of a machine does not mean much if its useful life is not known. We estimate the useful life of the wheel (which represents the greatest cost) at about 10 years. The other parts will be changed within a certain time period, as shown in Appendix A. We include these expenditures within the maintenance and operation costs.

To compare the cost of the rope pump with other well-known pumps, see figure 3.6.

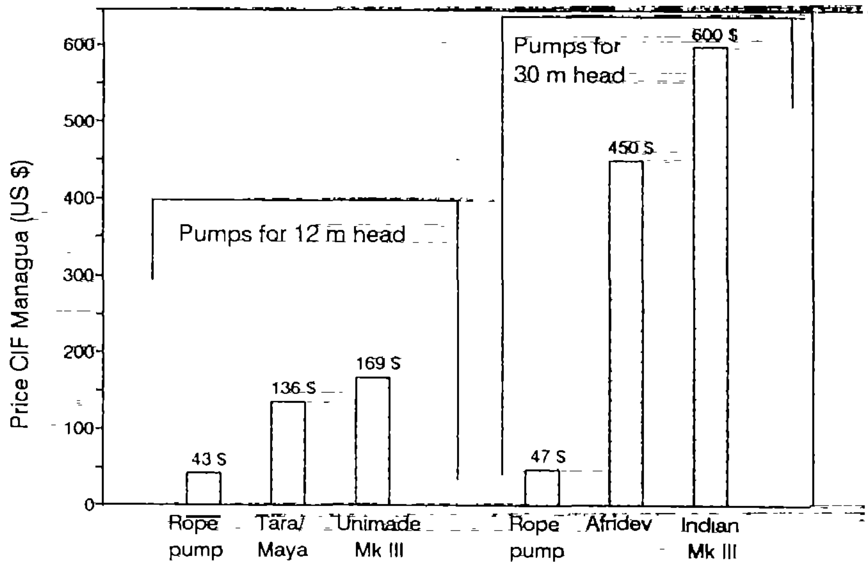


Figure 3.6: Prices of different pumps
The prices of a rope pump compared with other known pumps which are competitive in the range of depths of 0-10 meters and 10-30 meters.

In this chapter we analyzed the different characteristics of the rope pump: operation and maintenance, reliability, discharge rate, pumping head, efficiency rates, water quality protection and finally, costs. We now look at production issues.

Chapter 4: Production

One of the strong points of the rope pump is that it does not require a high level of technology for production, and can be produced in any country with a low industrial development level. Since many designs of the pump exist it is not possible to generalize and we must differentiate by model and by piece to analyze the aspects of production. We will do this in the second part. Here we limit the analysis to the production levels required for typical pump models (section 4.1) and explain how production is organized and how to involve small and micro-industry in this process (section 4.2).

4.1 Production levels

In order to discuss the feasibility of producing a piece in X or Y location, we define the four technological levels of production in table 4.1, depending on the tools and materials available at each level (3).

(3) We have limited the discussion to the tools and materials relevant for the pump's production and for the molds, but each of these tools mentioned is not always required in order to make the pump.

Table 4.1: Definition of technological levels of production

Production	Available tools	Available materials and level semi-manufactured inputs.
Home	Common carpentry tools (non-electric).	Fine wood Sand, cement, construction iron 1/4". A used tire.
Local	Simple Lathe for wood,110V,200W. Electrical welder 110 V, 50 A. Hand wheel to make rope.	Welding electrodes, construction iron in different diameters, galvanized iron pipes. PE fiber for rope.
Regio nal	Steel Lathe at 220 V Slide guage Ceramic oven reaching 1,300 degrees. Cinva–ram Manual Extruder for PE or PP with 100 N/mm2 pressure: heating 110V.	Iron or Bronze Bar up to 50mm. Stoneware Clay Feldspar PE or PP as raw material.
Natio nal	Multiple electnc extruder for PVC.	PVC as raw material

Now that the relevant characteristics of the different technological levels have been identified, we can analyze which piece can be produced at each level. This is demonstrated in table 4.2 for two types of pumps: "technified" and "user–built."

Table 4.2: Level of production of the pieces of a rope pump

	Home	Local	Regional	National
Slab	U,T			
Wheel	U	T		
Guide	U		T	
Pistons	U		T	
Rope		U,T	U,T	
Tubes				U,T

The Indicator "T" represents the tecnified pump, and "U" the user–built pump.

As can be observed in table 4.2, the user–built pump could be built **'at home,'** requiring that one buy only the rope and the PVC tubing, which is the greatest obstacle. The technified model can easily be built at the **regional level**, while the wheel, which represents 67% of the pump's value, can be manufactured at a local level. In both cases there is no need to import parts, although the raw materials (tires, steel, PE) are imported.

In Appendix B we have enumerated in detail all of the matenals, tools and molds required for the production of the two types of pumps.

4.2 Production Organization

As we observed in the last paragraph, the technical aspects of rope pump production are not at all complex. The major difficulty lies in the **organization of production.** Six elements with very different characteristics need to be collected, probably with six different suppliers.

For the "technified" pump these are:
- materials for the concrete slab at the building materials shop;
- the wheel in the metal workshop;
- the guide in the ceramics workshop;
- the PE or PP pistons in the extrusion workshop;
- the rope in the rope shop or in the market and
- the PVC tubing in the factory.

Although the metal wheel has been standardized to a maximum level, it still contains six different iron semi-manufactured inputs, apart from the old tire, welding, and paint.

For the user–built pump the situation is a bit simpler, but not much. Although there are not many sub-products, it is a question of finding **all the materials** (without exception):
- for the cover and the wheel, construction lumber and GI tubing; - fine wood for the guide;
- an old tire for the pistons;
- rope and
– PVC tubing.

Ignacio López Pérez
Pump workshop

How many pumps do you produce and what are the models?

"In terms of quantity, its what we make the most of – 70 rope pumps per month. We are testing a rope pump with an windmill; we've already installed it, and produce two per month for drilled wells with a motor. We are experimenting with a pump to pump wells dry for cleaning. In terms of hand pumps, it's the best because it gives the highest output for the least effort. In addition, it is in higher demand because not every one has electricity. It has also received a surprisingly strong response."

What have you done to improve the capacity of the shop and satisfy the demand?

"With the increase in demand, we have had to make special molds in order to decrease person/hours because we have a social commitment to reduce the costs of production. We decided to come up with better molds and designs. We did a structural analysis of the equipment in order to balance time and materials. For example, in welding during fabrication, and assuring the proper balance of the pulley wheel, we are now welding the pulley wheel and the handle at the same time. Another example is using designs that cut back the need for materials. In this way we save on production costs, and then the prices are lower."

How do you make improvements on the pumps?

"When we go into the countryside, we like to see how they work. What we do is get feedback from the installers, for example, the client doesn't like the sound of the brake. We have very good communication in this respect. We have improved many details such as the welded joints, the parts subjected to the most stress. In addition, we maintain our own standards."

What are the future possibilities for the rope pump?

"The outlook is good for the rope pump in the coming years. It has quite a prosperous future among the poor. Even if all the rural communities obtain electrical power, there are not going to be the economic conditions which would allow every one to buy electric pumps. The rope pump has been constructed with this in mind, and as long as there exists poor people, we will need to keep pace with the demand, in addition to training our personnel to face this challenge."

Photo 11: Mass production of pulley wheels

The use of molds for welding the pulleys is one of the innovations that allow for quality and uniformity, while maintaining high output. (Ignacio Lopez Workshop, Managua).

In many developing countries the communication systems are faulty, and an efficient banking system is not accessible to the majority of the small workshops. Distribution of raw materials or semi-manufactured inputs is not fluid and supposed delivery dates are not honored.

These factors lead to the inevitable conclusion that the installation of a rope pump requires **excellent planning.**

The easiest solution is to maintain a large stock of parts, but this is expensive and requires inactive capital. It also can induce poor planning in terms of ordering new sub-products on time. As one warehouse worker comments frequently: "...there is still a lot in storage."

Another strategy used is to gather all the tools to make the majority of the parts within **one business**: the value of the machinery to produce the wheels, guides, pistons, and rope adds up to approximately $5,000, which is relatively little.
The advantages of this strategy are:

- Easy planning of production;
- All of the machine operators know what a rope pump is and understand the importance of each piece of the pump.

However, the disadvantages are considerable:

- The distribution of raw materials and of the products is complex. Only part of the problem has been solved, and it is still necessary to find a considerable variety of rawmaterial: PE or PP, six types of steel, welding, paint, PE fiber for the rope, tubing, clay and glaze.
- A major part of the machinery is under-utilized (except for the welding equipment).
- The experience and specific knowledge existing in the specialized workshops is not utilized;
- This form of production is not based on the existing small industry, and this weakens the society's assimilation of the technology as discussed in sections 2.7 and 2.8.

We recommend the organization of production based on a network of existing small and micro-businesses. In order to achieve this, it is necessary to **support and control each of these micro–businesses** in the following aspects:

- It is very important that the craftspeople understand how the rope pump works, why it was designed, etc, through practice. We have had very good results with this strategy as regards motivation as well as generating useful ideas regarding how to produce or adapt sub-products.
- Look for ways of payment that help the micro-businesses to invest and grow, for example through payment in imported machinery.

Photo 12: Injection machine before starting on an order for 6,000 pistons...
The lever on the left feeds the raw material The polyethylene balls descend from the depository through a funnel and pass through the electric heater (the "voltage regulator" is seen above) towards the mold (not installed) To the right, the lever which presses the mold On the chart in front, a sample of three molds with their 1/2", 1" and 1/4" pistons.

- Emphasize strict delivery dates, including fines within the contract for days or weeks behind schedule.
- From the very beginning demand sufficient quality of the sub-products.
- In industry it is common to use a large contract to invest in the improvement of production methods. In the case of micro-enterprises we think it is important to explicitly separate the development of a sub-product or new method of production, with production on a larger scale, making different clauses within the contract:

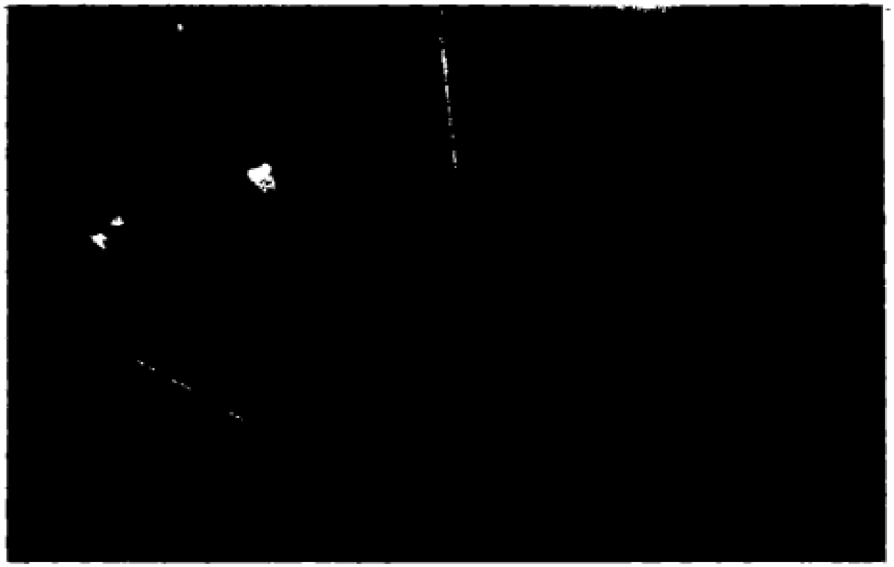


Photo 13: ...and after

The mechanism for introducing the raw material has been improved through the use of an electric motor with a transmission. This photo shows the opening through which the liquid polyethylene comes out.(Jose Evaristo Workshop, Managua).

1. Develop a production system, with X and Y molds, for a value of xx C$;

2. Produce a quantity of parts at a unitary value of yy C$. The workshop will not lose much if the effort fails, and will not be obligated to deliver products of insufficient quality.

With these observations we conclude the subject of production, and pass on to the perspectives and future development of the rope pump.

Chapter 5: Future Perspectives

In the last chapter in this section we briefly discuss the possible perspective for the rope pump regarding the implementation of the present pump (5.1) and for research and development (5.2). We also include the possibiltles for the special models of the rope pump described In the fourth part: the pump on a drilled well, post–mounted, fcr high discharge, with a motor, and with a windmill. And finally, we mention some research aspects with respect to construction, making reference to the respective sections in the second part.

5.1 Implementation

Given the characteristics described previously, we can conclude that the rope pump can be implemented without any problems under the following conditions:
- The well can be drilled or dug by hand and up to 25 meters deep.
- It can be a public or private well, but there must be some social control.
- The daily pumping is 4 m3 or less.
- The pump can be a model for an drilled or dug well, with a high discharge or post–mounted.

With close follow-up, the implementation of the pump under the following conditions can also be considered:
- A well up to 40 meters deep and/or with a demand of up to 8 m3 daily.
- A pump with a motor.

In Nicaragua every day the conviction becomes more widespread that the rope pump is truly the most appropriate pump under the above–mentioned conditions, and as the conviction spreads so does the demand for the pump, on the part of individuals as well as small and large institutional projects. When questioned about the future of the rope pump, Humberto, a co-ordinator of promoters answers: *"...this depends on the consciousness regarding the problem that the pump is resolving in rural communities. This depends on the level of consciousness of the donor agencies as well as the institution that assumes any given project and their ability to recognize that here in this country, what is needed is something that we can resolve with our own resources..."*

For implementation to be carried out on a greater scale, the network of producers, suppliers, distributors and installers still needs to grow. This is important not only to increase coverage, but also to foment continuous development of the pump; in technical aspects as well as different methodologies forimplementation (user–building, sales, institutional projects). This support can be given through exchanges of experiences (constructive) or by competition (conflictive). Given that many enterprises and private cooperatives are interested in protecting their product and their market, a combination of these two factors which encourage development would be the most probable.

5.2 Research and development

One central problem in researching the rope pump is that at the present time no organization is directing resources specifically towards pump **research and development.** Consequently, any research carried out responds only to the necessities of a particular organization at a certain moment, in an ad-hoc manner, with no medium or long-term planning.

Another related aspect is that the possible applications of the rope pump cover different fields: the provision of drinking water through public wells, use of private wells, use of water for cattle, for irrigation on a small scale, etc. All of these fields have been traditionally attended to by different organizations. Although for each application the problems are different (in technical aspects as much as in the methodology of implementation), it is not recommended that a different organization dedicate itself to each area. However, in Nicaragua today no multi-disciplinary organization exists that could attend to all of the above mentioned fields.

For these two reasons it is difficult to predict how and where research will develop in the coming years.

In general, we can define some areas of interest which we believe should be prioritized:

- As regards the model implemented by the DAR-Region V that is amply described in the second part, the necessity and possibility of improving certain elements should be studied, in particular the blockage system.
- For communal wells with more users and less social control (particularly with drilled wells), a more robust and vandalism-resistant model should be developed with better protection particularly for the rope. Price is not important in these cases; since a drilled well costs between $2,000 - $3,000, the $50 - $100 for a rope pump is not a signficant component. At the present time the DAR-Region V is working on this.
- It would be interesting to work in the development of pumps for pumping heads above 40 meters, maintaining high efficiency rates. At the present time, the DAR-Region V isworking on this.
- It would be important to monitor a large quantity of rope pumps regarding their useful life for different parts, to be able to know how to improve the design as well as to know the requirements for maintenance and the useful life of the pump, in partic-

ular for the blockage system and the different types of pistons and guides.

- It would be important to more systematically research the protection the rope pump provides against possible contamination of well water, and the possible measures to improve this protection if necessary.
- To attain the highest efficiency rate of the pump, particularly for great depth and in the long term, the wear on the injected pistons of different flexible materials (soft PVC, rubber) that permit less play should be investigated.
- As regards the special models described in the fourth part:
  - The models for drilled wells, for high discharges and post–mounted do not need to be improved at the moment. However, frequent monitoring would be appropriate.
  - The motor–driven rope pump functions in a satisfactory manner for wells that are relatively shallow. It would be important to widen the functioning area and look for its limits (for example, to what depth can pumping be done from a drilled well). Frequent monitoring would also be important. At the present time, the "Rope pump society" is involved in this work.
  - In the rope pump with a windmill, complete development is still lacking in the construction field, in the study of volumes pumped according to the wind speed, the demands for irrigation and/or drinking water, and economic feasibility studies before thinking of implementing it. Ignacio Lopez' workshop is involved in the technical development of the windmill.

With these perspectives regarding the future we conclude the first part, which is the general part of the book. In the second part we will enter into construction details of the pump.

Photo 14 (overleaf): User–built pump

Note the use of only local materials. The use of the container as the outlet spout is interesting (Chinandega).

2

Construction

**If you consult enough experts,
you can confirm any opinion.**

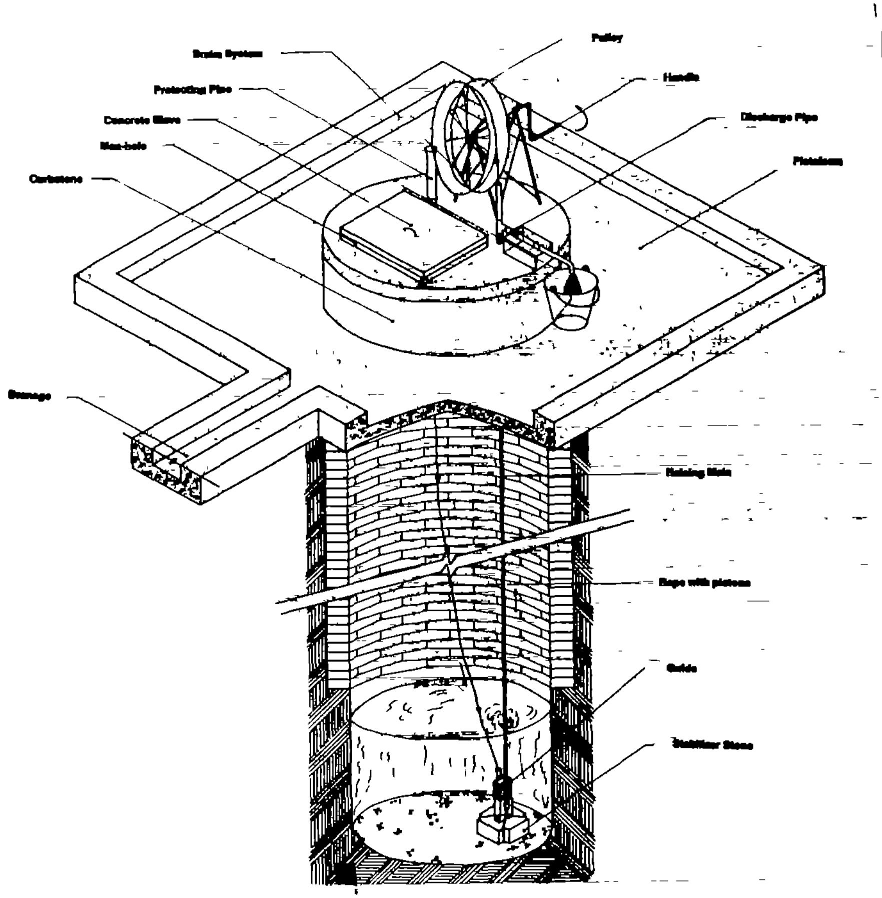


Figure 6.1: Complete pump

Chapter 6:
Description of the pump

In this second part, which is directed towards the technicians who will design and build the pump, we explain its construction and design in detail.
Following a more detailed general description of the pump than in section 6.1, we have analyzed the different parts:
- slab;
- pulley wheel;
- pistons, rope, and raising main;
- guide and stabilizing stone;
- discharge spouts.

We use the pump that DAR-Region V is installing in the community wells as an example, but always present other alternatives. We compare the alternatives in tables, in which the option of DAR-Region V is always in the first column and highlighted.
Where possible, the characteristics are quantified, but in some cases we give a relative comparative rating that varies between very bad and very good: --, -, +-, + and ++. Not all of the characteristics are mentioned; only those that demonstrate a difference between the alternatives.
If we are aware of alternatives, but do not have hands-on experience with them, we simply mention them in a footnote.

6.1 General Description

Figure 6.1 demonstrates a rope pump such as one installed in DAR-Region V. The visible part is made up of a **pulley wheel handle** which activates a **pulley wheel,** which is connected to a **support structure** through split **bearings.** The support structure—in this case made of welded iron—can also be made of wood. Another visible part is the **discharge spout** of the PVC tubes. However, the heart of the pump is a **rope** that has pistons every two meters. These pistons can be cut from an old inner tube, turned from wood or extruded from PE or PP. The rope passes over the pulley wheel and enters the **protection tube,** which serves as a guide to pass through the **well slab** of concrete or wood. Within the well, the rope lowers freely. At the bottom, under the water level, a **guide** (of glazed ceramic or wood) assures the fluid entry of the rope with the pistons in the **raising main** (common PVC, with diameter depending on depth, commonly 1/2", 3/4" or 1"). When raised, the rope with the pistons goes inside the raising main and returns by the pulley wheel. In order to leave the most important parts visible, the figure does not show the **pulley wheel protector.**

When the pulley wheel handle is turned, the pulley wheel is activated and friction makes the rope turn. The pistons fit with minimum play into the raising main and each one brings a certain quantity of water up. Once the tube is filled with water, the water column moves uniformly up, pulled by the pistons, with a speed a little less than the rope (this is due to the leakage between the pistons and the raising main). It can be said that the entire raising main functions as a a very long cylinder in which the pistons move in just one direction. At the top, the raising main is connected to the discharge spout, and through a T–joint the pumped water is diverted to the user's bucket. The outlet has a larger diameter to permit the water to be diverted around the pistons and not overflow from the top.

The weight of the water column exerts force on the pistons, these on the rope, and this transmits by friction the force on the pulley wheel. When finished pumping, the pulley wheel and the handle turn back in the opposite direction of the pumping, with the weight of the water column. At depths greater than ten meters, a blockage system is needed to prevent the pulley wheel handle from hitting the users and the loss of the entire water column. Therefore the next user should not have to again fill the entire raising main, as long as the water has not been lost through the leakage that always exists between the pistons and the raising main.

This finishes the general description of the pump along with its functioning. In the rest of the chapter we describe all of the pieces of the pump part by part.

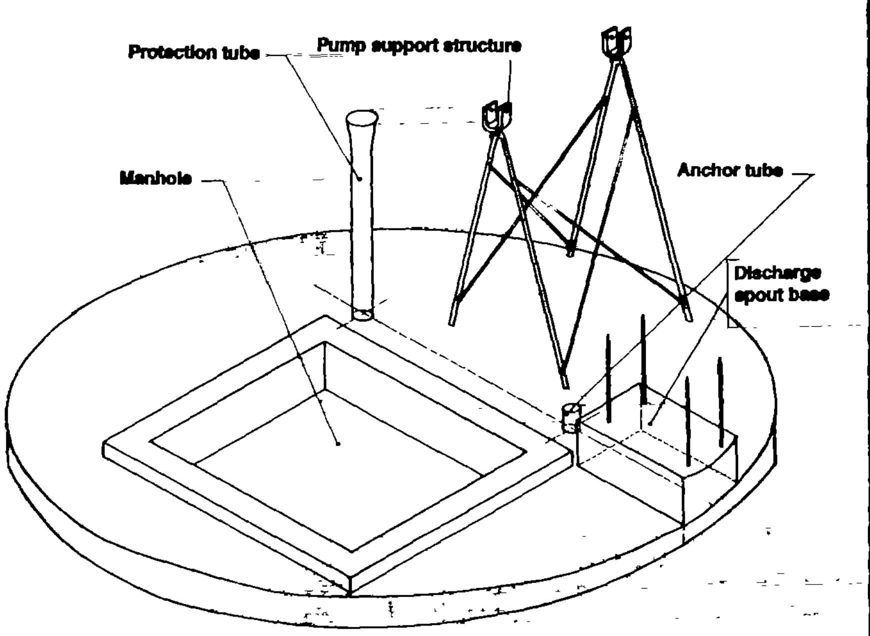


Figure 6.2: Concrete well slab

6.2 The well–slab

Figure 6.2 demonstrates the well-slab of the well; it is a **slab** of iron–reinforced concrete of 1/4" (3/8" if the diameter is greater than 1.2 m). The pump support is embedded in the slab. The **manhole** serves to install and take apart the pump, and to clean and deepen the well if necessary. It should be located very close to the support to facilitate installation and taking apart the pump. Its rim as well as the cover should be of concrete or iron (iron is more expensive but more hermetic and given the greater heat also serves to repel insects, etc). The **raising main** with the rope inside, comes out of the well through the **anchor tube.**

The rope crosses over the well-slab going inside the well through the **protection tube.** Both are made of PVC embedded in the concrete slab. The use of these tubes, together with the rim of the manhole keeps contaminated water that falls on the well-slab from entering the well. The location of these two tubes should be precise in order to avoid the rope rubbing against the openings of the tubes. The use and location of the base of the discharge spout are obvious. (Section 8.1explains the construction of the well-slab).

Alternative constructions

Although the model in this book has a concrete well-slab as is common in rural water supply and sanitation projects, the most common practice in Nicaragua is to leave the well exposed and to attach the pump to two wooden beams. It is also common to have a well-slab of planks. The characteristics of each option are demonstrated in table 6.1.

Table 6.1: Advantages and disadvantages of three types of well–slabs.

Criteria	1 concrete	2 planks	3 2 beams
Construction ease	+	++	++
Construction time and installation	8 wkhrs.	2 wkhrs.	2 wkhrs.
Protection of well	++	+-	--
Ease of dismantling	-	++	++
Weight	150 kg.	60 kg.	22 kg.
Useful life	20 yrs.	5 yrs.	5 yrs.
Price of materials	$10.00	$50/$2*	$15/$2*
Production level	home/local	home	home
Years of field experience	3 yrs.	8 yrs.	8 yrs.

* The first price reflects the purchase of the wood at market price; the second does not take into account the wood's value. It is very common in the countryside to simply cut down a few beams when one needs them.

Alternative 1: The making of the well-slab from concrete requires some knowledge of masonry, as well as a week of curing.

6.3 The pulley wheel

The **pulley wheel** (see figure 6.3 and Appendix C) is made up of the support structure, the axle with the pulley wheel and the pulley wheel handle, and the blockage system. It is the most complex piece; it contains all the moving parts and is subjected to the greatest concentration of forces.

The **axle,** made of a galvanized iron pipe of 1/2" or of 3/4", forms one single piece with the **pulley wheel handle** at one extreme and the **pulley wheel** at the other. In section 7.1 we explain why the height of the axle should be between 800 and 900 mm, and the radius of the pulley wheel handle between 250 and 300 mm.

Since the support structure is embedded in the concrete, it is important that the moving parts are easily moved. This is why the axle rotates in two **split bearings** which are replaceable with ease and make possible the quick dismantling of the axle.

Figure 6.4 demonstrates how the **pulley wheel** is made of two pieces of inner tube united under pressure by the portable pulleys. The form obtained is a "V," and guarantees high friction between the rope and the pulley wheel. The eight pulley supports are connected to the axle through spokes crossed as on a bicycle. The diameter of the pulley wheel depends, of course, on the availability of old tires but in section 7.2 we give criteria regarding the selection of the optimum diameter of the pulley wheel in relation to the other factors that influence it. We principally use old tires of 20", with an efective diameter of 540 mm. It is important that the tires be from heavy vehicles so that they are rigid and do not open with the pressure from therope.

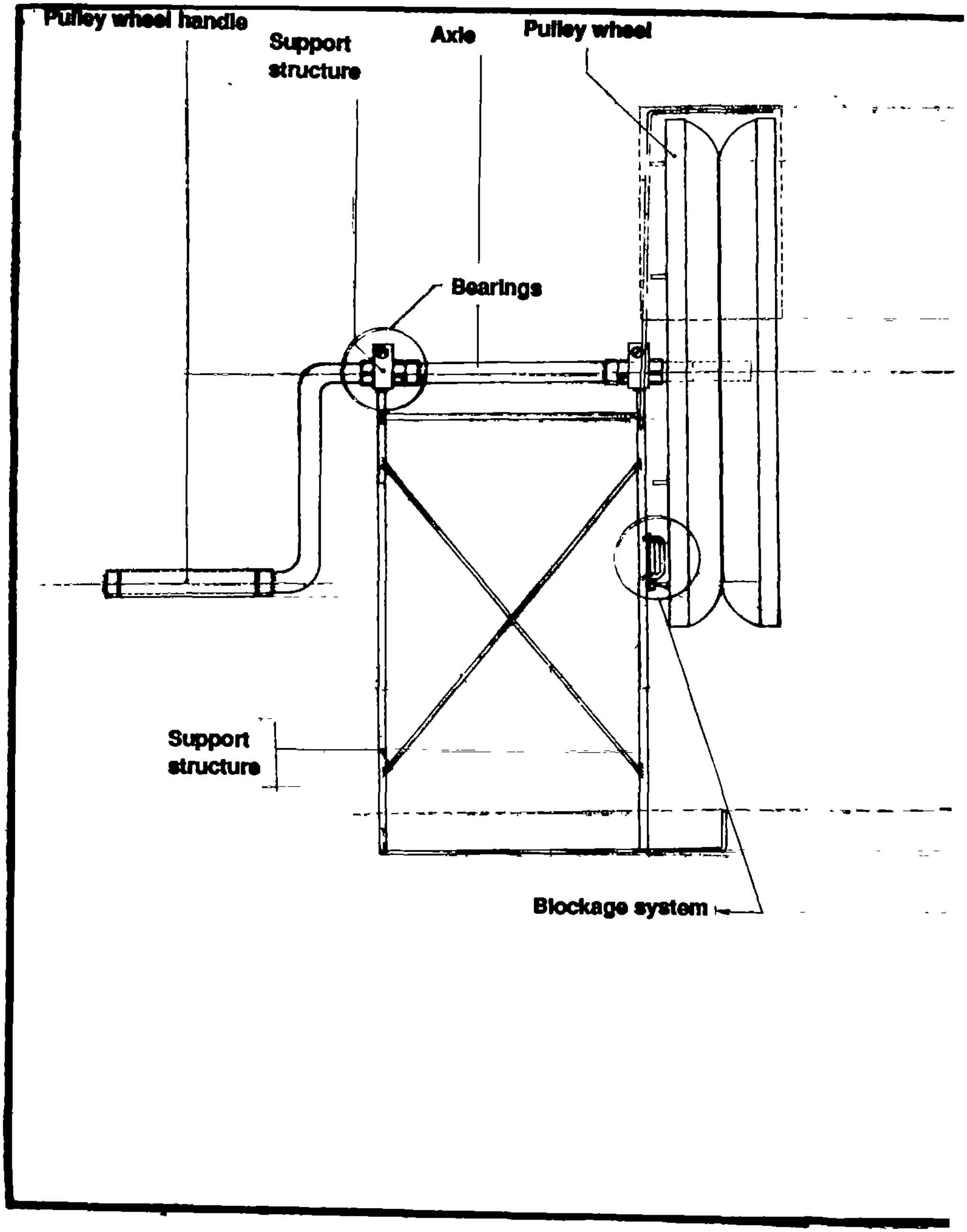
The **support structure** is immoving since it is embedded within the well-slab; it is important to protect it well against corrosion. We use an extra thick iron (5/8") for the feet. The piece can also be galvanized.4 The structure should resist force from all directions; particularly from children who use all of their body to move the pulley wheel handle.

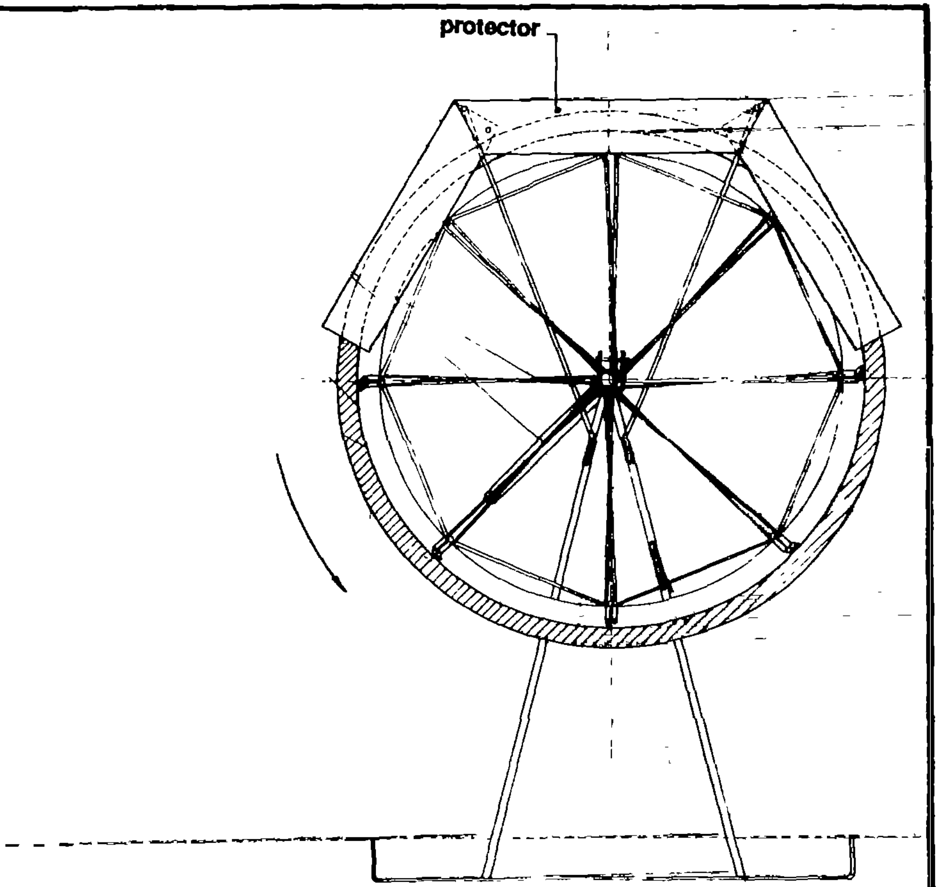
The **blockage system** (see photos 15 and 16) keeps the pulley wheel and handle from turning in the opposite direction of the pumping. It is subject to shocks. Its functioning is simple; the lever should allow the pins welded into the pulley wheel to go in one direction but not in the other. The lever is covered with a hose or inner tube to absorb shocks and lower the noise level (that bothers users). **One weakness of the design is that it is immoving,** given that it is welded to the support structure which is embedded. When a problem arises, there is no easy solution.

The **pulley wheel protector** is optional. It is made of sheet metal and rests on two iron 1/4" supports. Its function is principally to protect the rope and the pistons from the UV rays of the sun, from the dirty hands of the users (girls), and in some measure, protection from vandalism.

Before considering some construction alternatives, we emphasize the following; the wheel as it is described here and demonstrated in the plans, is made by two small enterprises with the most common and cheapest materials in Nicaragua. The design can be adapted without any problem to other materials if these are the most common. The sharp curves can also be changed by different constructions using welding (e.g. in the pulley wheel handle, the feet).

If the typical design presented in this book is abandoned with all of its variants described, an infinite number of very different de


Pulley wheel handle
Support structure
Axle
Pulley wheel
Bearings
Support structure
Blockage system

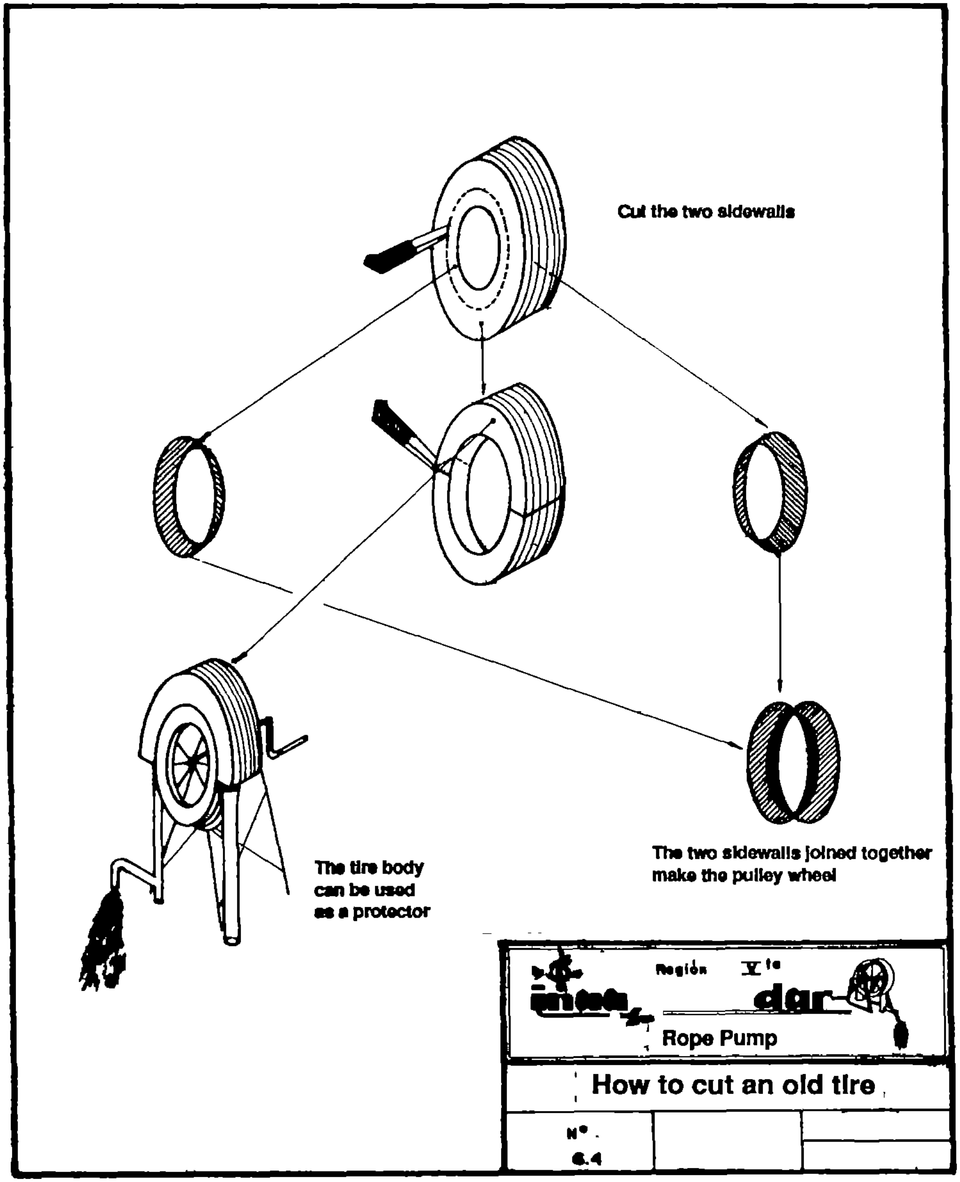


Región V ta

Rope Pump

Iron Wheel

N°: 6.3


Cut the two sidewalls
The tire body can be used as a protector
The two sidewalls joined together make the pulley wheel
Región
Rope Pump
How to cut an old tire
N°.
6.4

signs exist that range from only wooden structures to turned axles with ball bearings, etc. All of these are valid and depend on the creativity of the builder and the materials at their disposition.

However, it is important to always understand the background behind the construction alternatives to be able to design correctly under different conditions. It is also important to monitor innovations during a sufficient time period before implementing them on a large scale.

Alternative constructions.

We present here construction alternatives for three parts that have been discussed continually in Nicaragua in the last few years: the blockage system, the location of the pulley wheel, the suspension of the axle, and the pulley wheel protector.

Types of bearings

Traditionally, the rope pumps in Nicaragua have as bearings simply a fixed piece of tube within which an axle of 1/2" turns. This construction does not permit the changing of pieces if a saw and welding is not used. Particularly when the pump is embedded in concrete, it is extremely important to be able to take out the moving parts for any repair or change. This is why we have designed split bearings cut from a GI pipe.

(4). We have tried a moving support structure attaching it with anchor bolts embedded in the well-slab (similar to the system used with the Dempster pump), but the screws suffered heavy corrosion.

Table 6.2: Advantages and disadvantages of three types of bearings

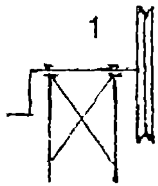
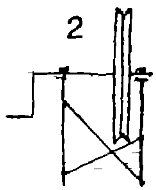
	1 Split bearings welded (Fig. A.2)	2 Split bearings bent (Photo 24)	3 Fixed bearings
Ease of replacing axle/bearings	++	++	--
Ease of construction	-	-	++
Initial price of bearing conjunction	$3.00	$2.50	$0.4
Price to change bearing	$1.50	$1.00	--
Years of field experience	-	1 year	8 years

<u>Alternative 2:</u> We have confirmed that the users have difficulty mounting these bearings. A lot of attention must be paid to this during training. This is why we began to design bearings of type 1. As the promoter Humberto comments regarding the bearings: *"With these 12 pumps, one was damaged by the bearings. The kids lose them because the bearings are a little mobile, and so this has meant that they get lost. The pump continues to turn but the pulley wheel handles gets worn out..."*

Blockage system.

Only in the case of shallow wells or of adult or experienced users can the discarding of the blockage system be contemplated. In all the other cases, it must be considered as an important security system. A type of construction that can compete with the design in this book is the pawl shown in the photo #16 (See table)

Table 6.3: Advantages and disadvantages of the two pulley wheel locations

	1 	2 
Rigidity of the support	++	+-
Maximum force on the bearing of the pulley wheel*	3.1	3.3
Maximum force on the bearings of the handle*	3.6	4.3
Ease for installing the pump**	++	+
Years of field experience	1 year	8 years

* The maximum force on the bearings is at the same time a measure according to the maximum load of the axle. It is expressed as a factor of the static force of the weight of the water column (which is assigned the value of '1'). For the two models the same distance between the raising main and the wall of the well is assumed.

** The distance between the pulley wheel and the manhole (see figure 6.1) should be minimal to facilitate the dismantling/installation of the tube of the raising main.

Photo 15: Blocking system used in the DAR–Region V

The rod allows the pins welded to the pulley to pass in one direction but not in reverse.

Photo 16: Alternative blocking system

This system has the characteristics of a party noise maker. It is strong but requires a lot of work and materials (El Papayal).

Table 6.4: Advantages and disadvantages of two blockage systems

	1	2
No. of stops per turn	8	16
Maximum free angle	50	22.5
Kinetic energy to absorb	(J) 18 J	8 J
Arm (mm)	250 mm	80 mm
Energy/arm (J/m)	72 J/m	100 J/m
Shock absorption possibilities	++	-
Ease of production and price	+	+
Years of field experience	1	1

Note: A blockage system design exists that consists of three teeth on the axle which although it does have enough strength, is well distributed. We mention this case because it is shown in various photos.

Location of the pulley wheel

While the model described here has a pulley wheel outside the support, the majority of the pumps in Nicaragua have a pulley wheel between the two bearings. Although this construction is not bad in itself, we think that it does not present any advantage over the design presented in this book. See table 6.4.

In alternative 2, the bearing of the pulley wheel handle is the only one that is rigid in the direction of the axle.

Protection for the pulley wheel

To protect the rope and the pulley wheel from the sun, dirty hands, and possible flies, various alternatives exist. Until now none could be implemented on a large scale, mostly because the users do not give them priority.

Table 6.5: Advantages and disadvantages of four types of protection systems

	Sheet Metal	Old Tire	Wood	Nothing
Water Protection	??	??	??	??
Protection against vandalism	-+	-	++	--
Protection of rope	++	++	++	--
Protection against insect nests	+	+	--	++
Esthetics	++	-	+	++
Acceptance by users	??	??	+	++
Price	$6.00	$0.00	$13/0	$0.00
Level of production	local	home	home	home
Years of field experience	1/2 yr.	1/2 yr	1 year	8 years

* The first price takes into account the purchase of wood at market price; the second does not take into account the value of the wood.

6.4 Pistons, rope and raising main

The **rope** within the pistons is 3 to 6 mm in diameter (generally 5), independent of the raising main's diameter and the depth (at least up to 40 meters). It is made of PE fibers and with three strands. It is a very common rope and can easily be made by any artisan, although good quality guarantees a longer useful life. The rope is the piece of the pump that wears out the most, see section 3.1.

The **raising main** is made of common PVC. Although the procedures for assembling are analyzed in detail in section 8.2, we give a general description of the tubing here. The different tubes are glued to the flare to the bottom to minimize friction on the pistons. The extreme interior has a flare to facilitate the entrance of the pistons, and is fixed with an inner tube to the guide. 0.3m below the well=slab, it is widened with a simple reducer to the diameter of the discharge spout; this tube croses the well- slab by the anchor tube. The widening of the diameter is in order to diminish the vertical speed of the water so that it will come out through the discharge spout and will not flow over.

All of the raising main with the guide and stablizing stone are hung from the anchor tube through a **wedge**, made of a piece of tube with the same diameter as the discharge spout. This is then connected **without glue** (to facilitate its dismantling) to the discharge spout through a T–joint.

The **pistons** are attached to the rope by a piece of braided rope and burned at both ends: see section 8.2. If the rope is not tightly twisted, this method does not work, so the pistons must be secured with two simple knots. Particularly when using rubber washers, it is important that the opening through which the

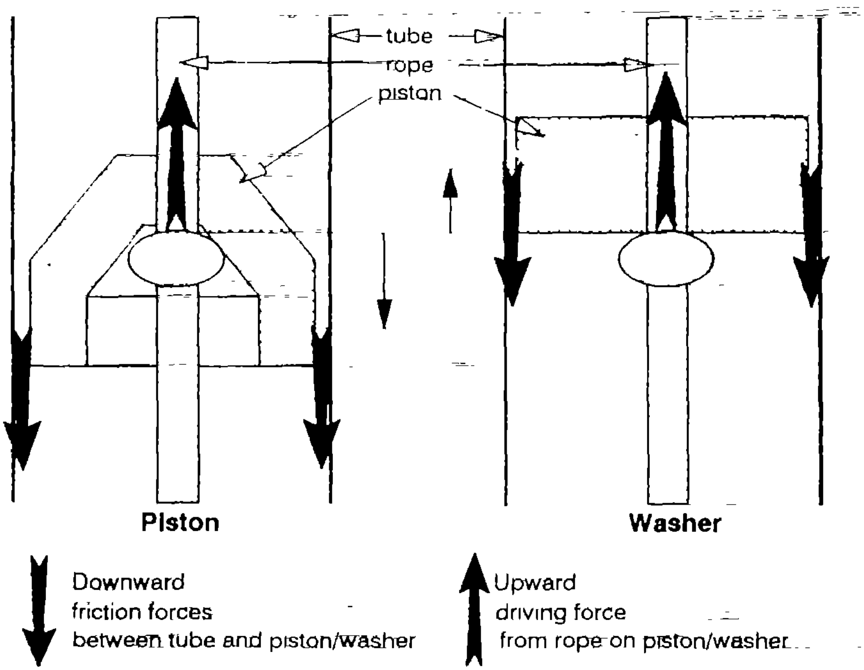


Figure 6.5: Forces acting on pistons vs. washers
(The hydraulic pressure is not shown to avoid complicating the figure.) Notice that in the case of the piston, the friction forces apply below the point of application of the force of the rope. In the case of the washer the opposite occurs, which provokes a lot of friction given the instability of the system.

rope comes out is as small as possible to minimize leakage and so that the tightness of the rope can direct the piston. The distance between pistons varies between 0.5 to 5 meters, depending on the quality of the piston. For example, for a piston with a play of 0.4mm, we recommend maintaining approximately 2 m. If the play is greater, the distance between the pistons should be less.

Through years of experience in Nicaragua, the pistons have gone through a fundamental improvement process, and it is primarily this improved design which has permitted us to achieve greater efficiency rates and greater depths than other rope pumps described in literature. The present pistons are made of polyethylene (PE) or polyepropilene (PP) injected 5, and has a conal form. As can be seen in the figure 6.5, the washer, the point of application of the friction forces (and also the resulting hydraulic pressure on the piston, is not show in the graphic) is located at a **higher point** compared to the force exerted by the rope on the piston through the knot. This provokes **instability,** which should be corrected continuously by more friction. To the

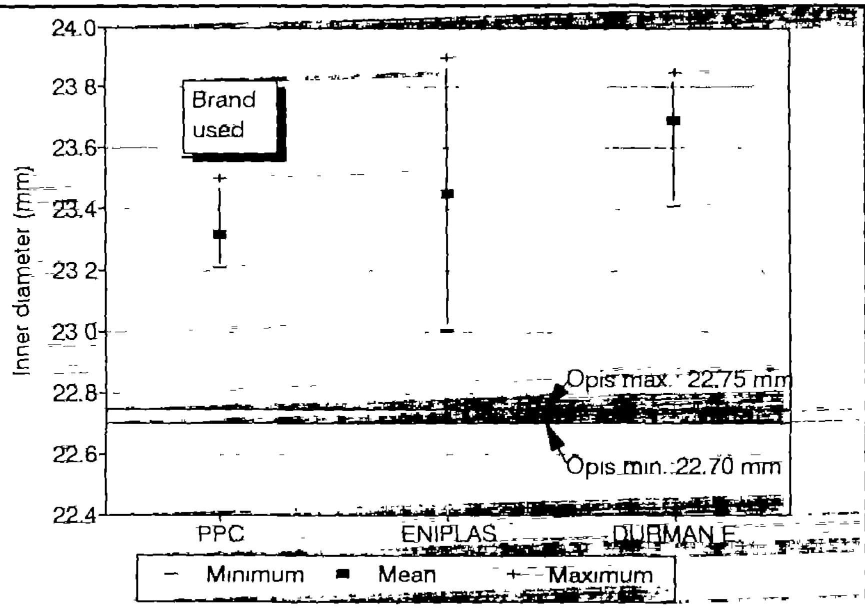


Figure 6.6: Variation of tube diameters

The figure illustrates the variation of the internal diameter of PVC tubes of 3/4"SDR 17 from three different factories. Note that the variation between the diameters of the pistons is much less than that of the tubes. Source: Heuthorst, 1991.

contrary, in the "new" model, the point of application, as well as the forces of friction as the result of the hydraulic pressure, are located **below** the upward force of the rope, creating a stable equilibrium.

In this manner, the friction between the pistons and the raising main has been significantly reduced, as well as the hydraulic losses due to the pistons leaning. The conic form also facilitates the passage through the guide and the entrance into the raising main.

Apart from the form, there is another crucial factor—the play between the piston and the raising main should be minimal. It is not possible to diminish the difference between the real diameters below 0.2 mm, because the variation in diameter of the tubing will not permit it. In fact,the pistons are made with greater precision than the tubing. See figure 6.6. Minimal play results in very high hydraulic efficiency rates, but it also has a cost–

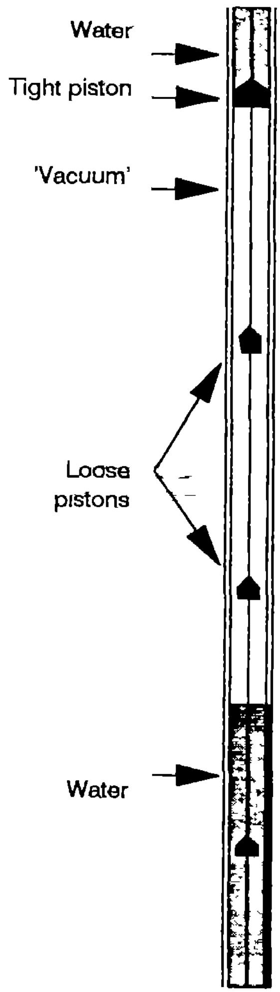


Figure 6.7
Creation of the "vacuum"

–any imperfection in the tubing obstructs the pistons. An imperfection could be any fissure in the tube (for example in the flare), a shock received, or dirt. Particuarly if the pumping head is less, it makes sense to opt for a greater play (up to 1 mm) to avoid these problems. In section 7.3 we study the effect of play on efficiency. For an illustration see table 6.6 for the measures for pistons and the raising main used in the DAR-Region V.

More important than the minimal play between the piston and the tube is the uniformity of the measures of the pistons. If they are not uniform, the leak in one piston will be much less than in the others, and only some pistons will work: figure 6.7. If a piston comes out tightly, an implosion will be heard given the vacuum created below it. This phenomenon not only negatively affects efficiency, but provokes greater and more irregular forces in the rope and tubing. This becomes a danger particularly when the pistons are made and corrected by hand, and at greater depths.

Table 6.6: Basic data on the raising main and the pistons

Characteristics	1	3/4"	1/2"
No. de Ident.	SDR 26	SDR 17	SDR13,5
Average interior diameter Otub (mm)	30.4 mm	23.3 mm	18.2 mm
Piston diameter Opis(mm)	29.8 mm	22.8 mm	17.8 mm
Play (mm)	0.6 mm	0.5 mm	0.4 mm
Diameter of discharge spout	1 1/2"	1 1/2"	1"
Depth aptitude (m)	0 - 12 m	10 - 25 m	20 - 35 m

This data is from pistons and used tubes by the DAR-Region V.
This table is just an illustration, not for directions!

Alternative constructions

The pistons can be made in many ways and with many materials (5), according to the necessity for high efficiency and the possibilities of production. We present here the most common alternatives with their appraisal, if this data exists.

Table 6.7: Advantages and disadvantages of four types of pistons

	1 PE or PP injected	2 Soft PVC	3 Wood	4 Rubber cut
Optimumform	++	+-	+	-
Precision/minimal play		+	++	+-
+-				
Resistance to wear	++	??	-	++
Maximum depth				
Proven (m)	40 m	40 m	30 m	25 m
Unit Price	0.06 -10$	0.?? $	$0.10	$0.00
Production level	regional	regional	local	home
Years field experience	6 yrs.	2 (?) yrs.	1 1/2 yrs	8 yrs.

Alternative 1: The technical specifications of these pistons are given in Appendix D.

Alternative 2: In reality, we have not had significant field experience with these pistons.

Alternative 3: These pistons can be made with a simple wood

(5) There is little difference in the mechanical characteristics between these two materials; both serve as material for the pistons.

lathe. The wood should be hard, fine, and water resistant. Preferably it should have resin to serve as a lubricant.(6) Some types used in Nicaragua are (in descending order): ambara = Granadilla (Algergia Retusa); Cortez (Tabebuia Guyacan); Guapinol(Hymenaea Courbaril); Coyote (Loncho Cartus Latifolius).

Alternative 4: Rubber from an old tire can be used, preferably between 8-12 mm thickness or from a bought rubber sheet. The punch should have its point of machibed steel, with an interior diameter that measures 0.1-0.3 mm less than the diameter of the piston desired. The punch is heated and without force the rubber is perforated. Depending upon the time the piston remains in the punch and its temperature, the rubber will burn longer. This influences the final diameter of the piston. A self-builder, Dorie, has a lot of experience with these pistons:

"...This type of pistons from a rubber tire are easier to make in the field and cheaper. It is not the same as making it with a hot punch or with a well-sharpened knife, as going to the factory to buy it. It is much cheaper to make it in the community."

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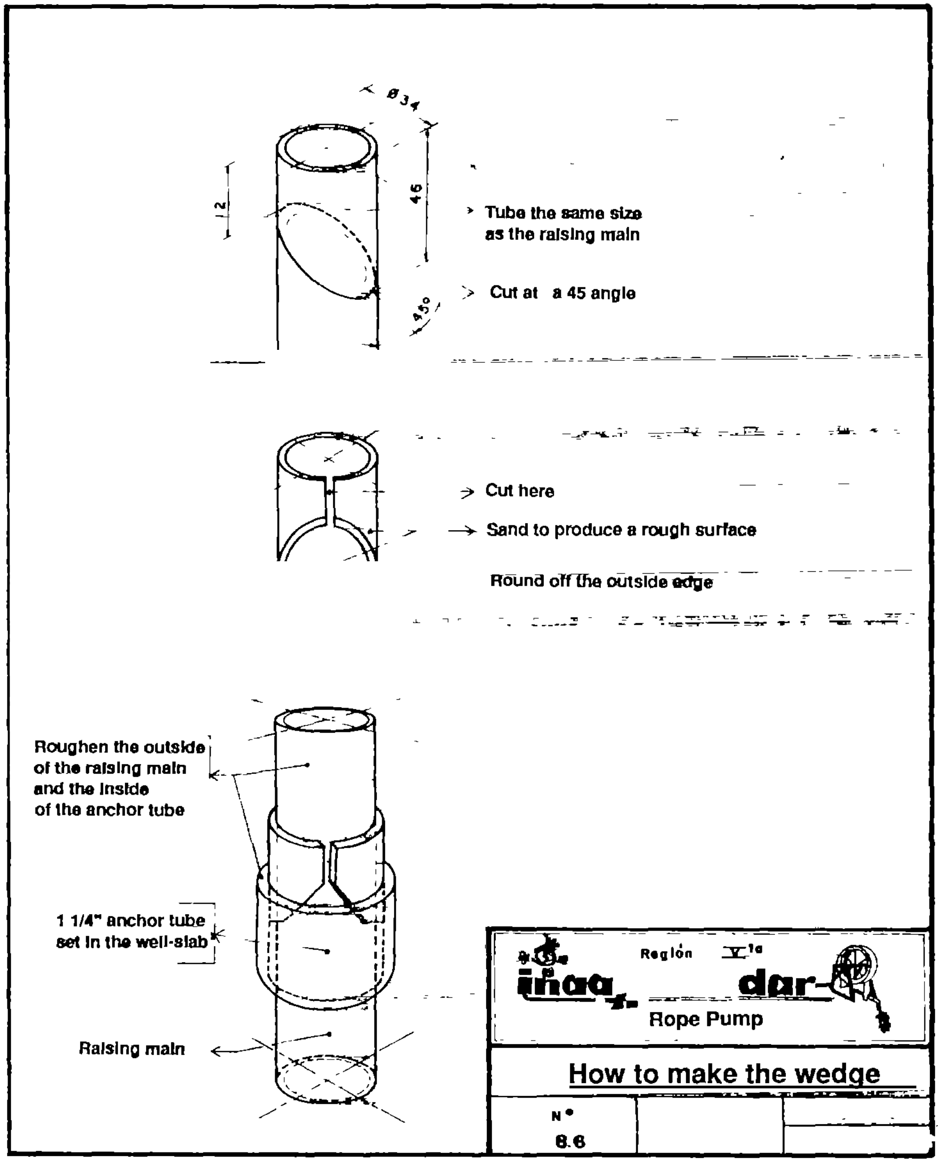
(6) Teijen, 1986 mentions **foam soles from sandals** as piston material. Given its flexibility, it could be an interesting option since it would minimize movement, but we don't have reliable data on wear.


Ø 34
45
12
45°
Tube the same size
as the raising main
Cut at a 45 angle
Cut here
Sand to produce a rough surface
Round off the outside edge
Roughen the outside
of the raising main
and the inside
of the anchor tube
1 1/4" anchor tube
set in the well-slab
Raising main
Región
Rope Pump
How to make the wedge
N°
6.6

6.5 Guide and stabilizing rock

The **guide**, shown in figure 6.8, is another key piece of the pump. Its function is to guide the rope and particularly the pistons into the raising main and keep them from rubbing against its entrance. It is essential with the guide to find the right combination of materials that will not wear out underneath the water—rope with glaze or glass.

While the guide is secured to the raising main with the inner tube, the connection with the **stabilizing stone** is done with a galvanized wire, rope, or the same inner tube. This stone weighs between 3-7 kg. and rests at the bottom of the well. It keeps the raising main from moving and guarantees a minimal distance between the opening of the tube and the bottom of the well (+_ 0.2m).

Alternative constructions

We have had good experience with four types of guides: hollow and solid glazed ceramic, wood with an isolator, and just wood. In table 6.8 we present some characteristics of each option.

Table 6.8 Advantages and disadvantages of five types of guides

	1 Solid Glazed Ceramic	2 Hollow Glazed Ceramic	3 Isolator with Wood	4 Isolator with Cement	5 Wood
Resistance to Wear	++	++	++	++	-
Resistance to Cracks	+	-	+	++	++
Water resistance	++	+	+-	++	+
Price	$0.00	$2.50	$3.00	$3.00	$1.50
Production Level	regional	regional	home	home	home
Years of field experience	2 yrs.	4 yrs.	7 yrs.	-	8 yrs.

Alternatives 1 and 2: A detailed description of their production can be found in Appendix E.
Alternative 3: This model consists of an isolator from electrical energy posts secured to a piece of wood.
Alternative 4: In addition to an isolator, this guide has 2 pieces of tube embedded, one connects with the raising main: it is not necessary to tie it to the raisng main with the inner tube/rubber strips. Besides, the greater weight makes the stabilizing stone unneccessary. This guide has considerable advantages. The only problem with implementation on a large scale is that it can be difficult to get access to the isolator.
Alternative 5: Regarding the wooden guide, the same observations apply as those made for wooden pistons.
Don Pompilio comments on the useful life compared to the

guide with isolator: *"...I brought a new guide with isolator. Before we had put in a piece of wood with a hole, and it was not working any more because it had had the same guide for three years. It was too worn down. It was not the same as this one with the isolator."*

6.6 The discharge spouts

The **discharge spouts** serve to divert the pumped water from the raising main to the user's bucket. As shown in the photographs in this book, it consists of a container with a greater diameter than the raising main, to permit the water to be diverted around the piston. In our case it consists of pipe with a larger diameter than the raising main given the relation demonstrated in table 6.6. It includes a T–joint, a piece of horizontal tube with an elbow at the end (this is not indispensable) and a piece of vertical tube to avoid the water from overflowing. The well-slab is secured through two iron jointings 1/4". To permit the dismantling of the pump, the T–joint is not glued to the raising main.

Construction Alternatives (7)

Although the great majority of the discharge spouts are made of PVC, there are some made of galvanized iron:

(7) In Guatemala the discharge spout has been replaced in some experiments with a cement chamber (called a flare). It seems to work well, but as all other forms it requires a PVC raising main. We do not see much advantage in using this other construction method, with a great work investment, for a piece that can be made with the same standard PVC tubing.

Table 6.9: Advantages and disadvantages of the PVC and GI discharge spouts

	PVC	Galvanized Iron
Resistance to vandalism	-	++
Installation ease	++	--
Life duration	4 years	15 years*
Price of a 1" pipe	$1.20	$8.40
Price of a 1 1/2" pipe	$2.40	$12.50
Production level	National	National
Years of field experience	8 years	3 years

* Note that this is more than the useful life that we attribute to the support structure (10 years).

Alternative 2: The use of galvanized iron pipes in the discharge spouts to guarantee greater protection against vandalism is onlyvalid when the rope also is well-protected, given that this is the piece most vulnerable to vandalism. Its installation requires plumbing tools (pipe cutters, adjustable wrenches for pipes).

In this chapter we have discussed the different construction alternatives for all of the elements of the pump: the well-slab, pulley wheel, pistons, rope, tubing, and guide. In the following chapter, we will see how to calculate certain key measures of the pump.

Dorie Bargman and Willian Israel Torrez Munguia "Puente de Paz"

What is the purpose of promoting the use of the rope pump?

"We, as Puente de Paz, have been working here in potable water projects in the countryside. The purpose and objective of installing rope pumps is to provide a safer method for drawing water. It is also to have an impact on health, because the well is more or less covered. When the wells are communal we install the pumps and request that they use concrete. And when the wells are private, what we do depends on the resources of the individual. But the wells must always be covered and given a chlorine treatment in order to have a positive effect on health and make things easier."

What are the characteristics of your rope pump?

"In the communities, with the owners, we all construct the pumps out of wood, because the low cost makes it more accesible to the population. The wood can be found in the countryside. We supply the tubes or we buy imported tubes, and there are homemade ways to construct them. The type of piston we make is totally homemade; we use an old tire, and the wheel around the handle is also of rubber. Everything is simple."

"The type of handle that we use is easy to take apart. There are only three pieces so it is easier to take apart and put back together. Any damage to the pump during use can be easily repaired by the user, even without a wrench, because it is screwed together so with little effort it can be taken apart."

"If the wood rots, they can look for a carpenter to do the work, while a pump made of iron would require the help of a welder. And in some areas where one has to travel for hours, or there is no vehicular access, many people are not going to care enough to do that work
They will just uncover the well and begin to use buckets."

Do you conduct maintenance training?
"The training is sufficient because the user builds alongside us and as we go along we explain each step. The construction isn't complicated; there's only measuring to be done. The installation is a practical matter. In terms of maintenance, the owners or the community have constructed the pumps with us so they feel capable and confident in taking them apart, putting them back together, and changing parts."

Who participates most in the construction and installation, and what have been the results?
"Those that participate most in terms of construction are the men. When it is time to do the installation, the women become more involved, but all they have to do is observe. And the women are the ones that draw the water."

"The first model we made had its faults, and we went about fixing it up, adding a few things, putting them on and taking them off until we had arrived at the model we have now. The experience has yielded positive results. We show samples to the people, explaining the advantages and disadvantages. We show them samples of wood and we provide other, easier alternatives for making the guides, and let them decide."

"The rope pump is a technology developed here in Nicaragua. Demster, another type of hand pump, comes from the U.S.; and with the embargo, who could find replacement parts during the war? Yet, although there is no longer an embargo in effect, it is difficult and expensive, and access to parts can't be guaranteed in the countryside, maybe in the city they are, but not in the countryside."

"Those that do the construction are the people, the users, with our help. They support these rope pump projects because they are more accessible and less expensive. According to our experience, they have worked out well so far. No one has come to us with complaints. Instead, they help us out, and come to us for help in the construction of their own pumps."

Chapter 7: Mechanical and hydraulic characteristics

For easy and efficient operation, it's important that the pump be **designed according to the size of the user**, so that the human part of the task is easier. This means that the physical strength of the user must be taken into account when calculating the relationship between the size of the pulley wheel crank and the force and power needed to operate the pump. The study of this relationship is called ergonomics.

In this chapter we will first define the relevant ergonomic parameters; then we will show how to choose the size of the wheel and raising main according to the depth of the well; and finally we will see how these factors influence the efficiency of the pump. In the text, we will limit ourselves to presenting the minimum amount of information necessary to understand these phenomena, and we give general instructions. For the complete calculations, we refer to Appendixes F and G.

7.1 Ergonomic factors

Below we explain the most relevant ergonomic factors. We give estimated values according to practical experience and the available literature.

–The determining factor in manual pumping is the **available human power**, that is, the force with which the user turns the pulley wheel crank. During a period of 1 to 5 minutes, **a child can generate approximately 40 watts, while an adult man can**

Photo 18: Why so high???

In determining the proper height, one must keep in mind not only the average height of the users, but the height of the littlest as well! (El Pochote).

generate up to 150 watts. Let's visualize these values: a child who generates a force of 40 watts pumping a well that is 10 meters deep will take a little longer than one minute to fill a 20 liter bucket. An adult man who generates 150 watts can do the same in 20 seconds. If, on the other hand, the well is 40 meters deep, the child will have to pump almost five minutes, while the adult man can do it in a little more than 1–1/2 minutes.

–To generate maximum power, the **maximum force exerted on the pulley wheel crank should be 50 – 120 Newtons** (5 – 12 kilos). This is if both arms are used.

–To generate maximum power, the **maximum turning speed of the pulley wheel crank should be 0.7 – 1 revolutions per second.**

It is very important to take into account certain dimensions that influence how much energy a person can generate and how long it takes for him/her to get tired:
–Since the operation of the pump consists of a turning motion, the ideal height of the axle should be a little higher than the average elbow height of the users. At thisheight, there is the least amount of useless movement of the rest of the body. For Latin American adult women, the ideal axle height is between 1 and 1.2 meters.
–With the same goal of avoiding useless body movement, the distance between the axle and the grip of the pulley wheel handle (handle radius) should be equal to the distance between the elbow and the center of the closed hand. Again, for Latin American adult women, the ideal length is between 0.27 and 0.33 meters.
–To be able to operate the pulley wheel crank with both hands, the crank handle should be at least 0.3 meters long. The apron should also be built in such a way that the user can easily position herself.

In choosing these dimensions, it is important not only to adapt them to the average size of the users, but to also take into account the smallest and weakest users. For example, a community well should be designed taking children into account, while an irrigation pump may possibly be used only by men. The dimensions used by the DAR in Region V for community well pumps are:
- axle height: 0.8 to 0.95 meters
- handle radius: 0.28 meters
- initial force: 40 – 100 watts.

With this information we can calculate the amount of water a person can lift in a given amount of time, and how the load and the speed of the pulley wheel handle should be selected for the most efficient operation by the user. On this basis, in the next two sections we calculate the factors that need to be taken into account so that both the person and the pump perform as efficiently as possible.

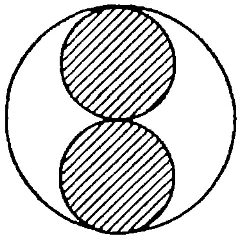
7.2 Choosing diameters for the pulley wheel and the raising main

When the pumping head is greater, the weight of the water column is also greater. In order to not increase the force required on the handle given the greater weight of the water column being lifted, we can vary two factors: the diameter of the raising main and the diameter of the pulley wheel. One user, Ram;n Enrique, experienced this very directly:

"...The problem with the pump was that it had a one–inch pipe, not a 3/4", and it didn't work. The bigger the pistons, more strength was required, and in the 20 meter deep well, it was hard to turn. The rope wasn't the problem, the rope worked fine. Of course, the rope with that kind of pipe doesn't last as long because it has to work harder, there's more tension. When I saw that the pulley wheel was ruined and had a serious problem, I brought someone to help. Now, with this 3/4" tube it works fine. It would be good toput it in all the wells, or in any well that has a lot of water."

We will discuss first the influence of the **diameter of the raising main.**

The force on the pulley wheel crank depends on the weight of the water column lifted by the rope. It is as if the rope was lifting a very narrow and tall bucket (the width of the raising main and the length of the pumping head). If the well is deep, the force required to turn the crank is greater. If the diameter of the raising main is large, the force required is also greater. This means that for a shallow well, a bigger diameter raising main can be used; for a deep well, a smaller diameter tube is preferable. A raising main with bigger diameter requires more effort, but it yields a greater flow of water as well.



It is important to remember that by choosing a tube with a diameter, for example, two times greater, the volume of water (and therefore, the effort as well), increases by two multiplied by two, or four times. This is illustrated in the following graphic.

The second influencing factor is the **diameter of the pulley wheel.**

The combination of the crank handle and the pulley wheel acts like a lever: if the pulley wheel is smaller, the force felt on the crank handle is also less, but in turning the crank, the rope will also rise more slowly. Less force needs to be generated, but the volume of water lifted is also less. If, on the other hand, the pulley wheel has a **bigger** diameter, the force felt on the crank is also greater, and the rope will rise faster (with more volume). As we will see in section 7.3, for greatest efficiency, it is best to try to use the biggest possible pulley wheel.

In general, we recommend the measurements shown in Table 1. The measurements are general recommendations, and may vary according to the specific situation and needs of the users.

Table 7.1: Recommended pulley wheel and raising pipe diameters

Pumping head range (m)	0-6	0-10	10-20	20-30	30-40
Pulley wheel tire (")	20"	20"	20"	20"	12"
Raising main (")	11/2"	1"	3/4"	1/2"	1/2"
Effective pulley wheel diameter Opol (mm)	540mm	540mm	540mm	540mm	350mm
Raising main diameter Otub (mm)	44.5 mm	30.4 mm	23.3 mm	17.8 mm	17.8 mm

The shadowed ranges are the most common.
The calculations are noted in Appendix F.

We know that there are two factors that we can vary in order to optimize the system: the diameter of the pulley wheel and the diameter of the raising main. As is seen in Table 7.2, we prefer to vary the diameter of the raising main tube, leaving the pulley wheel the same. The other option would be to vary the pulley wheel, leaving the tube diameter the same. We don't have much experience with this alternative, mainly for fear of wearing out both the rope and the pulley wheel due to the great concentration of stresses that would be required. However, this option could be advantageous when the variations in the pumping head are relatively small.

Table 7.2: Advantages and disadvantages of varying the diameter of the raising main vs. the diameter of the pulley wheel

Vary raising main tube diameter; maintain pulley wheel diameter fixed:	Maintain raising main tube diameter; Vary pulley wheel diameter:
Standardization of wheels (1); range of pipes and pistons. Implies greater initial investment (molds for pistons) and greater diversification of PVC accesories and pistons (15 accesories).	Standardization of PVC accesories and pistons (6 accesories); range of 5 wheels. Getting enough tires of different sizes may be difficult.
Relatively low costs for deep wells due to small diameter tubing.	Costs go up according to well depth.
Maximum piston speed assures high efficiency.	Slower piston speed at great depth implies less efficiency.
Force exerted on blocking system, tension on rope, and intensity of friction between rope and pulley wheel do not significantly vary with well depth.	Force exerted on blocking system, tension on rope, and intensity of friction between rope and pulley wheel increase significantly with well depth.

7.3 Hydraulic and mechanical efficiency

Compared to other hand pumps, the efficiency of rope pumps is quite high. Optimizing efficiency is especially important in very deep wells and for irrigation applications. Understanding the factors that influence hydraulic and mechanical efficiency is essential in order to be able to give these aspects the necessary attention in the design and production phases.

The **total efficiency** of the pump ranges from 60% to 90%, a very high percentage for hand pumps. High efficiency is particularly important in deep wells where the pumping of water implies serious work. In wells with a pumping head of 35 or 40 meters—the deepest wells in which we've installed rope pumps—the efficiency is still very high, and it is only a question of testing the pump in even deeper wells to see whether the same efficiency holds up. The only reason this hasn't been done is because there aren't any deeper wells in the region.

Next, let's analyze efficiency: **the total efficiency of a pump is the product of hydraulic efficiency multiplied by mechanical efficiency.**

Mechanical efficiency is calculated as the loss of friction between the pistons, tubes and water, between the rope and the pulley wheel, the guide and the water, and in the bearings. By maintaining the bearings well greased, there's not much that can be done to improve this aspect: these frictions are low and inevitable. It is difficult to accurately measure mechanical efficiency, but on the basis of practical experience, we estimate it at 80 – 90%.

Hydraulic efficiency consists of the water leakage from the narrow gap that inevitably exists between the piston and the wall of the raising main. In other words, it is the difference between the speed of the water column and the speed of the rope and pistons. This efficiency level is easy to measure, and practical tests demonstrate that it varies between 80 and 95%. Hydraulic efficiency depends on various production factors,especially the play of the pistons and their speed. To understand more about the influence of each factor, the DAR–Region V developed a theoretical model that was tested in 53 practical tests (See annex G). The influence of the different factors on hydraulic efficiency is reflected in figures 7.1 – 7.3.

Next we introduce the factors that have a bearing on hydraulic efficiency, in descending order of importance:

- the gap between the pistons and the raising main tube;
- the speed of the pistons;
- the distance between pistons; and lastly,
- the diameter of the raising main tube.

The most important factor—and the most difficult to optimize—is the **gap between the piston and the raising main**, called δ.

As is seen in figure 7.1, hydraulic efficiency depends primarily on this gap; the downward curves are steeper than in the other graphics. Each tenth of a millimeter is important! We also see that the efficiency of a wider diameter tube is better than that of a narrower tube. This can be explained by the ratio of the surface of the ring through which water escapes to the total surface of the tube. This surface ratio, for a gap of any given measurement, is always greater in narrower tubes than in wider ones.

Our experience is that the minimum possible gap (difference in diameter between the raising main and a piston) is 0.2 mm. Such a small gap can be successfully used only when the tubing is of good quality and is installed with great precision.

Good quality tubing is judged by the uniformity of its interior diameter (see figure 6.6), its roundness, and the absence of irregularities such as, for example, constrictions at the base of the flare. The installers must work with great precision so that the pistons don't stick. They must also be able to detect the inevitable problems that arise with such little play.

We discuss this aspect more fully in Part 3. In less deep wells in particular, it may be much better to allow for more play, for example, a gap of 0.6 – 0.8 mm.

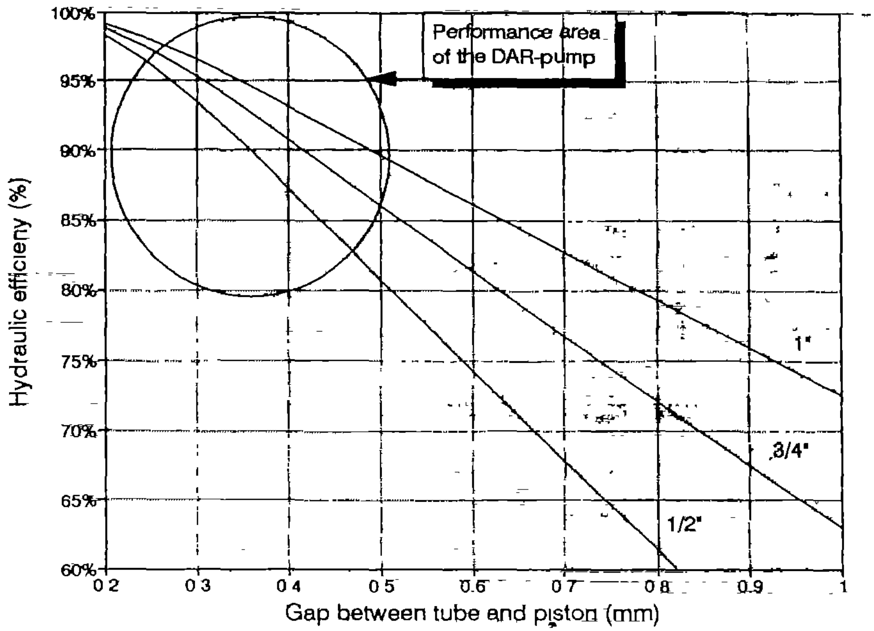


Figure 7.1: Hydraulic efficiency as a function of the gap between the pistons and the raising main tube Values valid for Hpis = 2 m and Vpis = 1.4 m/s.

The second most important factor is the **piston speed** (Vpis). As can be seen in figure 7.2, if the speed drops below 0.8 meters/second (m/s), the efficiency level drops drastically, but above a velocity of 1.8 m/s, efficiency does not increase significantly. The current speed is generally limited to 1.5 m/s, due to the diameter of the pulley wheel (maximum 540 mm., that is, a 20" tire), and the ergonomic characteristics of a maximum turning speed of the crank handle of one revolution per second. As we saw in the previous section, we can vary the force on the pulley wheel crank handle by varying the diameters of the tube and of the pulley wheel. This last variation directly affects the speed of the pistons. It is, therefore, preferable to choose a

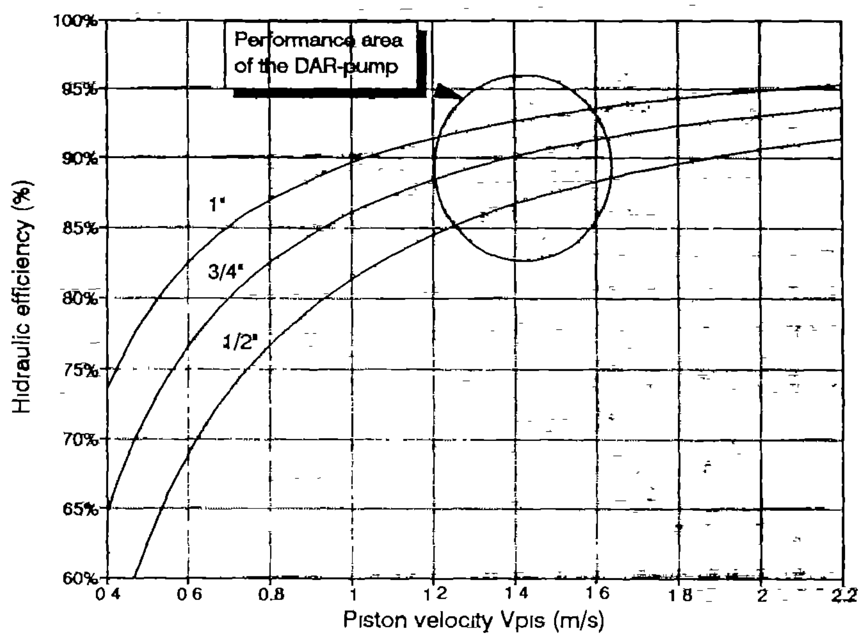


Figure 7.2: Hydraulic efficiency as a function of piston speed Vpis. Values are valid for δ= 0.4 mm and Hpis = 2 m.

narrower tube and guarantee greater speed with a bigger pulley wheel than to do the opposite: use a wider tube with lower speed. However, with the 20" tires used up until now, it will be difficult to achieve the 2 m/s speed that it considered optimal.

The third factor is the **distance between the pistons** (Hpis). Figure 7.3 shows that efficiency drops steadily but not very sharply. It is logical that minimizing this distance improves hydraulic efficiency, but at the same time, it causes a serious decline in hydraulic efficiency due to the friction between the pistons, water and raising main. We don't know the exact magnitude of this friction, but we suspect, based on experience, that the optimal distance is around 2 meters.

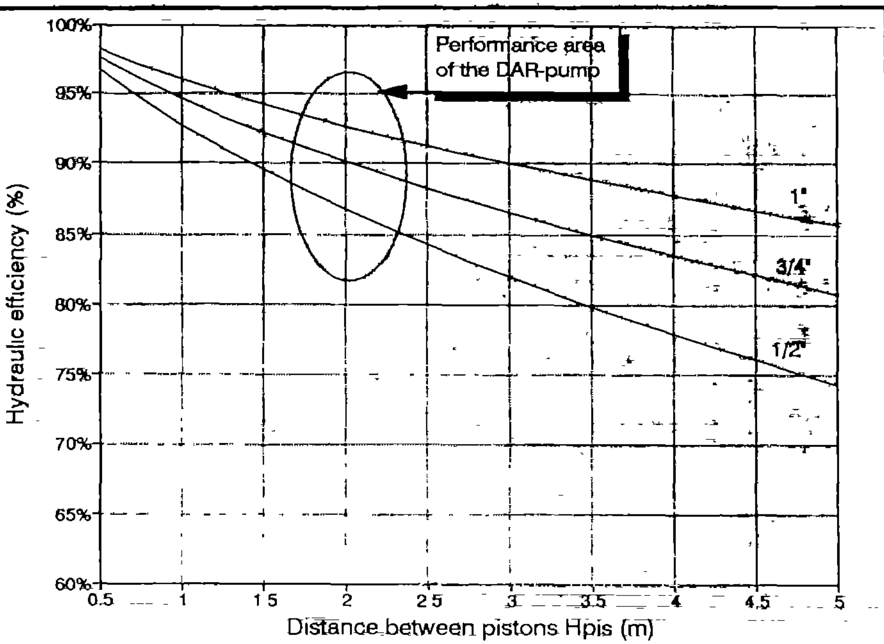


Figure 7.3: Hydraulic performance as a function of the distance between pistons Hpis.
Values are valid for δ= 0.4 mm and Vpis = 1.4 m/s.

As can be seen in the three graphics, a fourth influencing factor is the **diameter of the raising main tube** (Øtub). We have already explained how this affects efficiency. However, its impact is not sufficient to be able to optimize the pump's efficiency. For example, a 1" tube, at a speed of 0.5 m/s, results in poorer efficiency than a 1/2" tube at a speed of 1.5 m/s, although both combinations result in the same force exerted on the crank.

The main point of the graphics is to illustrate the effects of varying the different factors. If the dimensions of a pump approximate the values mentioned in the graphics, one can see the pump's true hydraulic efficiency. If the values are very different, the curves will be more or less steep, and the calculations in annex 7 would need to be consulted. However, in the majority of cases it is not important to know the precise hydraulic efficiency. Another factor that must be taken into account is that as the months go by, the pistons wear out, increasing play and affecting efficiency. Depending on use, we recommend changing the pistons every year or two, but if high efficiency is required, they can be changed more frequently.

With the information discussed in this chapter, pumps for all-common applications can be selected and designed. In other cases, for example, for very deep wells, for very big or very small wheels, etc. it would be important to refer to the calculations shown in annexes F and G.

Photo 19 (overleaf): A job for everyone
Pump installation over a drilled well. Note the 1/2" raising main on the left and the 3/4" protection tube on the right (El Pochote).

3

Installation, operation and management.

**Trust only those
who stand to lose as much as you do
when things go wrong.**

Chapter 8: Installation in hand–dug wells

In this chapter we give a detailed description of how to install a rope pump in hand–dug wells with a concrete slab, like that which is being used in the DAR in Region V in Nicaragua. This type of slab and pump is only one example; there are many possible alternatives. Although we don't go into detail about such alternatives here, we do refer to them in the second part.

The installation of the pump in the community well offers an excellent opportunity to train the users in the installation, operation and maintenance of the pump. Since all the activities are carried out in the same community, it is feasible for women to participate. As Cony, a promoter points out: "Just about everyone has the right to participate, and everyone can participate, including the women. The kids can participate in the installation and repair. It's not hard at all, that's how I see it."

As with any construction project in the countryside, **good planning is essential**. Having **all** the materials and resources in place, the pump can be installed in less than two half–days; one to pour the concrete slab, and a few hours the following week to complete the installation.

Before beginning the collection of materials, the diameters of the tube and the pulley wheel must be chosen according to the depth of the well. In section 7.2 we describe these procedures.

8.1 Construction of the slab

Here we list the necessary conditions and tools for the construction of the slab. The quantities listed here for the materiales are for a slab with a 1.2 meters diameter; for other sizes, the quanitities need to be adapted accordingly. We finish with a summary of the step–by–step procedures.

Conditions:

–a flat place near the well where the slab can be poured; a paved space is ideal, but not necessary.
–the possibility of building a fire in the same place (if this is not possible, the flare can be made before going out to the well).
–at least two people, one of which should have experience in masonry.
–availability of water to make the mix and to clean the tools.
–previously determined diameters for the raising main and the pulley wheel.

Necessary tools:

–a machete to clean the pouring area (if necessary)
–a pick to level the pouring area (if necessary)
–chalk to draw on the pavement (if there is a paved area for pouring)
–a 2 meter x 2 meter sheet of plastic to cover the ground.
–a strip of sheet metal (tin), 75 mm. x 4 meters, to make the outside slab mold
–2 shovels for mixing the concrete mix
–1 or 2 buckets
–1 or 2 masonry trowels
–1 or 2 pliers to twist the fastening wire
–a metal–cutting saw
–a wood–cutting saw

–a rasp
–a hammer
–a plumb bob
–a 3 meter measuring tape
–a knife
–a bottle with a neck of less than 18 mm. diameter

Optional tools:

–carpenter square
–a 1–meter long board for evening out the surface
–a fine screen sieve to strain sand

Materials:

–3 20–liter buckets of " gravel
–4 20–liter buckets of sand
–100 lbs. of cement
–24 meters of " iron rod
–10 meters of #18 or #20 fastening wire
–a pulley wheel of appropriate diameter
–4 meters of 1" x 4" wood for the mold of the manhole and the base for the outlet spout
–3 meters of 1" x 1" wood for the mold of the border of the manhole
–3 meters of 1" x 2" wood for the manhole cover mold
–approximately 25 2" nails
– if the pouring area is dirt, approximately 12 1" stakes, 300 mm. high; if the pouring area is paved, 10 2–5 kilo rocks
–100 mm. PVC delivery tubing. The diameter of the tube should be " bigger than the outlet spout tube (see table 6.6)
– 450 mm. of 1" PVC protector tube
–any kind of material that can protect the fresh slab from the sun (banana leaves, old newspapers, plastic)

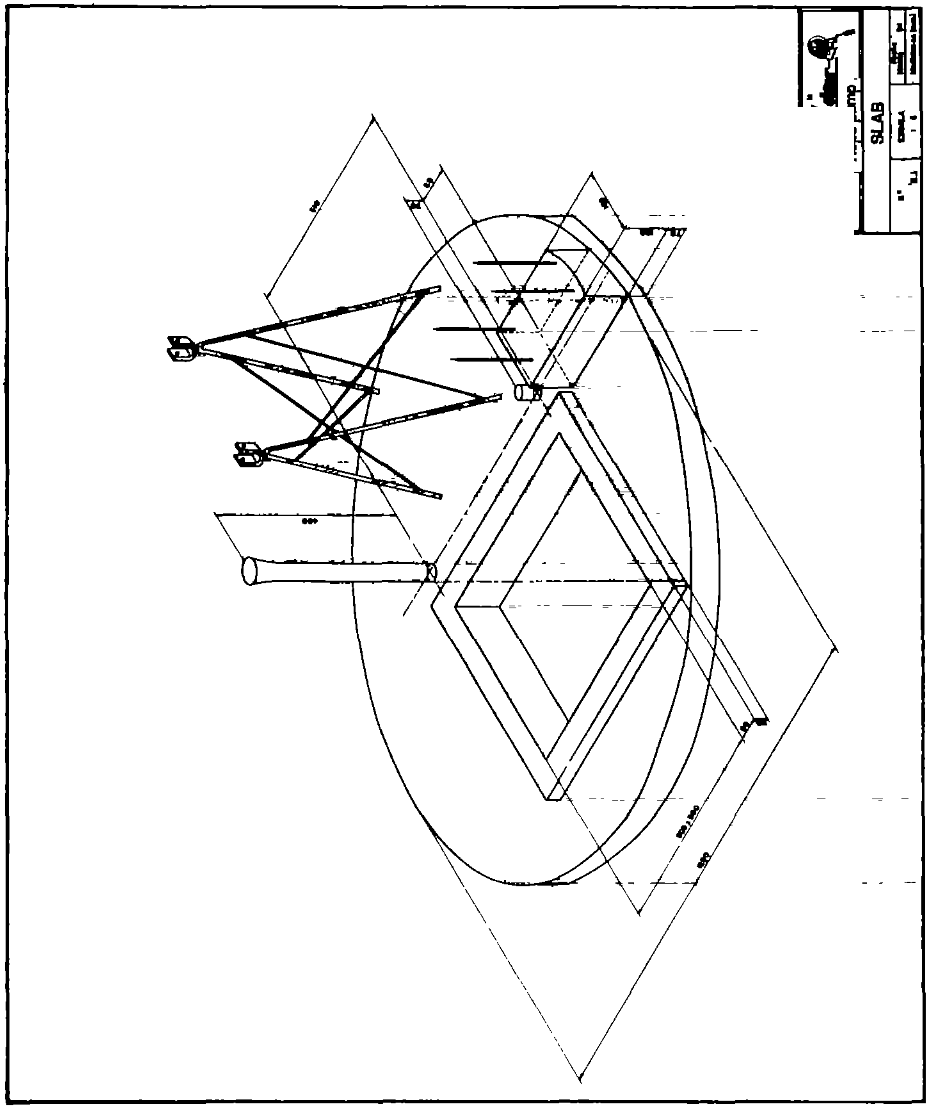
Photo 20: Putting together the well slab
The mold for the slab consists of a band of zinc held in place by rocks Observe the manhole, the anchor tube for the raising main, the protection tube, the iron rods fastening the outlet spout

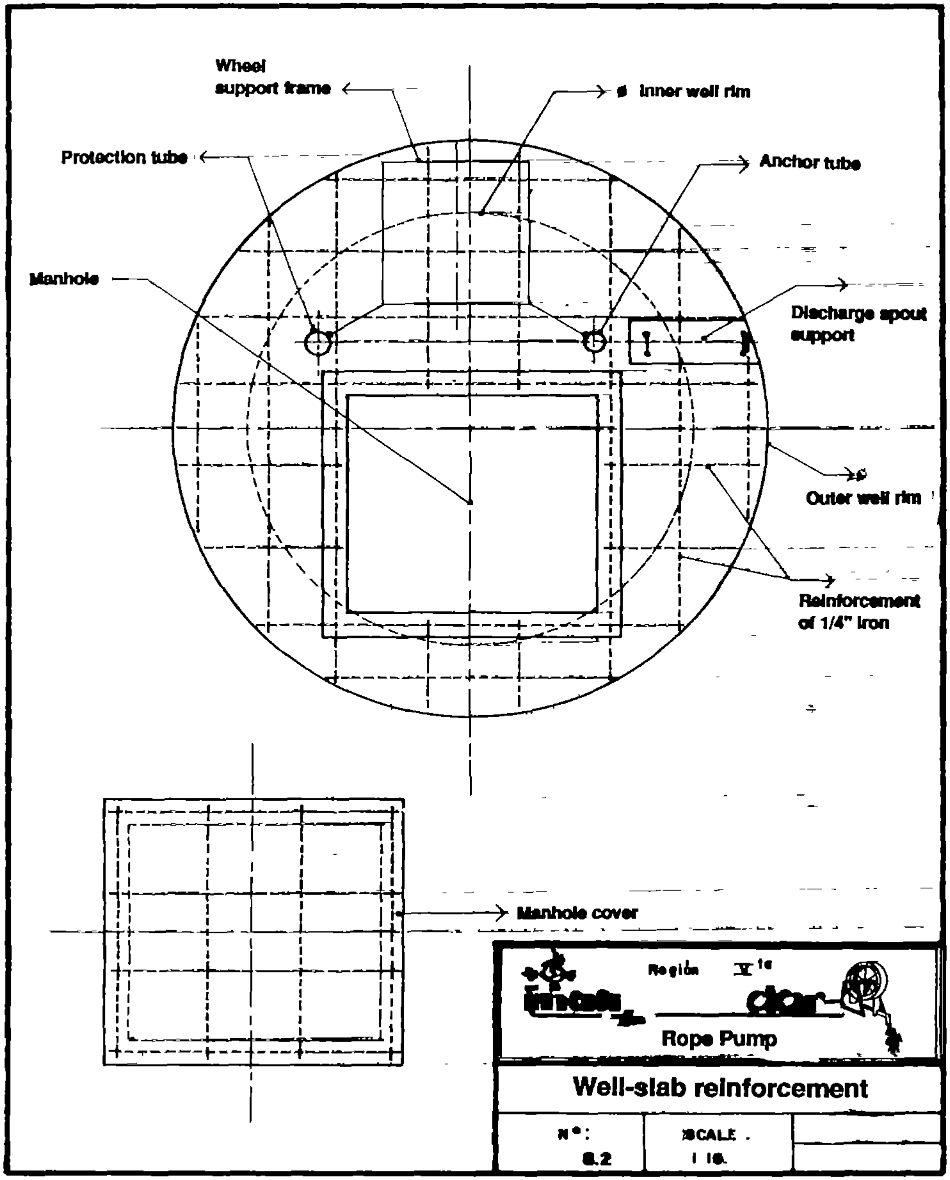
Photo 21: Cast well slab
The same slab shown in the photo at left. The pulley, whose only purpose was to put in place the anchor tube and the protection tube, is now gone. The protection tube with its flare is seen (Papayal).

Step–by–step instructions:

It is important not to work alone, but to organize the tasks in such a way as to involve as many people as possible: men, women and children. This is not only to make the work easier and faster, but to show how easy it is to make the slab and install the pump. Many of the activities described below can be done at the same time.

–Clean the place where the slab will be pour: it should be flat and preferably level. Lay out the plastic.
–Join the strip of sheet metal in a circle according to the diameter of the well, placing it on top of the plastic, with the stakes or


SLAB


Wheel support frame
ø Inner well rim
Protection tube
Anchor tube
Manhole
Discharge spout support
Outer well rim
Reinforcement of 1/4" iron
Manhole cover
Rope Pump
Well-slab reinforcement
8.2

rocks inside. Be careful not to cut your hands on the sheet metal!

–Determine the position of the pump, the outlet spout and the manhole (see figures 8.1 and 8.2).

–Make the frame for the manhole, nailing three 1" x 1"s in a U–shape, leaving the fourth side free to make it easier to lift the mold. Make the rim frame for the manhole and the frame for the base of the outlet spout.

–Make a flare on the protector tube (a similar flare will also be made on the lower tube; this is a more delicate task). The flare is made by heating the end of the tube over fire and inserting the bottleneck. It is important not to heat too much of the tube—just the end—or else the tube will get deformed and there will be a constriction (see figure 8.3) that will interfere with the movement of the pistons. You can avoid heating too much of

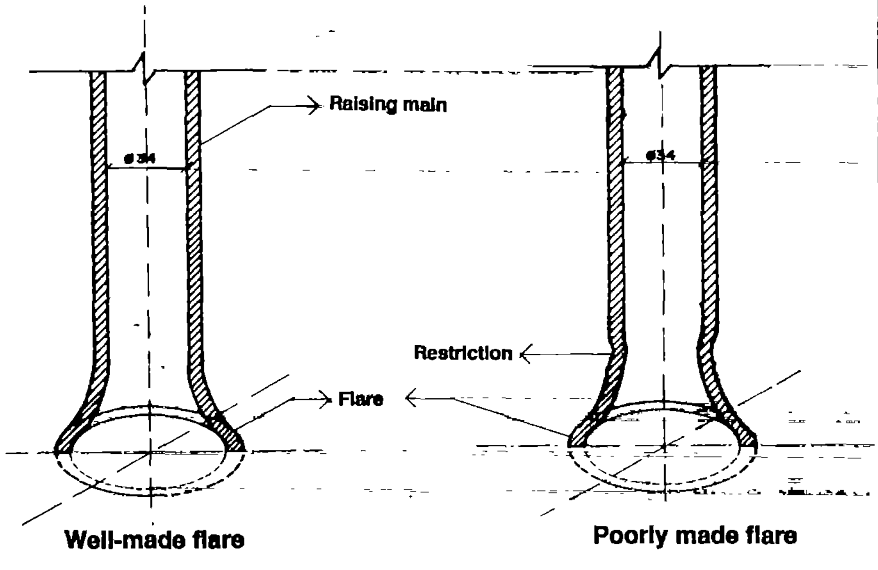


Figure 8.3: Restriction in the flare

the tube by wrapping the tube in wet rags or newspapers, leaving only the end for the flare exposed.
–Roughen the outside lower 100 mm. of the protector tube and of the PVC delivery tube that will be embedded in the concrete. The protector tube goes with the flare facing up so that the rope and pistons can enter easily.
–Cut the iron rod and brace the frame. The distance between rods should be 150–200 mm. (See figure 8.2). Position the pump support, placing it in such a way so that the iron rods don't interfere with the correct positioning of the delivery tube and protector tube.

It is important to position these two tubes exactly underneath the pulley wheel, using the plumb bob. If they are not positioned

Photo 22: Incorrect placement of the protection tube
This protection tube has no flare, and is badly placed: the rope, and in particular the knots and pistons rub against the tube and in a few months will be worn out.

correctly, or if they are not exactly vertical, the rope will rub against the tubes and will wear out very quickly; see photo #. When they are correctly positioned, fasten the support to the frame and the tubes to their respective guides in the wheel, and if possible, to the frame as well.

– Cut, position and fasten the two tall " iron rod 'U's to the frame. These will serve to secure the outlet spout.

–Make the mold for the manhole cover, and brace the frame.

– Sift half a bucket of sand, to be used later for the surface texturing.

–Make a mixture of 3 buckets of gravel, 3 of sand and 1 of cement. Thoroughly wet the frame and pour the slab. As the concrete fills the frame, take out the stakes or rocks. Make sure the water and protector tubes stay in their correct and upright position. The thickness of the slab should be 50 to 60 mm. Don't fill the mold with cement all the way up to the full height of the sheetmetal strip! Let the mixture dry about 10 minutes, then position the frame for the manhole rim and the frame for the base of the outlet spout on the moist mixture, and fill them.

–Wet the frame of the manhole cover and pour it.

– Make a mixture of half a bucket of sifted sana and bucket of cement for the surface texturing.

– Protect the slabs from the sun and the wind.

– After three hours, flood the slab with water, filling the extra 15–25 mm. of the sheetmetal mold. If this is not possible, make sure someone is able to wet the slab at least 6 times a day for curing.

8.2 Installation of the pump

One week after the slab is pour, we can begin to install the pump. But the first thing we must do is guarantee the following conditions, tools and materials:

Conditions:

–a well that has been washed with its rim at a height of approximately 300 mm and the poured slab cured for a week.
–at least 6 strong people to position the slab on the rim.For the installation, at least two people—preferably the new owner or some of the users—are needed.

Necessary materials:

–raising main as long as the depth of the well. As we described in section 6.4, **it is essential that the entire raising main be of the same brand and schedule:** any difference in diameter in the tubing can cause serious problems for the pistons!
–outlet spout: tube reducer, 'T' connector, elbow connector, and approximately 1 meter of outlet tubing (See table 6.6 for dimensions).
–a guide.
–rope (two times the length of the well, plus 2 meters, plus 5% for the knots).
–sufficient number of pistons (one for each meter of pumping head).
–rubber inner tube (strips of more or less 30 mm. wide for 2 meters total).
–a stabilizing rock (2 – 7 kilos), more or less square (cement blocks work well, but not in acidic water: they will dissolve in a few months).
–a bit of grease to lubricate the bearings.

Optional materials:

–half a bucket of sifted sand
–1/6 bucket of cement
–1 kilo of lime
–wheel protector
–bleach to disinfect the well

Necessary tools:

–adjustable or fixed wrench for the security bolts of the bearings
–knife
–pliers
–pipe–cutting saw
–PVC glue
- hammer
–measuring tape
–pole to lift the slab.
–thick fastening wire, longer than the total depth of the well (at least 7 meters are needed to fasten a tube).
–cigarette lighter to burn the ends of the rope.

Optional materials:

–two buckets
–bricklayer's trowel
–pipette, for measuring the bleach.

Step–by–step Instructions:

–Secure the pistons on the rope, using a strand about 25 mm. long, braiding the rope and burning the ends (See figure 8.4). A strand goes both above and below the piston. The pistons should be secured about 2 meters apart. Make sure all the pistons are facing the same direction. This task takes a long time. Children can easily participate.

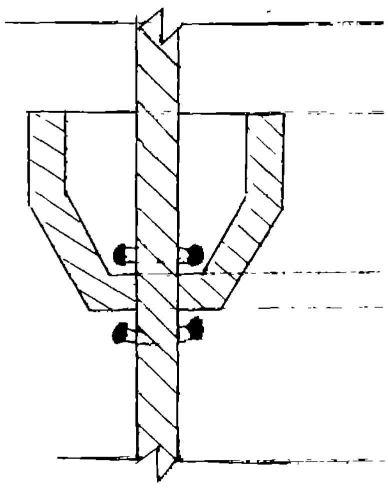


Figure No.8.4: How to attach the piston to the rope.

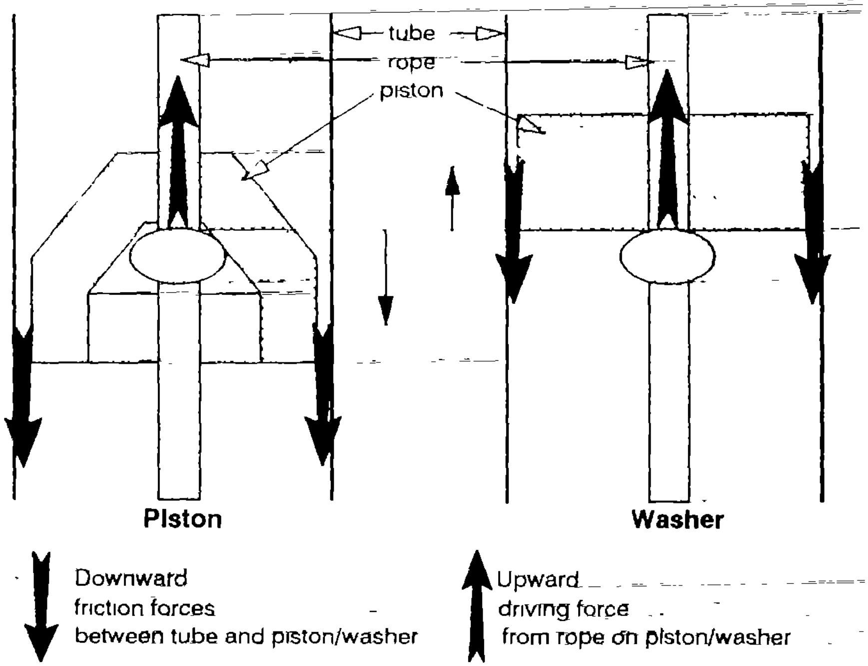
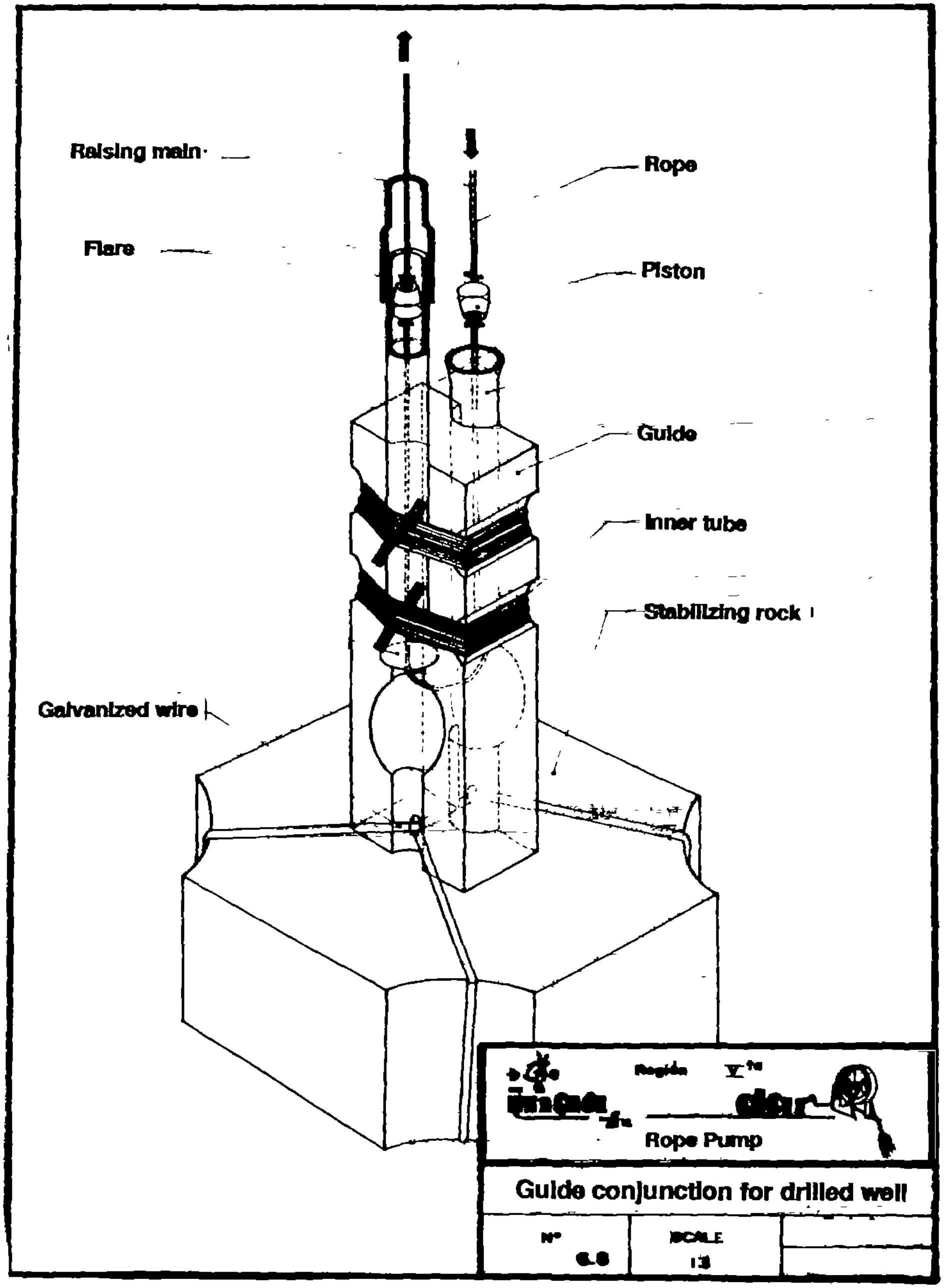


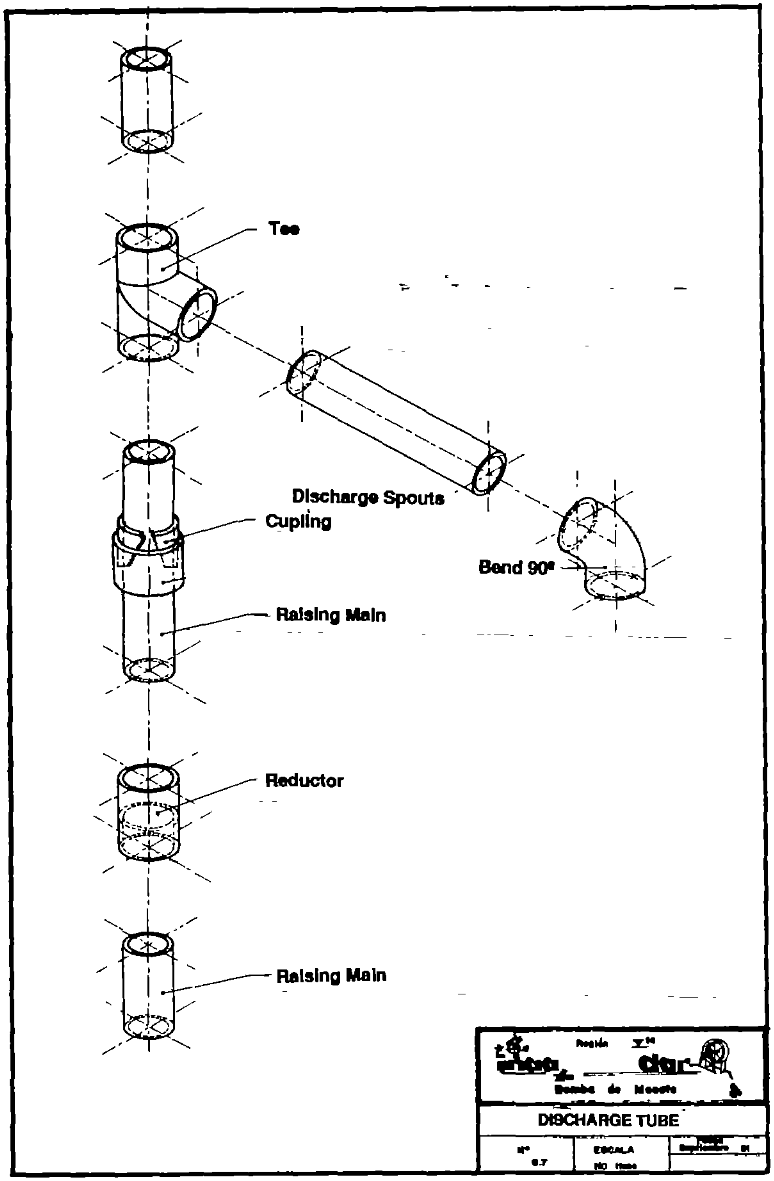
Figure 6.5: Forces acting on pistons vs. washers
(The hydraulic pressure is not shown to avoid complicating the figure.) Notice that in the case of the piston, the friction forces apply below the point of application of the force of the rope. In the case of the washer the opposite occurs, which provokes a lot of friction given the instability of the system.

rope comes out is as small as possible to minimize leakage and so that the tightness of the rope can direct the piston. The distance between pistons varies between 0.5 to 5 meters, depending on the quality of the piston. For example, for a piston with a play of 0.4mm, we recommend maintaining approximately 2 m. If the play is greater, the distance between the pistons should be less.

It can also be done beforehand.
–Widen the flare of one of the tubes, using the same procedure as for the protector tube (see description above). Be even more careful this time, because the pistons must be able to pass through smoothly.
–Plane the inside edges of the raising main and join them with PVC glue, with the flare facing down to avoid friction and wear of the pistons in the joints (See figure 8.5). Make sure not to get the tubes dirty, or the pistons will stick.The lower tube should be the one with the wider flare. Measure (using the tubes) the total depth of the well and cut the upper tube, leaving 300 mm. above the rim.
–Secure the guide with strands of inner tube to the raising main, making sure the widened flare rests in the groove of the guide (See figure 8.5). Don't use more than 2 or 3 layers of inner tube, as the pressure of each layer adds up and together they could deform the tube. If the tube has a smaller diameter than the groove of the guide, reinforce it with a nipple cut from the same tube to widen its outer diameter and at the same time reinforce it.
–Using the fastening wire, insert the rope with the pistons into the raising main tubes, starting from below. Remember to pay special attention to the direction of the pistons!
–The rope should pass through the big opening of the guide. It's important to demonstrate these steps very clearly to the users/ owners, given that replacement of the rope is the most common corrective maintenance procedure, and errors often occur (for example, the rope doesn't pass through the guide, or the pistons face downward. Don Ramón had this experience:
"...I installed it wrong, I put the tube in all the way, put the rope in and didn't put it through the porcelain piece, which should be fastened securely with its turns so that the rope and the pistons don't hit. I forgot about the porcelain piece, I wanted to turn it over, but it wouldn't. When I saw Alfonso, a very responsable



Guide conjunction for drilled well


Tee
Discharge Spouts
Cupling
Raising Main
Bend 90°
Reductor
Raising Main
DISCHARGE TUBE
ESCALA

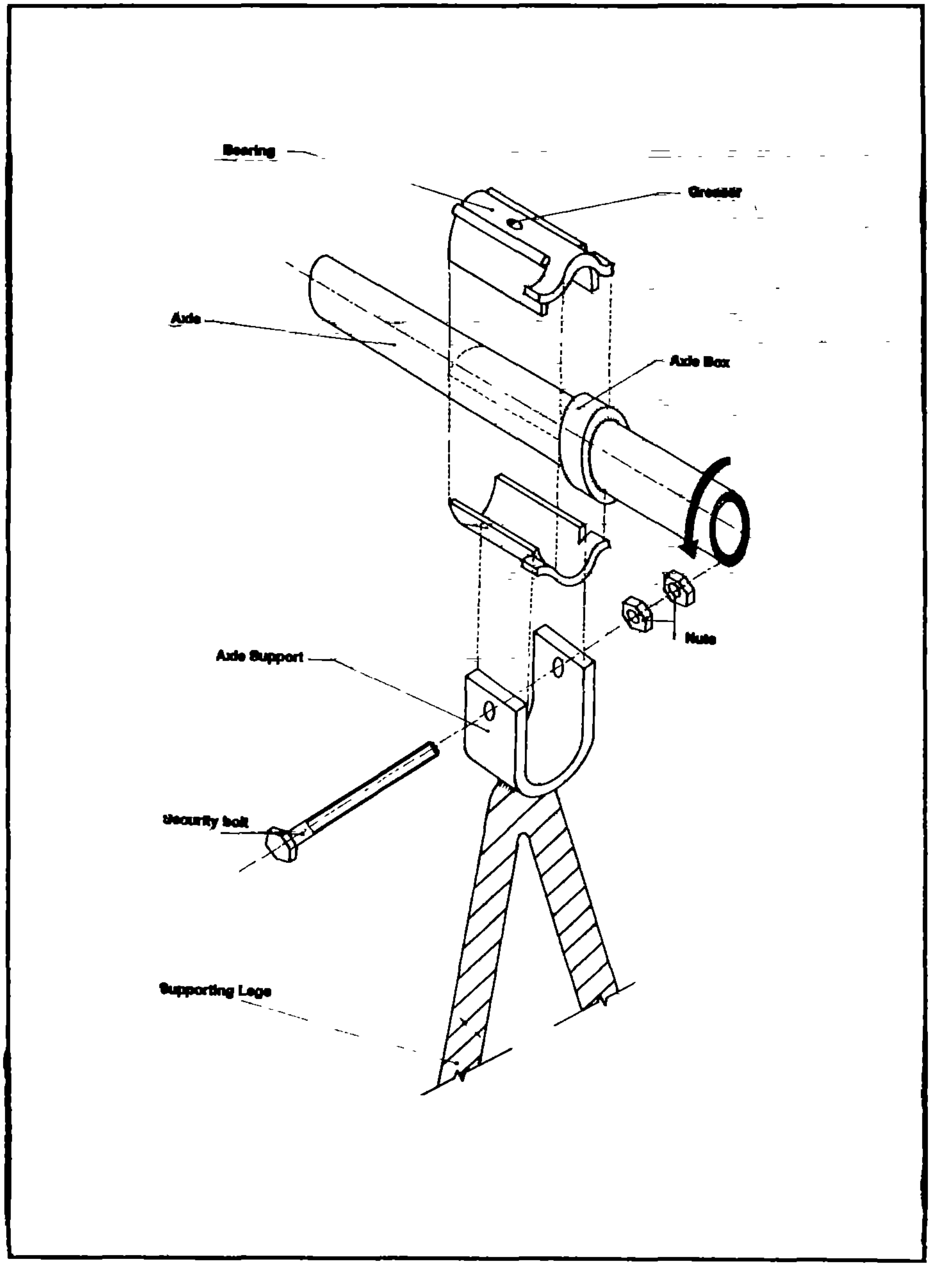

Bearing
Greaser
Axle
Axle Box
Nuts
Axle Support
Security bolt
Supporting Legs

Photo 23: Well placed bearings
The wide "wing" of the upper bearing half rests against the support and prevents the bearing halves from rotating. Narrow "wings" prevent the bearing halves from becoming dislodged (Papayal).

kid, he came to put the tube together. When we turned it over, the rope entered the tube, cracking it as it went in and all of a sudden the tube split and the rope broke."

–Test to see if the pistons pass through the guide and easily enter through the flare into the raising pipe.

–Temporarily tie the ends of the rope so they don't get lost in the tube.

–Tie the stabilizing rock to the guide with galvanized wire.

–Take the mold off the slab and place it on the rim of the well. Be careful of your fingers! Make sure the delivery tube sticks out 30 mm. above the slab. If it sticks out more, cut it. Roughen the inside top part where the wedge will go.

–With an extra piece of raising main tube, make a wedge, as

Photo 24: Poorly placed bearings
The wide "wing" of the upper bearing half is incorrectly compressed between the support and the ring welded to the axle. Thus the lower bearing half has too much play and is coming loose. We hope to have overcome this problem with the new design presented in Table 6.2 (El Pochote).

shown in figure 8.6.
–Lower the combination of the stabilizing rock, guide, raising main and rope through the manhole, making sure the raising main is correctly positioned and constantly checking that the rope is in the right place: the raising main next to the delivery tube, the rope loose and next to the protector tube. If the well is deep, or has a lot of water,this positioning cannot be controlled or corrected once the tubing is lowered. Keep a certain tension on the loose rope so it doesn't get tangled with the guide or the stabilizing rock.
–Cut, plane and glue the two outlet spout tubes, the elbow connector, the 'T' connector and the tube reducer (See figure 8.7).
–Untie the temporary knot, pass the rope through the delivery

tube and the protector tube (using wire) and through the outlet spout. Make another temporary knot.

–Insert the raising main into the protector tube, and cut it at least 30 mm. above the tube's end. Be careful not to cut the rope! Inside the well, the raising main should be straight and vertical, not sagging or warped, but the stabilizing rock should rest at the bottom. Plane the end of the tube and roughen the part that will be pressed tight by the wedge (See figures 8.6 and 8.7). It is important that the wedge be made in such a way so that it will exert even pressure on the raising main (See chapter 10, problem 1)

–Secure the raising main tube to the delivery tube, inserting the wedge. Gently hammer the wedge.

–Join the outlet spout tube reducer to the raising main tube and bend the anchors to secure the outlet spout.

It is very important **to not use glue** on the wedge or on the joint between the raising main and the outlet spout, as this will make it impossible to take the pump apart.

–Make a good knot, without tensing the rope, but leaving 100–200 mm. play. Cut the rope, leaving 100 mm. at either end, burn the ends and braid them together.

–Grease the bearings and make sure they are correctly positioned. Make sure the bearing halves are in pairs and that the lower bearing half isn't the same as the upper one (see figure 8.8 and photos 23 and 24). Insert the bolt without tightening the nut very much. Screw on the lock–nut.

–Do a test pumping. At first there will be a lot of friction between the pistons and the tubes due to whatever dirt there may be in the tubes. If the friction doesn't disappear after pumping a few buckets of water, take out the tubing and look for where the pistons are hitting against the tube.

–Once everyone has tried the pump, it's good to untie the knot and let the rope fall—as if by accident—into the well, so that the new owners and users can take apart the pump, retrieve the

rope, and put it back together again. At first they may be afraid, but in about ten minutes they will feel confident that they can handle this part of the operation of the pump.
–Put on the rope and wheel protection.
–Seal the slab onto the rim with a mix of cement and sand.
–Place the manhole cover over the manhole and seal it hermetically with a mixture of lime and water. This mixture allows the cover to be re–opened if the pump ever needs to be taken apart.
–Disinfect the well with bleach, using the correct amount of bleach.
–Make sure not to touch the pump while the mixture is drying.
–During the first few hours of operation, the rope and knots will stretch some and it may be necessary to shorten the rope a little by cutting it.

Now that we've seen how easy it is to install a rope pump,
we can go on to look at the pump's operation and maintenance, both of which are, in fact, technically simpler than the installation.
They do, however, require careful attention.

Chapter 9: Maintenance

In this chapter we will first analyze maintenance planning and then give a brief description of the various maintainance tasks.

9.1 Maintenance Planning

As with anything that has moving parts, regular maintenance is necessary to keep it in good running order and for it to last a long time. **Preventative maintenance** is always better than **corrective maintenance**; preventative maintenance can be planned and scheduled according to the users' convenience, it is less work, and it helps avoid down time of the pump while you look for or make replacement parts. Don Ponpilio, a veteran with these pumps, gives the following advice to his clients: "*...As I explained, in order for the pump to work well, the users should be careful and fix it before it breaks down. The rope is worn out? Change it. Explain how to change it, have the rope and the pistons beforehand, and it can be replaced without having to take out the pipe. Just loosen the rope, tie on the new one, pull it in the opposite direction, so that it doesn't pull up water, and it's easy to take out...*"

If regular maintenance is done, the pump can last up to 10 years, although it will be necessary to replace some of the major parts.

In annex A, we show a sample calendar of maintenance activities. This calendar is only a guide. A lot depends on the quality and the kind of rope, pistons, guide, paint and wheel. In the two calendars shown (one for a "home–made" pump and one for a "technified" pump), two factors are taken into account: the pumping head and the amount of water pumped.

9.2 Maintenance Tasks

Here we describe the most common maintenance tasks. They are listed in descending order of ocurrence. We don't go into detail when the procedures are similar to those used in the installation, since they are described in section 8.2.

Changing the rope

Depending on the protection of the pulley wheel, the use of the pump, and the quality of the guide, the rope should be changed every once in a while. It is best, and easiest, to do this before the rope breaks. It is easiest to change the pistons at the same time you change the rope, even if the pistons are not yet worn out (they can be saved to be used for the next time you change the rope). Tie the new rope with the pistons attached to the old rope (be careful with the direction of the pistons), pass it through the tubing and when it comes out again, tie it. Thus,it is not necessary to take out the tubing.

Materials needed:

– new rope;

– new or used pistons.

Tools needed:

– cigarette lighter, matches or burning ember;

– knife

Changing pistons

Pistons usually last about twice as long as the rope. You can see if they need to be changed by watching and listening to how fast the water goes down the raising main when you stop pumping. The water shouldn't go down faster than 0.1 to 0.4 meters per second. Make sure the new pistons you get are the same size as the used ones, and that they weren't made for a different kind of tubing! Since changing the pistons is done at the same time as changing the rope, the procedure is the same as above.

Paint

To avoid corrosion, it is essential to paint the pump structure. It's not necessary to take it apart, but it is important to clean it well with a steel brush and sandpaper, and then wipe it off with a rag soaked in solvent. Then apply one or two coats of anti–corrosive paint, and one or two coats of lacquer or shellac. Sand lightly between each coat.

Materials needed:

- 1/16 liter of anti–corrosive paint
- 1/16 liter of lacquer or shellac
- solvent

Tools needed:

- steel brush
- sandpaper
- small paintbrush

Changing the guide

It is time to change the guide when you begin to notice that the rope is wearing out faster than normal. To change the guide, you have to take out the tubing (see section III.2), although you don't have to take the rope out of the tubing.

Materials needed:

- new guide
- strip of rubber inner tube

Tools needed:

- knife
- cigarette lighter, matches or burning ember

Changing the bearings

When you notice too much play in the bearings, they should be changed. Just take the rope out of the pulley wheel (without undoing the knot), take out the security bolts with a #10 or adjustable wrench, and change the two pairs of bearing halves. The correct positioning of the bearing halves is very important (see figure 8.8 and photos # and #)!!!

Materials needed:

- two pairs of bearing halves
- grease

Tools needed:

- #10 or adjustable wrench

Changing the outlet spout

When the pump is in direct sunlight, the ultra-violet rays will affect the PVC outlet spout pipe, causing cracks. Changing the outlet spout is easy and doesn't require much explanation.

Materials needed:

- 'T' connector, elbow connector and outlet spout of the correct diameter

Changing the raising main

If the well has loose sand, the sand will affect not only the pistons but will wear out the raising main as well.

Materials needed:

- raising main tubing
- strip of inner tube

Tools needed:

- knife
- cigarette lighter or matches
- small tube of PVC glue
- a bottle with a neck less than 18 mm. diameter
- saw to cut pipe

Changing the wheel

Within several years, the intensive use of the pump can weaken, and even break, the welding of the spokes. The rope, along with the effect of the sun, will eventually damage the rubber of the pulley wheel.

Materials needed:

- new wheel
- a small amount of grease

Tools needed:

- fixed or adjustable wrench

In this chapter we discussed maintenance planning and the necessary tasks to keep the pump in good working order. In the next chapter we will analyze some of the most common problems and their solutions (troubleshooting).

Chapter 10:
Troubleshooting

In the last chapter of this section, we will look at some of the most common problems that occur during installation, operation and maintenance. We'll describe the symptoms, the possible causes, and possible solutions. Both the problems and their possible causes are listed in descending order of probability.

Photo 25: Broken water raising main
In the foreground of this photo is clearly seen the stabilizing stone, fastened by a rubber tire to the glazed ceramic guide. The upper tube is the protection tube; the lower tube, which is the water raising main, has moved downward, and the rope has cracked it. The pistons catch within the fracture. See problem 4 (Pochote).

Problem 1

Symptoms: the rope moves, but gets stuck at regular intervals. By pulling it harder, it loosens and moves a few meters. The obstruction may vary from being almost complete, to being barely noticeable.

Possible causes	Solutions
The raising main has some defect or obstruction that is causing the pistons to rub or get stuck when they pass. This could be:	Find the defect or obstruction by observing the position of the pistons when the rope gets stuck. Watch to see if the rope stretches a lot (this problem is described below); if it doesn't stretch much, the problem is close to the top.
1.– The widened flare at the opening is constricted.	1.– Cut the flare and make a new one.
2.– The inner tube that ties the tube to the guide is too tight, deforming the tube;	2.– Loosen the innter tube some, using no more than 3 layers. Did you use the reinforcing nipple? If the defect doesn't disappear, they only solution is to use higher schedule tube. This means you also have to change the pistons!
3.– One of the flares is constricted (a common manufacturing defect);	3.– Cut the constricted flares, and make new ones by heating the tube, or use joints.
4.– Some kind of damage in the raising main (for example, someone stepped on it, or it got bent);	4.– Change the damaged part of the tube.
5. – The inside diameter of the tube is not uniform (bad quality).	5.– Change tubing suppliers, or use smaller diameter pistons.

The same problem, except that it happens every 10 to 30 turns of the pulley wheel (depending on the depth). The same causes described above, but they affect only one piston. Identify which piston has the problem (some irregularity or bigger diameter) and grind it.

Problem 2

Symptoms: the rope gets completely stuck; it won't move forwards or backwards even a millimeter. Alfonso, a promoter in 'Palo de Hule' describes the problem like this: "*...In some of the visits I've made after the pump is working, there have been some problems. There was one where some garbage got into the tube, and the rope was completely stuck. But the user fixed it.*"

Possible causes	Solutions
1.– The rope was very loose and got tangled in the guide.	1.– Take out the tubing, untangle the rope and cut it so that the play is between 100 and 200 mm.
2.– Something is caught between the flare of the raising main and a piston (for example, an inner tube or a plastic bag).	2.– Take out the tubing, try to remove whatever is causing the obstacle (which may be impossible—in which case you will have to cut a piece of the tube). As a preventative measure, keep the slab sealed; or make a filter around the guide and the tubes out of a piece of 4" or 6" slotted PVC tube.

Problem 3

Symptoms: The rope can be moved, with some effort, a few meters forwards or backwards, but then gets stuck. The rope is very worn out.

Possible causes	Solutions
1.– The guide has come unstuck from the raising main; the rope has dragged along a crack in the raising main.	1.– Cut the affected part of the raising main and change it. Make another flare and carefully secure the guide to the new tube.
2.– A very worn out guide has been used and it has a deep crack.	2.– Change the guide.

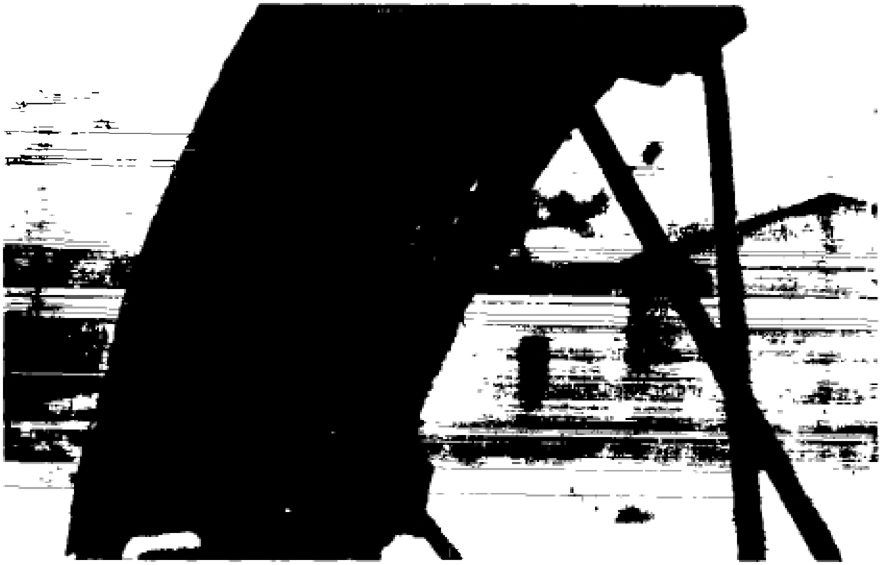


Photo 26: Rope in the pulley wheel
When the tire walls aren't very strong, or when the pull on the rope is very great, the rope can get caught within the center of the pulley wheel. See problem 5 (San Juan).

Problem 4

Symptoms: The rope gets stuck between the rims of the wheel.

Possible causes	Solutions
1.– The pulley wheel supports aren't holding the two rims of the pulley wheel together.	1.– Push the pulley wheel supports together, or insert a wedge between the supports and the rims.
2.– The rims of the pulley wheel are weak and spread apart.	2. – Use more spokes, or thicker tires for the rims.

A general solution is to cover the 'V' of the pulley wheel with a bed of inner tube. This will not work if there is too much force: the rope will slip.

Problem 5

The rope slips on the pulley wheel.

Possible causes Solutions

1.– The rope got dirty (probably from the tube) with soap, oil, grease, or gas), affecting the friction coeffiecient.2.– The pulley wheel is not in enough of a 'V' shape, possibly because the inner tube packing is too thick.
4.– Too much force on the rope because the pistons are sticking.
5.– Too much force on the rope because the diameter of the tubing is too big.3.– The rope has too much play. (This problem occurs more frequently in shallow wells that have a lot of water.)

1.– Take out the rope and clean it with lots of soap and water.
2.– Change the inner tube packing or the pulley wheel (if it's the pulley wheel itself, it is a production defect).
3.– Shorten the rope by cutting it until it has a play of 100 to 200 mm. Tensing the rope is not recommended: it causes too much friction and wears out the guide.
4.– See problem 1.
5.– Use smaller diameter tubing for the raising main. If you want to keep the same volume of water, use a bigger pulley wheel.

Problem 6

You hear an 'imploding' sound every few turns. The flow is intermittent. This only happens in deep wells.

Possible causes Solutions

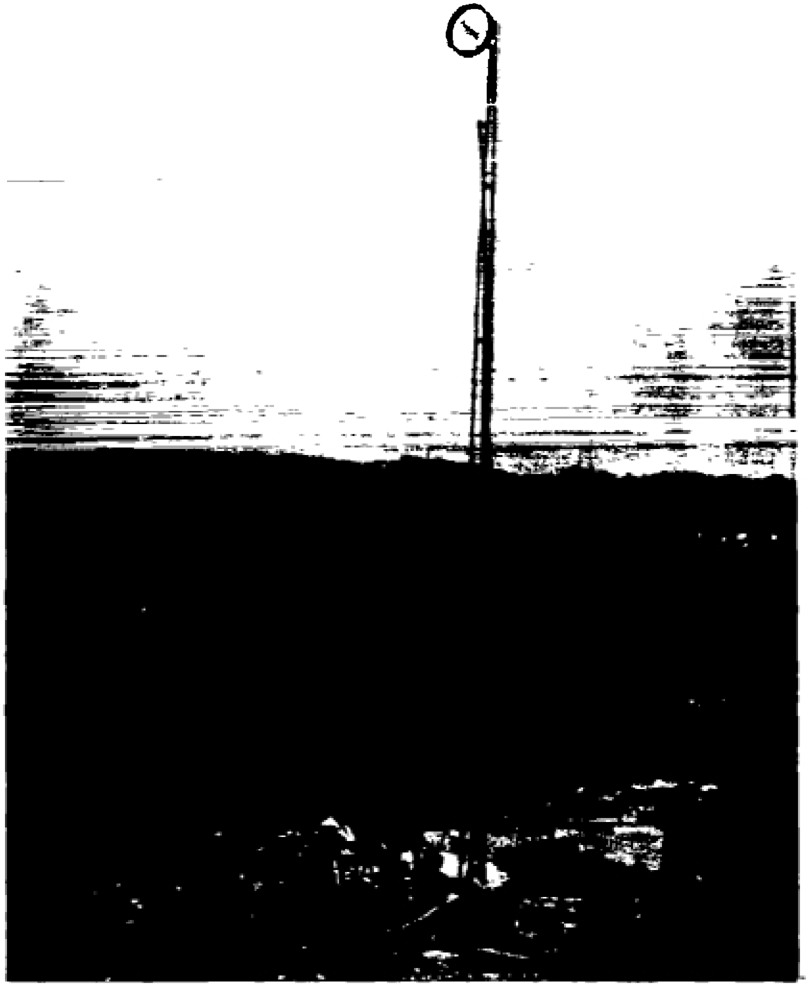
1.– One or more of the pistons has a bigger diameter than the others and is working 'alone'. This produces a 'vacuum' underneath the piston.

1.– Figure out which pistons are causing the problem and fix them by grinding them.

Photo 27 (overleaf): Post–mounted rope pump

The pump can draw water up to 8 meters above ground level. One can see the post with tension wires, the water raising main, and the outlet spout which descends before heading towards the photographer. The rope hangs unhindered from the upper pulley, winds almost completely around the pulley wheel, and enters the protection pipe through the upper guide (Santo Tomas).

4



Special Models

Other people's tools
only work
in other people's gardens

Up to this point, we have only discussed rope pumps installed in hand–dug wells. However, the principle of the rope pump is that it can be adapted for a variety of specific uses, not only for pumping drinking water, but also for production applications. In this last section, we describe five special rope pump models:

– in drilled wells
– on posts
– for high discharge
– with a motor
– with a windmill

For each model we discuss the issues involved, its capacity, a description of the model, and experiences and perspectives.

We feel that the first three models are sufficiently developed so that they can be used without much problem. For these, we describe their construction and installation, similar to that described in sections two and three ('Construction' and 'Installation, Operation and Management')If you are not directly involved in these activities, you can skip the corresponding sections.

Chapter 11: Rope pump in drilled wells

Issues involved

Although the majority of wells used for drinking water are hand–dug, machine– and hand–drilled wells are also frequently found. In the context of this book, the only difference between the two is depth: hand–drilled wells are generally less than 20 meters deep, while machine–drilled wells are usually over 60 meters. In order to not complicate the terminology too much, we use the term 'drilled wells', since most of what we describe can be applied to both machine– and hand–drilled wells.

It is easy to adapt a rope pump for use in a drilled well. It is also possible to eventually run the pump using an electric or combustion motor to pump very deep water.

Scope of Model

Rope pumps are currently being used in drilled wells (with a minimum diameter of 4") with pumping heads of some 40 meters. It seems that even greater depths are feasible, although they haven't been tested. The model described here (with two handles) supplies 8 cubic meters of water per day.

Experiences and perspectives

In various places, pumps have been used on drilled wells without serious problems. The reason that this model pump is not more widely known than the four or five models that are currently in operation is simply a lack of demand. The model described in the study of Pochote has worked well under severe conditions for 9 months without major problems. The DAR–Region V is working on developing this model, emphasizing greater depths.

In conclusion, we feel it is appropriate to promote this model on a broader scale, monitoring its use in deeper wells.

11.1 Description

The main difference between a rope pump for a hand–dug well and a pump used in a drilled well is the small diameter of a dril-ledwell (4" to 12"). As the rope leaves the pulley wheel, it is directed by a **guide** towards the inside of the well (this guide is the same as the guide underneath). Depending on the form of the lining tube of the well and the pedestal (if there is one), the guide support can be welded to the well's metal cover or to the support structure.

The rope lowers into the well through the **protector tube.** The function of this tube is greater than in a hand–dug well, as it protects the rope and the pistons from rubbing against the iron lining tube and the wall of the well. (If the well is completely lined with PVC tubing, it is not necessary to use a protector tube.

In general, the guide will not be placed at the bottom of a drilled well, but rather 10 meters below the minimum static level, depending on the draw–back of the well. All of the tubing, with the guide and the stabilizing rock, are suspended from the metal cover with a clamp covered with inner tube to tighten the tubes (the weight of the water column always weighs on the rope). To prevent the raising main from getting deformed (which will affect the passing of the pistons), the tube reducer between the raising main and the outlet spout should be placed underneath the cover.

Photo 28: Pump over a drilled well
This pump was designed based on experiences with the pump in El Pochote. The axle is a 1/4" GI pipe, and the pulley is placed between the bearings, but not directly over the center in order to allow for the blocking system. The well is hermetically sealed by the slab. (Nueva Guinea)

Another difference with respect to a 'normal' pump is that drilled wells don't have a rim: the support structure (embedded in the apron) is taller: the ideal height for the axle should be 800 to 900 mm. Since it is taller, it needs to be stronger: the iron legs should be of 3/4" instead of 5/8", with support braces on all four sides.

In addition, a second crank can be added, increasing the load on the bearings, the axle, and the spokes. For an ideal adaptation for various users (including children!), the second crank can be of a different diameter and at a different height (with a platform or stool).

Although the current design was developed in the DAR–Region V, it is a second generation design and has supposedly overcome some of the deficiencies of the earlier models (like the Pochote model), we still don't have enough long–term experience, and therefore prefer not to present the detailed plans in this book: we limit ourselves to showing the photo.

11.2 Installation

The design of the pump (and therefore, the installation) depends mainly on how the the drilled well is built: the material used, the diameter and height of the well's lining tube, the dimensions of the base (if it has one), etc.

As with pumps for hand–dug wells, this installation also requires two half days: one to embed the support structure and the other for the actual installation.

Embedding the pump

In general, the pump's support structure is embedded in the apron. The positioning should be such that the raising main is exactly plumb underneath the pulley wheel. The base for the outlet spout should be placed at a height so that it is easy to put on and take off the bucket. Its section is 150 x 150 mm. minimum, with a reinforcement of four " rods. Embed the outlet spout. If the height of the spout allows, it's wise to make a platform for the users to put their buckets on, leaving some 500 mm. between the spout and the platform. When you coat the apron with cement, take into account the space needed by the two users. At the same time, pour the triangular stabilizing rock (see figure 11.1).

Installing the pump

Once the total depth of the pump has been determined, place the pistons on the rope, pass it through the guide and the raising main. Since drilled wells are generally deeper, it may be easier to pass the rope through the individual tubes before joining them together. The rope can also be passed through the tubing all at once, but this requires a huge length of thick iron wire (#12).

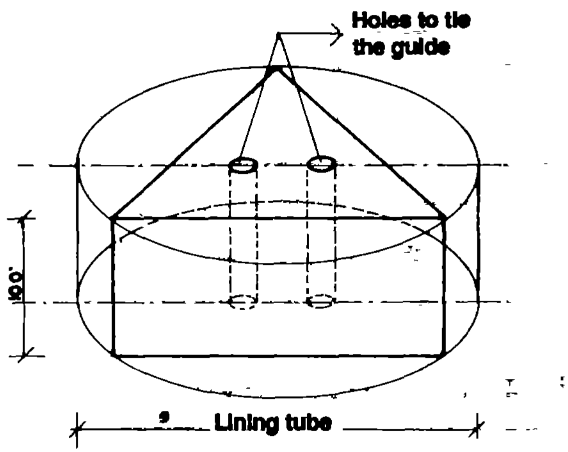


Figure No. 11: Stabilizing rock for drilled wells.

If the well is completely lined with PVC tubing, the rope can belet down loose. If the lining is made of iron or is only partial, the rope should be lowered through a protector tube for the entire depth of the well in order to avoid rubbing, wear, and contamination. This protector tube has the same diameter as the outlet spout, and is joined to the guide in the same way as the raising main.

After having secured the guide, joined the tubing and tightened the clamp attached to the cover, the whole thing is lowered into the well. Since the diameter of the pulley wheel is larger than that of the lining tube, the rope will not simply lower into the well: it must pass through the **upper guide** (the same as with the lower guide). The upper guide is fastened with rubber to the protector tube and/or to a device welded to the wheel support or to the cover.

The rest of the installation is exactly the same as with an ordinary installation.

Extra materials needed (in addition to those needed for a 'normal pump'):
–an upper guide
–the lower guide should be the type with two grooves for the two tubes.
–protector tubing for the total pumping head (if necessary)
–steel cover for the lining tube, with its clamp.
–wood to frame the apron, the base for the outlet spout, and the platform.

Photo 29: Post–mounted pump
One possible arrangement of the pump on a post: filling elevated tanks to create closed gravity systems. This model is from the "Rope Pumps Society" (Los Cedros).

Chapter 12:
Post–mounted rope pump

Issues involved

There are many cases in which it is necessary to pump water to some height above the ground in order to achieve certain pressure. This could be to transport the water through pipes over long distances or to fill tanks on a tower structure (for example, to have a closed water system).

Scope of Model

The main limitation of this model is the limited amount of available human energy: filling a 500–liter tank from a 20 meter drop (for example, from a 15 meter deep well to a tank 5 meters above ground), takes about an hour, an amount of time we consider to be the daily maximum.

For reasons of stability, and for the mentioned energy limitations, the maximum above–ground height we recommend is about 8 meters.

The maximum distance water can be transported by pipe is 70 to 100 meters (assuming flat terrain). One problem is the start–up: there will inevitably be water wastage at the beginning (overflow ar the outlet), until all the water in the pipe has accelerated to its speed.

Experiences and development

There are various models that have worked over the last 6 months without problems. We don't see any particular problems of wearing out of parts. We consider that this model pump can be promoted without any problem. It would be worth monitoring models that have used long pipes (more than 40 meters) or that are very high above ground level (more than 5 meters).

12.1 Description

By using a **post** to support the **upper pulley wheel**, the raising main and the outlet spout, water can be raised to a certain height above ground. The motor force in this case is not applied at the highest point, but rather at the height of the rim with a normal wheel. The rope goes up through the raising main up to the post, around the upper pulley wheel (that spins freely), back down loose and then around the working wheel about 270$ before being guided by the **upper guide** into the **protector tube** to enter the well. This guide is connected with rubber to the protector tube.

The design of this pump depends primarily on the kind of post being used. Figure A.11 shows the case of a 6 meter high 1" GI tube, while photo 29 shows a 9 meter high pump.

Another influencing factor is the type of outlet tubing and its path: seefigure 12.1. If you need to pump water over a long distance, the choice of diameter of the outlet tubing is somewhat more complicated than for normal pumps. Table 12.1 gives general indications, but always take into account that at the beginning of the pumping, all the water that is in the tubing must accelerate, causing initial water wastage.

Table 12.1: Choosing the diameter of outlet tubing for rope pumps on posts.

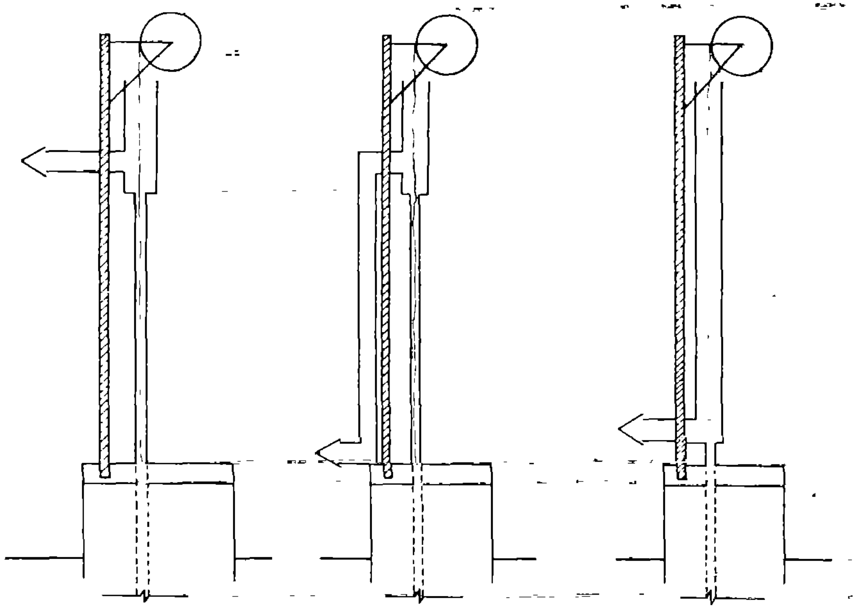
Available drop (m)	Diameter of outlet piping 3/4"	1"	11/4"	11/2"
1			30	67
2		14	72	149
3		27	115	
4		39	158	
5	7	52		
6	11	65		
7	14	78		
8	18	90		
9	21	103		

The table gives horizontal distances (m) over which water can be pumped depending on the diameter of the tubing (") and the available drop (m). It assumes a discharge of 1.1 liters/second.

12.2 Installation

As with pumps for hand–dug wells, two half days are needed: one for embedding the posts, and the other for installation.

Before beginning, it is important to think about (the possibility of) the type of outlet tubing to avoid having to make corrections from the top of the post.



CASE 1
The supply tank is located very close to the well, and the outlet spout can go directly to it by air. This situation is infrequent.

CASE 2
The destination of the water is far away and the entire pumping head is needed. The depth of the well is less than the height of the post. This is the least recommended option, given the relative complexity of the tubing.

CASE 3
The depth of the well is much greater than the height of the post. The outlet tubing can begin at the level of the rim without much loss. This is the most desireable situation.

Figure 12.2: Outlet tubing for a post–mounted pump.

Embedding the pump

The anchor for the post, the delivery tube and the pump wheel are in a line, where it is important that the anchor is positioned on top of the rim so that it is well supported. The protector tube is located off this line, to prevent the rope from rubbing against itself.
The anchor is a piece of 1" GI tube embedded in the concrete slab, sticking out some 50 mm. above the slab. To assure a a strong embedding in the concrete, pieces of iron are welded onto it.

Installing the pump

Having placed the slab over the rim, the pump is installed in the normal way, leaving about 200 mm. of the raising main sticking out of the delivery tube. The rope immediately passes through the raising main secured to the lying down post. It is easiest to fasten **all of the tubing** and the rope to the post, even though it is only provisional, before raising the post. This is to minimize the work that would have to be done above once the post has been raised.

After securing the tubing to the post, connect the three tensors and bury the corresponding spikes.

Lifting a 6–meter high post is a job that requires good planning, and above all, good coordination so that no one is put in danger. At least one person per tensor is needed to maintain tension around each spike, two people to lift the post, and a coordinator to watch and direct. Once the post is upright and the tensors are tight and secure, the installation of the pump can begin: cut and connect the two parts of the raising main, guide the rope through the upper guide, and tie it. Finally, install the outlettubing according to the specifications required by the situation.

Photo 30: A high discharge pump
The photo shows a pump used by the DAR–Region V for emptying the wells. One can see the two cranks, the absence of a blocking system, and alongside the pulley, a 1 1/2" piston (Santo Tomas).

Extra materials needed (in addition to those needed for a 'normal' pump):

–40 meters of #12 wire
–3 0.8 meter iron or wooden spikes
–an upper guide, more rope and pistons
–outlet tubing, according to the specifications required by the situation.

Chapter 13:
High discharge rope pumps

Issues Involved

In many areas, the need exists for the ability to pump, using human energy, greater quantities than can be pumped with a normal rope pump. For example, to pump wells dry, irrigate small areas, water cattle, etc. Many times no energy source other than human labor is available.

Description of model (13)

The high discharge rope pump is nothing more than a strong pump with a larger diameter raising main and two pulley wheel handles.

The raising main can be 1 1/2 or 2 inches, according to what is allowable (see annex F for calculations). This implies that special pistons have to be made, along with a guide and extra–large stabilizing rock. Since this model has no blocking system, the construction of the wheel is very simple: the pulley runs between two bearings of the normal design. Nevertheless, the force is greater and we reccomend the use of 3/4" iron for the feet, 3/8" for the spokes with an axle 3/4".

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(13) The literature (for example, Lambert et al., 1990) mentions models with raising mains up to 3 or 4". It also indicates the possibility of installing an inclined pump to pump from lagoons and canals.

Scope of model

The limitations are due to the power that the operators are able to achieve: pumping a well dry with two teams of two men each, we have reached volumes of 2 L/s at 10 meters of pumping head, but at lower heads higher volumes are sustainable for a long time. In principle, there are no limits on maximum depth, always assuming that the optimal raising main diameter is chosen according to available power.

Experiences and development

There are now various years of experience with these models, and since the differences with the normal pump are minimal, we do not feel that there is any limitation in terms of their large-scale implementation. Neither do we consider it necessary to go into greater depth concerning their construction and installation.

Chapter 14:
Motor–driven rope pumps

Issues involved

We have mentioned several times the greatest restriction in the application of special models: the limited human power and energy available. The motorized rope pump overcomes this limitation, which in principle expands its application to irrigation, pumping wells dry, fill tanks on platforms, pump water from great depths, etc. This broader application significantly increases the possibilities of what the rope pump can cover.

Description of the model

A combustion or electric motor works with a small pulley (wheel of 12") through a reducer (a v–belt with a small pulley of 12" and a large, 20" pulley). The greater rotating speeds of the axes impede the use of the simple bearings described in this book: we reccomend wooden, bronze or ball bearings.

Scope of model

There is not sufficient experience to define with precision the scope of this model; pumping can be done with a 2.5 kw motor, for example, 12 m3/hour from a depth of 12 meters, or 4.5 m3/hour from a depth of 40 meters.

Experiences and development

No pump of this model has been functioning for more than several months, and thus we cannot say much about its behavior in the medium and long term, nor about possible construction problems related with phenomena such as fatigue, etc. To date, we do not have experiences with more than 2.5 kw of power, but nothing indicates that a more powerful motor would not be feasible. Pumping heads of more than 40 meters should be possible, although there are no existing prototypes functioning. We do not reccomend the implementation of this pump model unless it is for experimental purposes or under the strict monitoring of the manufacturer.

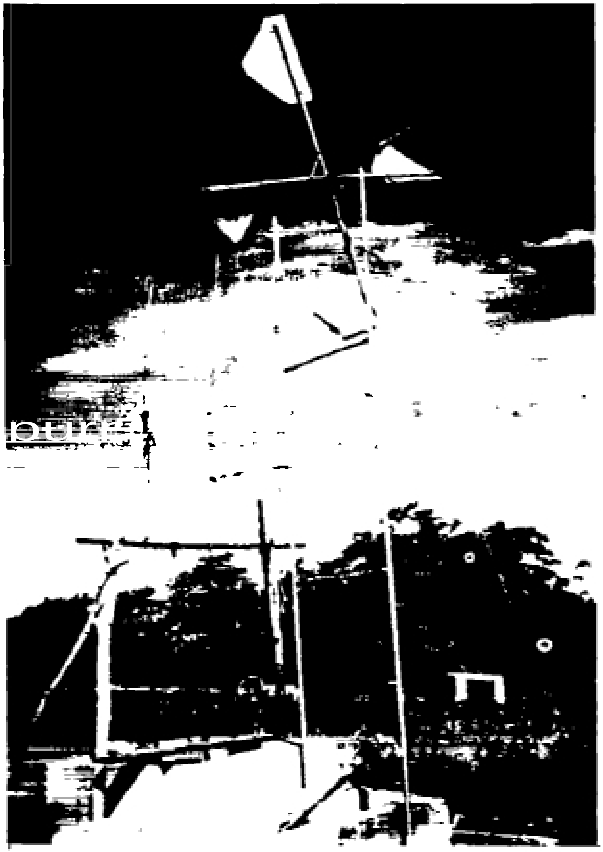

Photo 31: Pump on a stationary windmill
Note the simple construction of this mill. The pulley at the far end of the rotor axle immediately activates the pump's rope. A 1/2" pump is connected, but to the left can be seen a 1/4" pump for periods of higher winds. (Tipitapa).

Chapter 15:
Rope pumps with windmills

Issues involved

In zones with stable wind systems, it could prove interesting to use wind energy to pump water for cattle, irrigation, or even for use as drinking water.

The philosophy of rope pumps driven by windmills is to use a small mill, leaving open the possibility of working the pump by hand in case of mill or wind failure.

Description of the model

As power is limited, the rotor has a relatively small diameter (3 meters maximum). Although it should always be taken into account that the wind is a very irregular and sometimes even dangerous energy source, the small rotor allows for a relatively simple, but safe, construction model.

Two different designs exist.
The most simple has a fixed head, which doesn't turn with the wind. (See photo 32 .) Although its yield is small due to this limitation, the simplicity of the structure is such that this model could be very interesting. One potential problem is the absence of a security system.

The second model (see photo 32) does have a head that rotates on a limited angle (120 degrees), which assures higher yields but also makes construction more difficult. It does have a security system.

Experiences and development

Both models are in the technical development phase, and it is still too early to predict their potential scope or characteristics (for example, the discharge rate according to wind speed and direction.) While the concept seems interesting, both technical aspects and economic feasibility still need to be studied.

Photo 32: Pump on a rotating windmill
With a tower clearly higher than the stationary model, this design has a rotating head and a security system. At a distance of some 3 meters along the ground one can see the transmission, as well as the pump's tubing. (Ignacio Lopez Workshop, Managua).

With this description of the wind mill we come to the end of special models, and, by the same token, we conclude this book about the challenges that popular technology of rope pumps poses to all of our readers.

A

Appendix

Appendix A: Calculating maintenance costs

In this appendix, we present a calendar of maintenance costs, given the useful life of each of the pieces of the pump. At the same time, we take this opportunity to detail the calculation of cost of materials for maintenance. These costs do not include labor!

We drew up a series of tables for each rope pump prototype: the "technified" models (iron wheel, PE pistons, glazed ceramic guide) and the "user–built" (wooden wheel, rubber pistons and wooden guide). The useful life is given in months: the figures in bold type have been verified in the field, while the normal figures are estimates. The tables take into account two factors: the quantity of water pumped daily and the pumping head (10, 20 or 30 meters).

In terms of daily pumping, we use the categories defined by Arlosoroff, 1988, which are as follws:

- 8 m3/day (equivalent to 40 barrels): Intensive use public well
- 4 m3/day (equivalent to 20 barrels): Normal public well
- 1.5 m3/day (equivalent to 7 barrels): Private or several family well

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Photo 33 (overleaf): "Aerial–pump" pole
The post with stairs and tension wires is clearly observed; the raising main to the left, and the outlet spout to the right. The rope with the pistons hangs unhindered from the upper pulley (Santo Tomas).

Table A.1 Technified pump: daily pumping 8 m3.

Pumping head	30 m Value	Life	20 m Value	Life	10 m Value	Life
Rope	3.10	**5**	2.10	**5**	1.10	**5**
Piston	2.40	**10**	1.60	**10**	0.80	**10**
Paint	3.00	**24**	3.00	**24**	3.00	**24**
Guide	2.50	**12**	2.50	**18**	2.50	**36**
Bearings	1.00	12	1.00	18	1.00	36
Outlet spouts	1.27	**48**	2.23	**48**	2.23	**48**
Raising main	8.40	24	5.60	36	5.23	48
Axle with pulley and pulley wheel handle	20.00	18	20.00	24	20.00	48
Monthly total ($/mo.)	2.76		1.93		1.09	

Table A.2: Technified pump: daily pumping: 4 m3.

Pumping head (m)	30 m Value	Life	20 m Value	Life	10 m Value	Life
Rope	3.10	**10**	2.10	**10**	1.10	**10**
Piston	2.40	**20**	1.60	**20**	0.80	**20**
Paint	3.00	**24**	1.60	**24**	3.00	**24**
Guide	2.50	**24**	2.50	**36**	2.50	**48**
Bearings	1.00	24	1.00	36	1.00	48
Outlet spouts	1.27	**48**	2.23	**48**	2.23	**48**
Raising main	8.40	24	5.60	48	5.23	48
Axle with pulley and pulley wheel handle	20.00	36	20.00	48	20.00	48
Monthly total ($/mo)	1.46		1.09		0.92	

Table A.3: Technified pump; daily Pumping: 1.5 m3.

Pumping head (m)	30 m Value	Life	20 m Value	Life	10 m Value	Life
Rope	3.10	**20**	2.10	**20**	1.10	**20**
Piston	2.40	**40**	1.60	**40**	0.80	**40**
Paint	3.00	**40**	3.00	**24**	3.00	**24**
Guide	2.50	**48**	2.50	**48**	2.50	**48**
Bearings	1.00	48	1.00	48	1.00	48
Outlet spouts	1.27	**48**	2.23	**48**	2.23	**48**
Raising main	8.40	48	5.60	48	5.23	48
Axle with pulley and pulley wheel handle	20.00	48	20.00	48	20.00	48
Monthly total ($/mo)	1.04		0.93		0.85	

Table A.4: Technified pump; daily pumping: 4 m3.

Pumping head (m)	20 m Value	Life	10 m Value	Life
Rope	2.10	6	1.10	6
Piston	–	18	–	18
Paint	3.00	24	3.00	24
Guide	–	6	–	12
Outlet spouts	2.23	48	2.23	48
Raising main	5.60	48	5.23	48
Axle with pulley and pulley wheel handle	2.50	24	2.50	24
Monthly total ($/mo.)	0.74		0.57	

Table A.5: Technified pump; daily pumping: 1.5 m3.

Pumping drop (m)	20 m Value	Life	10 m Value	Life
Rope	2.10	**12**	1.10	**12**
Piston	–	**36**	–	**36**
Paint	3.00	**18**	3.00	**18**
Guide	–	**12**	–	**24**
Outlet spouts	2.23	**48**	2.23	**48**
Raising main	5.60	48	5.23	48
Axle with pulley and pulley wheel handle	2.50	36	2.50	36
Monthly total ($/mo.)	0.57		0.48	

Appendix B:
Materials, tools, gauges and molds

In this appendix we present all the materials, tools and molds needed for the production of the "technified" and "user–built" rope pumps. We also give approximate values for machinery, as well as the tools required for making the molds. We refer to tables A.1 and A.2 respectively.

Table A.6: Materials, tools, gauges and molds needed forthe construction a "user–built" rope pump

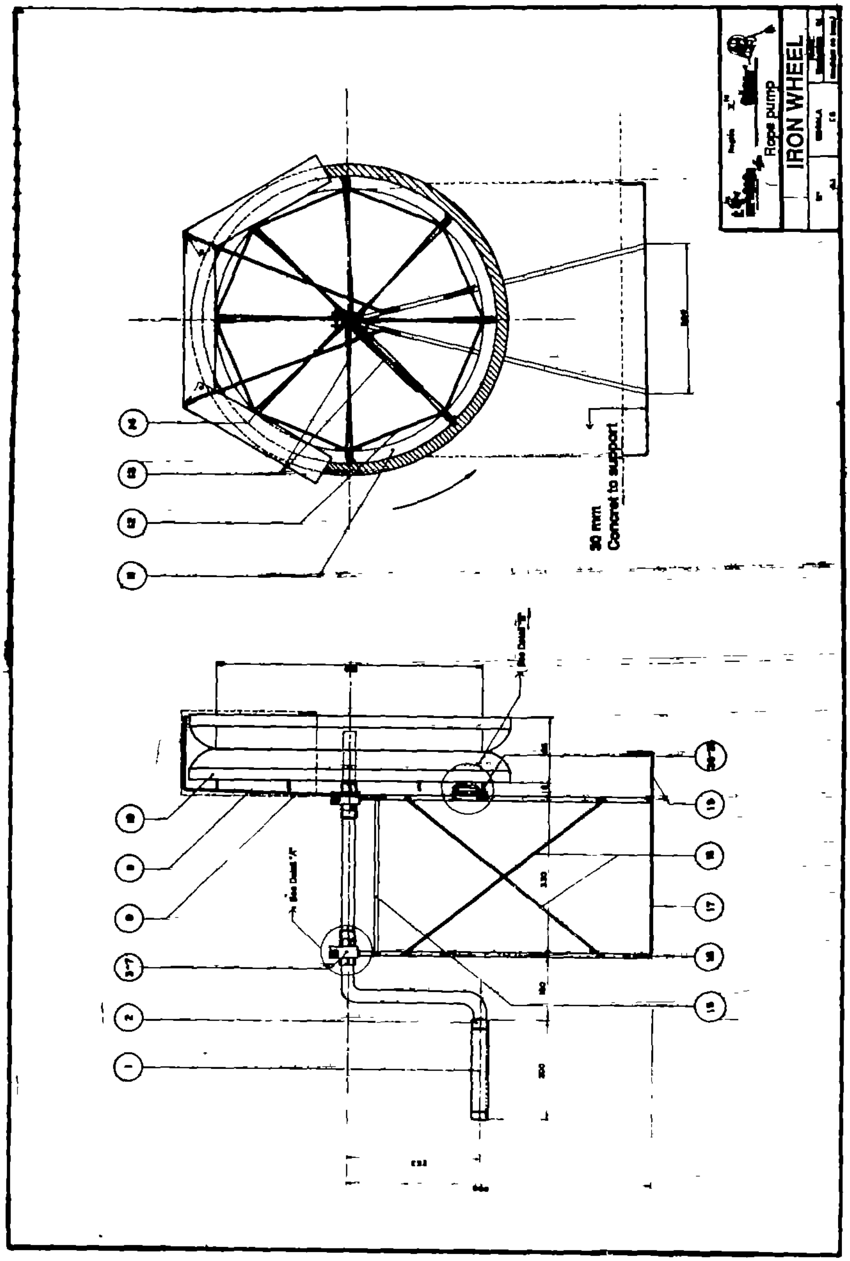
Part	Material	Tool Needs	Mold & Gauge Needs	Tools for Molds & Gauges
Slab	Construction Wood	Carpentry Tools ($30)	—	—
Wheel	Wood, 1/2" GI tube	Carpentry Tools ($30)	—	—
Guide	Fine wood	Carpentry Tools ($30)	—	—
Pistons	Old tires	Knife fire.	Steel mold for each piston	Simple metal lathe
Rope	PE fiber	Wheel ($30)	—	—
Tubing	PVC	Multiple extruders machines	Multiple complex molds	Advanced lathes and milling

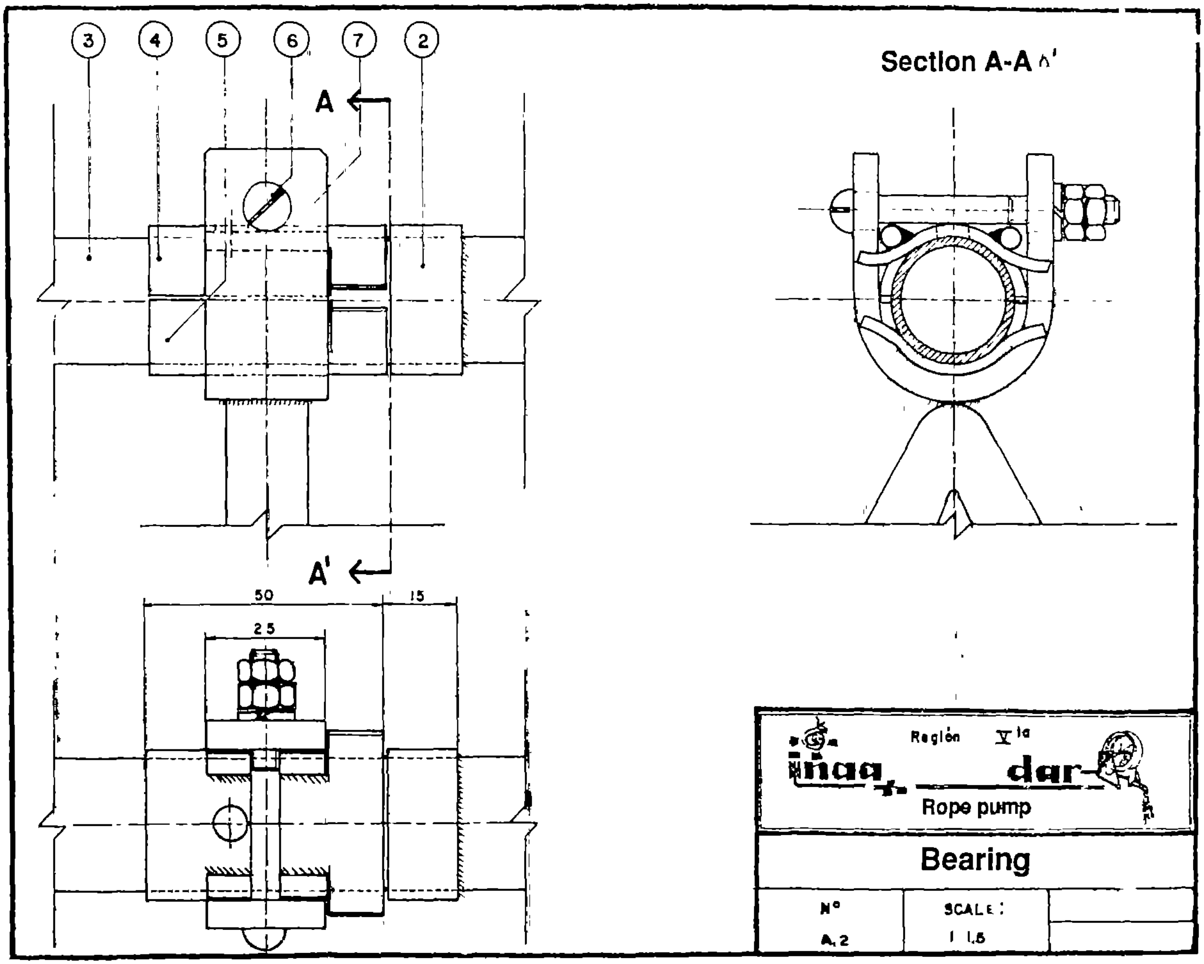
Table A.1: Materials, tools, gauges and molds needed for the construction of a "technified" rope pump.

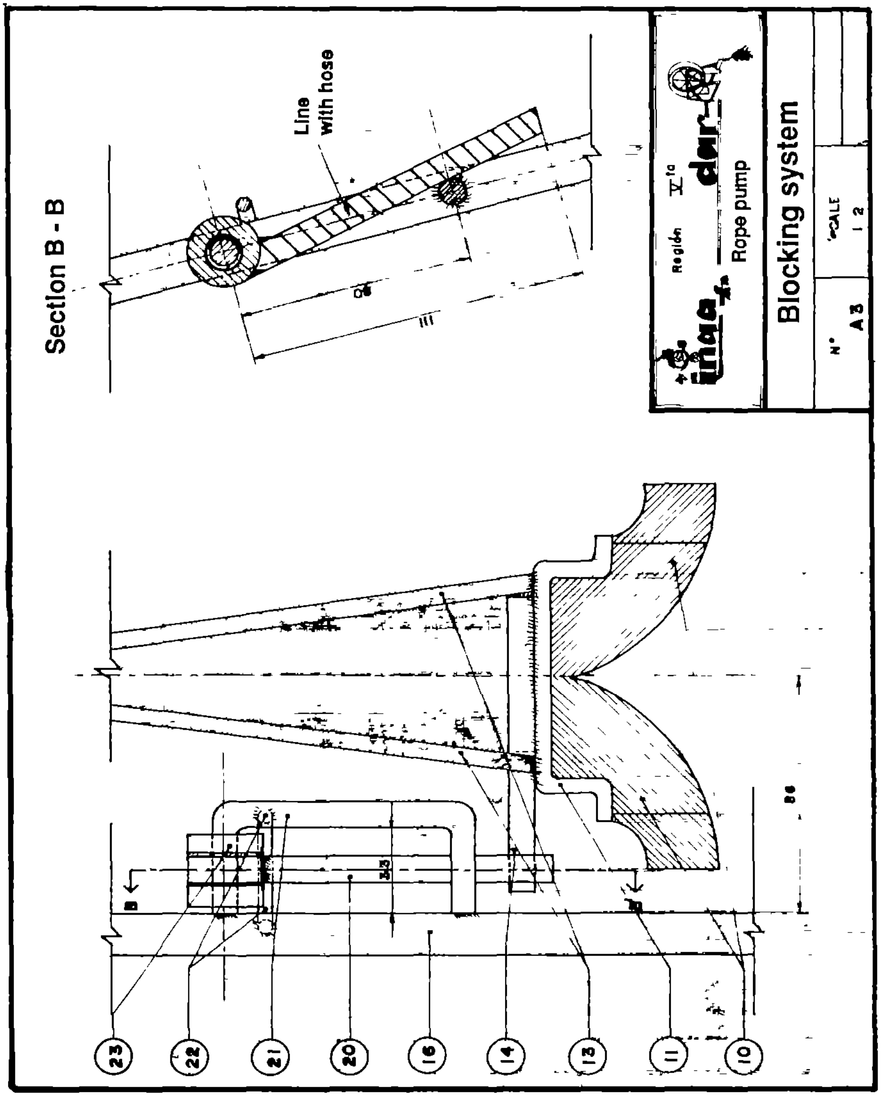
Part	Material	Tool Needs	Mold & Gauge Needs	Tools for molds
Well	Concrete	Normal	Zinc for the outer mold ($1), wood for toolsmanhole ($3)	Carpentry and construction
Wheel	Welded Iron	Electric Welder 110 V 50 A ($400)	Wheel gauge($15), frame gauge ($3) (optional), both of welded iron	Electric Welder 110 V 50 A
Guide	Glazed Ceramic	1,300o oven ($3,500) – cinvaram kneader110V ($2,500) (not essential), ceramic tools.	Wooden mold ($20)	Carpentry tools
Pistons	PE, PP in granules	Manual extruder110V ($100)	One mold of steel or bronze metal ($60)	Simple lathe,
Rope	PE fiber	Wheel ($30)	—	—
Tubing	PVC	Multiple extruders	Multiple complex molds	Advanced lathes and milling machines

Appendix C: Materials for the pulley wheel in hand–dug wells.

Part	Material	mm	quant
1 Wheel handle	Tube "	200	1
2 Bushing	Tube "	10	4
3 Axle	Tube 1/2"	1,250	1
4 Superior bearing	Tube "	50	2
5 Inferior bearing	Tube "	50	2
6 Bearing block pin	Iron 1/4"	30	4
7 Security bolt	5/16"	40	2
8 "U" support f.bearing	1" x 1/4" strip	120	2
9 Protection	sheet metal	22	1
10 Support f. protection	Iron "	650	2
11 Pulley	Tire	1	
12 Pulley support	Iron 1/4"	170	16
13 Brake pin	Iron "	120	8
14 Spoke	Iron 1/4"	250	16
15 Strut	Iron 1/4"	1,440	1
16 Feet	Iron	1,200	2
17 Base	Iron 1/4"	340	4
18 Diagonal	Iron 1/4"	460	4
19 Tube guide	Iron 1/4"	200	2
20 Brake lever	Iron "	105	1
21 Brake absorption	Hose	100	1
22 Brake support	Iron "	160	1
23 Brake security	Iron 1/4"	70	1
24 Brake bushing	Tube 1/2"	25	1


Rope pump
IRON WHEEL
30 mm
Concret to support


3
4
5
6
7
2
A
A'
50
15
25
Section A-A'
Región V
Rope pump
Bearing
N°
A.2
SCALE:
1:1.5


Section B - B
Line with hose
Rope pump
Blocking system
A3
23
22
21
20
16
14
13
11
10

Materials Total

Material	mm	unit
Tube "	340	
Tube 1/2"	1,275	
1" x 1/4" points	240	
Iron "	2,400	
Iron "	2,525	
Iron 1/4"	11,930	
Old tire		1
3/16" bolts		2
Hose	100	

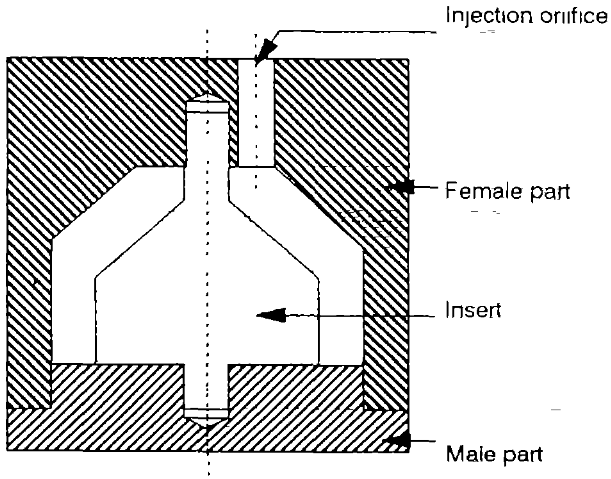


Figure A.4: Gauges for injected pistons

Appendix D: Specifications of the PE and PP injected pistons.

In this appendix we make some observations about the production of PE and PP injected pistons, the focus is on the molds and the injector machine.

Mold

Figure A.4 represents the simplest form for a steel or bronze mold to inject the pistons. All that is required for its fabrication is a simple lathe. We do not give measurements; they should be chosen based on the following criteria:

- range of interior diameters of the tubing and its uniformity
- the play that is to be maintained
- the choice of materials, which depends on their composition, which defines both physical and mechanical characteristics.

With respect to the mold depicted in the figure, it is possible to omit the insert, making it one piece with the male part. Nonetheless, this requires more precision while turning the lathe. The mold is designed in such a way that neither the injection orifice or the union of the female and male parts affects the smooth surface of the piston's outer border.

If a milling machine is available, multiple molds may be made, which would signficantly step up the pace of production.

Injector machine

The injecting machine can be either manual or electric; the pressure in the mold should reach 100 N/mm2. Heating is electric and the temperature should reach 200 degrees C.

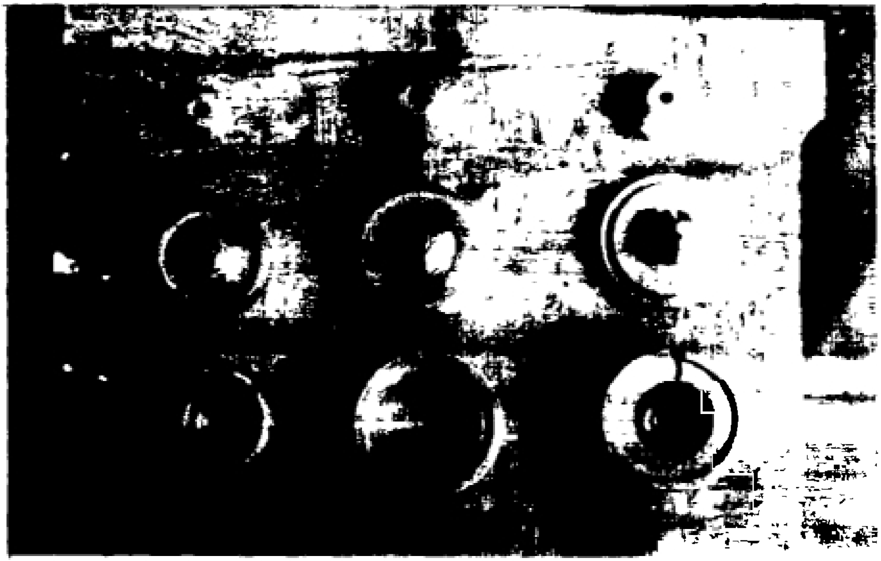


Photo 34: Piston molds

Three molds for cast pistons, in their simplest form: in the first row, the female parts; in the second row, the male parts with inserts; and in the last row, the pistons. From left to right: 1/2", 1" y 1/4" (Jose Evaristo Workshop, Managua).

Appendix E: Specifications of the glazed ceramic guides

In this appendix we describe, step by step, the production process of the glazed ceramic guides; creating the form, first firing, glazing and second firing. We do this for both the "solid" and "hollow" models.

We consider some basic equipment and significant experience with ceramics to be essential; if you do not have this, it is better to choose another type of guide

Given what has been stated above, in this appendix we will use fairly technical language without attempting to explain to "lay" people all the different terms relating to ceramics.

Solid Guides

High–temperature (with a vitrification point of 1,250 to 1,300 degrees) stoneware clay should be used, with little water absorption capacity and maximum shrinkage of 14%.)

Creating the Form

– Dry the clay, break and grind it, mix it with water and strain with a sieve of 80 holes per inch (120 is better).
– Extract the water from the clay slip until the mass reaches the right consistency.

Photo 35: Cinva–ram with mold for a guide
Within the cinva–ram there can be distinguished three slabs which form the rear and the sides of the mold. In the upper section, shown by one of the cooperative members, can be clearly distinguished the parts sticking out which will form the trough for the tube and the opening through which the pistons will pass.

– There are two options for shaping it:

– A mold with a "cinva–ram" (15) machine. While the clay is leather hard, one has to cut the orifice that the piston travels through. (See photo 35 .) It must be symetrically smooth.

– A manual extruder to give its general shape (cut A–A of plane A.5), and after several days of drying, the curves can be made with knives.

It is clear that the first method is quicker, and only requires a simple wooden mold within the "cinva–ram" machine. In the

(15) – the "cinva–ram" machine has its principal application in the production of cement blocks, earth–cement or adobe.

shape both of the mold and the mouth of the extruder, a contraction of 10 to 14% total during the whole process must be taken into account.

– Dry the guides carefully in a shaded, windless place for five or six days, then sand them, especially the curves of the orifice.

First Firing

– As the guides are pieces that are thicker than is normally found in ceramics (+ 40 mm instead of 8 – 15 mm), the drying and firing must be done very carefully in order to avoid cracks. If cracks are noted, it means that the drying must be done in a slower fashion. Just before firing, it is preferible to dry them several days in the sun (turning them occasionally) or, better yet, close to an oven at a temperature of 50 – 100 degrees to assist in the dryingprocess.

– Load the kiln and heat it slowly (1 degree per minute) with the door somewhat open (to let moisture escape) until reaching the point where "chemical water" escapes (380 – 400 degrees). Maintain the kiln at this temperature to let all moisture escape.

– After all the humidity has escaped from the guides, increase the temperature by 1 degree per minute until reaching 950 – 1,000 degrees.

– Leave the kiln closed as it cools down to avoid thermal shock (this takes about two days).

Glazing

– Obtain the glaze: if you cannot find it, it may be prepared. A mix of 50% ground glass with 50% feldspar is preferible, or if not, 50% concrete (volcanic lava) with 50% feldspar. Grind in a mill and strain to a mesh of 120 holes per inch.

– Clean the guides with a moist sponge and glaze them.

Second Firing

– Since one firing has already been done, the temperature can be raised rapidly according to the capacity of the kiln until the point of vitrification is reached: 1,200 – 1,300 degrees. This is considered to be a relatively high temperature, but it is necessary to assure the vitrification of the clay and glaze. Now the piece will not be affected by water.

– Leave it to cool down in the kiln.

Hollow Guides

This technology, while less apt for our ends given that it is fairly weak, is very common in the making of ornaments. Liquid **defluctuated clay slip** is used (see figure A.7).

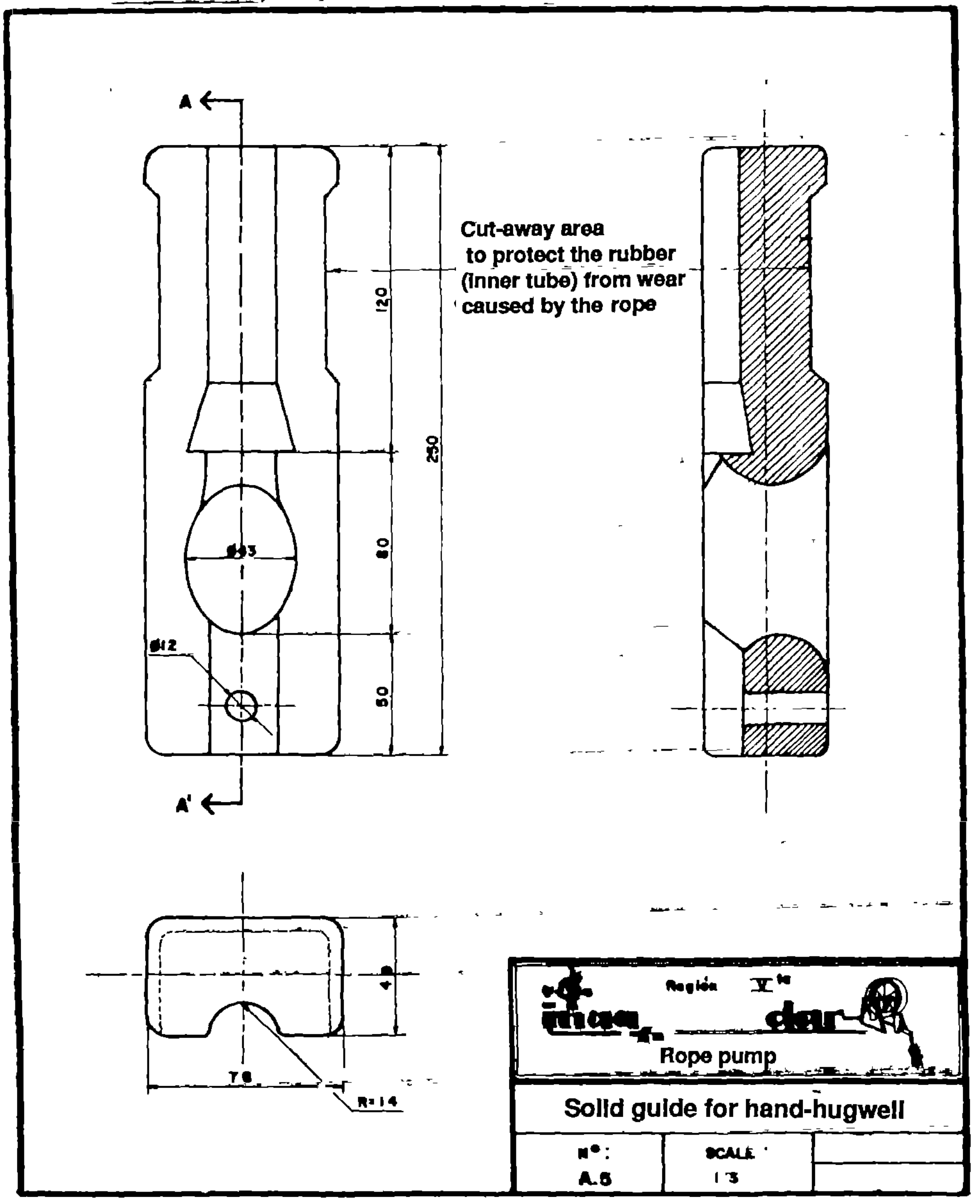
Create the form

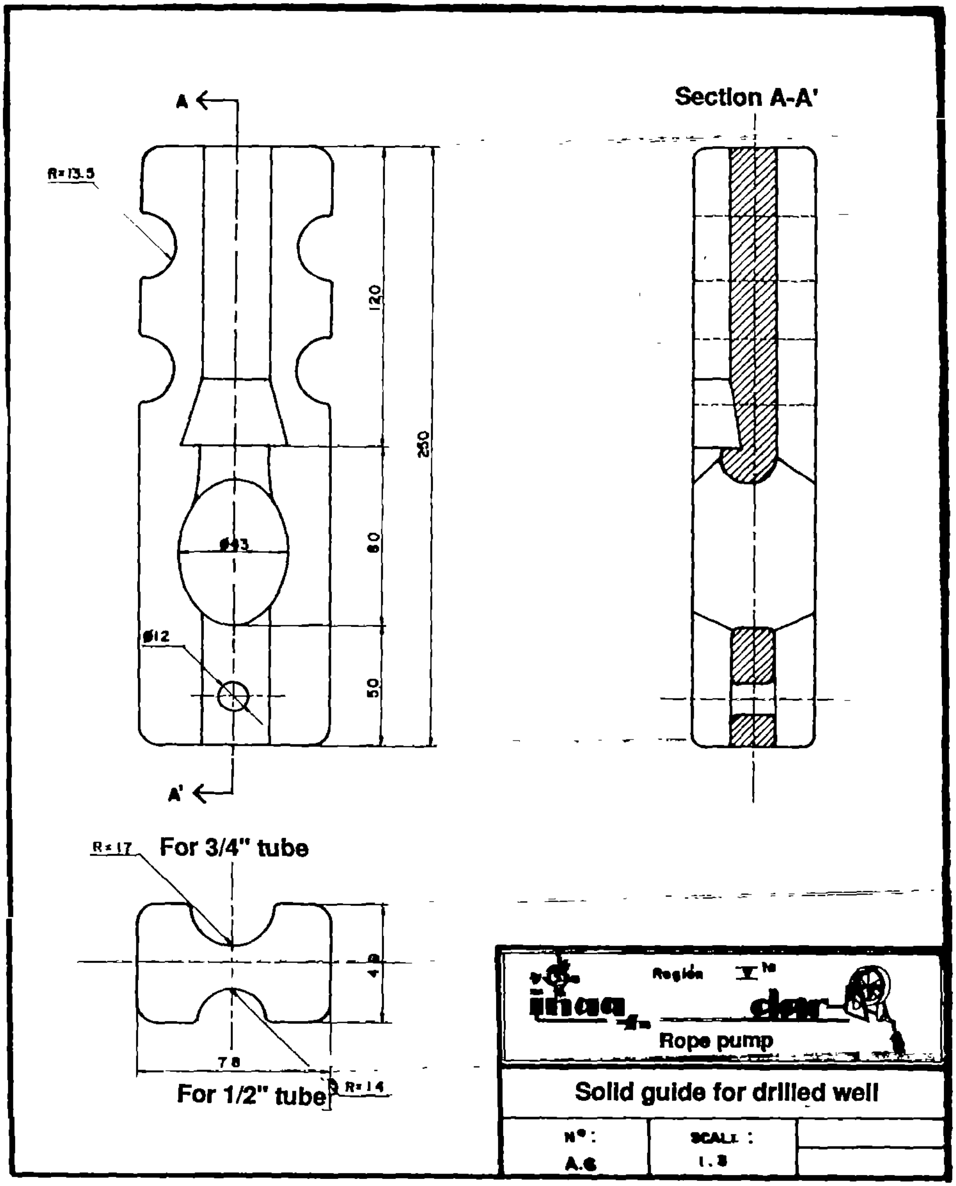
– The starting point is sets of molds of cast plaster. In the forming of the molds, the contraction has to be taken into account.

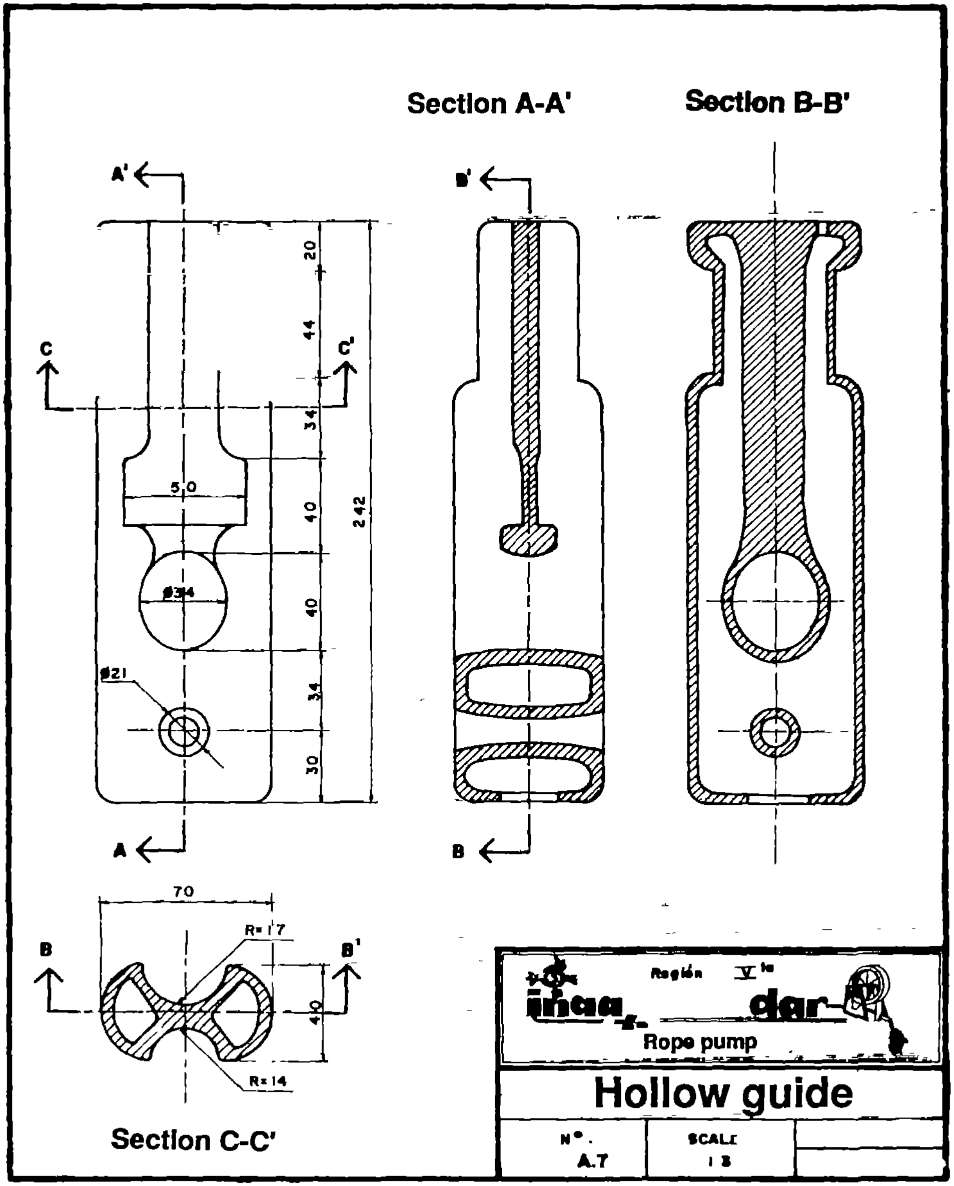
– The molds are filled with liquid clay, and then emptied out until a layer of clay forming in the interior part of the mold is noticed. After several hours, the mold may be opened.

– Leave them to dry several days before putting them into the kiln to fire. As the walls are less thick, the drying and the escape of moisture is not as critical as in the case of the solid guides.

One alternative that could prove interesting, but which we have-not tested, is that of using the same molds, but leaving them solid instead of emptying them out.


A
A'
120
250
80
50
ø12
40
78
R=14
Cut-away area
to protect the rubber
(inner tube) from wear
caused by the rope
Rope pump
Solid guide for hand-hugwell
N°:
A.5
SCALE
1:3


A
A'
R=13.5
120
80
50
250
ø43
ø12
Section A-A'
R=17
For 3/4" tube
78
For 1/2" tube
R=14
Region
Rope pump
Solid guide for drilled well
N°:
A.6
SCALE:


Section A-A'
Section B-B'
A'
B'
C
C'
20
44
34
40
242
40
34
30
50
ø34
ø21
A
B
70
R=17
R=14
40
B
B'
Section C-C'
Región V
Rope pump
Hollow guide
N°.
A.7
SCALE

Appendix F: Calculating pulley wheel and raising main diameters

In section 7.2 we discussed the selection of the pulley wheel and raising main diameters so that the demand of force and power be adjusted to the optimal offer medium (defined by the ergonomic parameters of the users). In this appendix, we deepen the discussion of the calculations regarding this topic.

Four categories of parameters enter into play in these calculations:

- the ergonomic parameters;
- the invariable parameters;
- the variable factor that we cannot influence (the pumping drop) and;
- the two variable parameters that we have at our disposition for optimizing the system: the pulley wheel and raising main diameters.

The **ergonomic parameters** are fixed ranges that we cannot influence. They are the following:

- **handle** Pulley wheel handle diameter (500 mm.)
- **Fhandle** Torque on the pulley wheel handle, between 50 N and 120 N.
- **Pin** Input power developed by user; varies from 40 W to 150 W.
- **f** Frequency of axle revolution of the pulley wheel handle with a range of 0.7 – 1 revolution / second.

The **invariable parameters** that influence the calculation of forces are:

- **g** Acceleration of gravity (9.81 m/s2)
- **rope** Mechanical yield (estimated at 0.8)
- **-rope** Rope diameter (5 mm)
- **! PI** (3.1416)
- Specific weight of water (1,000 kg/m3)

The variable factor that we cannot influence but which does guide the selection of the diameters is:

- **Hhead** Pump drop (m)

The two parameters that we can vary to optimize the system are:

- **-po1** Effective diameter of the pulley wheel (mm) and:
- **-tub** Real interior diameter of the raising main (mm).

In working with these formulas, we must respect the units used in this list. The formula that defines the torque on the pulley wheel handle is:

Fhandle = 1/ rope * -po1 *!/4 * (-tub 2—rope 2) * *g * Hhead (1)

-handle

This formula can be simplified by introducing two combined variables:

C a constant (N/ (m*Ltr)), and
VOL rev Volume per revolution (Ltr)

C = ———————— = 7.7 (N/(m*Ltr)) (2)

rope * ! * -handle

VOL rev = -po1 * ! * !/4 * (-tub2—rope2) * 10 –6 (ltr) (3)

We note that the volume per revolution VOLrev combines the only two variable parameters that define the force over the lever: -tub and -pul. In other words, the volume per revolution is a measure of the forces acting on the lever.

Now, we must take into consideration that the speed of the piston influences the hydraulic efficiency (see appendix G.) The rotating frequency of the pulley wheel handle f assumed as optimum for the user in the range of 0.7 – 1 s–1 defines Vpis (speed of the piston), varying between 1 and 1.5 m/s, while the optimum speed is estimated at 1.5 to 2 m/s. It thus implies attempting to maintain -pul maximum (540 mm, which corresponds to a rim of 20"), and varying the diameter of the raising main -tub.

Let's return to the calculations. Introducing C and VOLrev (equations 2 and 3) in equation 1 gives us:

Fhandle = VOLrev * C * Hhead (N) (4)

and also:

Pin = Fhandle * -handle * ! * f (W) (5)

With these formulas (4) and (5) we can calculate with ease the force on the pulley wheel handle and the input power required in the different cases. Figure A.8 gives the force on the pulley wheel handle as a function of the pumping head, for a range of volume per revolutions used by the Region V DAR as reflected in Table A.3. In this table we reflect some values for five common volumes per revolution.

Table A.3: Recommended diameters of the pulley wheel and raising main depending on the pumping head (The ranges highlighted are the most common).

Range of pumping heads m)	0–6	0–10	10–20	20–30	30–40
Tire for pulley wheel (")	20"	20"	20"	20"	20"
Raising main (")	1 1/2	1"	"	1/2"	1/2"
Pulley wheel diameter - po1 (mm)	540	540	540	540	350
Raising main diameter (mm)	44.5	30.4	23.3	18.2	18.2
Volume per revolution(Ltr)	2 .6	1.2	0.7	0.4	0.25

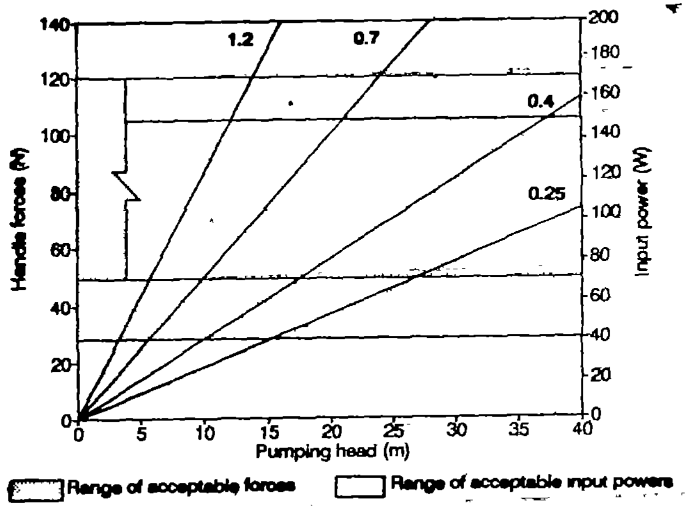


Figure A.8: Force on handle and input power

The figure demonstrates the force on the pulley wheel handle and the power required as a function of depth. It takes into consideration the four volumes per revolution presented in table A.3: 1.2, 0.7, 0.4, and 0.25 liters. The calculation of inputpower was made assuming a speed of f = 0.8 revolutions per second. The two bands give the acceptable ranges from the ergonomic point of view. As may be noted, the limiting factor is the input power and not the acceptable forces. In the case that the pump requires greater forces, the user will turn it more slowly to maintain sustainable power. That will lower the piston speed and thus, the yield.

As we have defined VOLrev, we can take advantage of this entity to easily calculate the flow Qreal:

Qreal = hyd * VOLrev *f (L/s) (6)

With the calculation method presented in this appendix, the force on the pulley wheel handle Fhandle and the input power Pin, can be easily calculated and thus the optimum values for the raising main -tub and the pulley wheel diameter -po1 may also be determined. We can also see how to calculate the pump flow Qreal.

Appendix G: Calculating hydraulic efficiency

In section 7.3 we discussed the mechanical and hydraulic efficiency of the rope pump, and we referred to this appendix for the calculations. Thus we now present a theoretical model for the calculation of hydraulic efficiency, developed by Heuthorst, 1991. We first present the model, and then discuss its validity, defining its premises and limitations, and comparing it with data found in the literature.

Presentation of the model

Above all, it is important to emphasize that for convenience, in this appendix, **all the values introduced in the formulas are in units of the International unit system.** The difference with the preceding is that all the measures of tube and piston diameters, etc., are in meters and not in milimeters and the flows are reflected in m3/s instead of Ltrs/s.
To calculate the hydraulic effienciency hyd, we need to calculate the loss flow Qloss that drips out in the ndragow ring between the piston and the wall of the raising main:

$$\eta_{hyd} = \frac{Q_{rea}}{Q_{theor}} = \frac{Q_{theor} - Q_{loss}}{Q_{theor}} \qquad (1)$$

We define the direction of Qloss downwards as positive (+).
Qteor is easy to calculate:

$$Q_{theor} = V_{pis}\left(\O_{tub}^2 - \O_{rope}^2\right)\frac{\pi}{4} \qquad (m3/s) \qquad (2)$$

$$Q_{loss} = Q_{pres} - Q_{drag} \qquad (m3/s) \qquad (3)$$

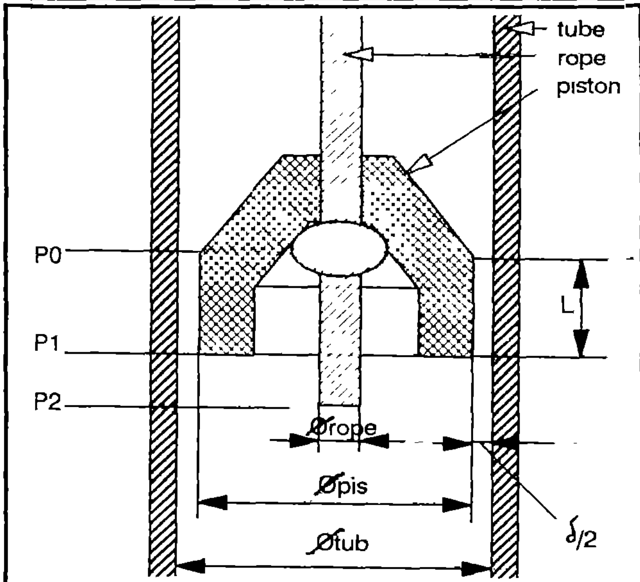


Figure A.10: Principal parameters that influence the calculation model for hydraulic efficiency of the rope pump.

In order to calculate Qloss we define three pressure factors P0, P1 and p2 (See figure A.9). The fall in pressure (P0 – P1) is due to friction losses on the ring, while the drop in pressure (P1 – P2) is provoked by exit losses. The model analyzes each piston as if it were independent, that is, they all demonstrate the same loss. It also does not take into account entrance and exit effects. Thus, (P0 – P2) corresponds to the pressure on the water column between two pistons(14):

$$(P0 - P2) = (P0 - P1) + (P1 - P2) = \rho * g \, Hpis \quad (N/m2) \qquad (4)$$

Now that we have defined the pressure that is exercised on different parts (Note that the value of P1 is unknown), we can give the formulas to calculate the two flows Qdrag and Qpres (without entering into flow study theory):

(14) – Not taken into account are the dynamic effect of water flow such as the acceleration of water and the friction between the water and the tube. This is acceptable because it represents less than 1% in our conditions.

$$Q_{pres} = \frac{2\pi(p_0 - p_1)\varnothing_{tub}^4}{\varrho\, \nu\, L}\left\{1 - \left(\frac{\varnothing_{pls}}{\varnothing_{tub}}\right)^4 - \frac{\left(1 - \left(\frac{\varnothing_{pls}}{\varnothing_{tub}}\right)^2\right)^2}{\ln\left(\frac{\varnothing_{tub}}{\varnothing_{pls}}\right)}\right\} \quad \text{(m3/s)} \qquad (5)$$

$$Q_{drag} = \frac{V_{pls}}{2}\,\frac{\pi}{4}\left(\varnothing_{tub}^2 - \varnothing_{pls}^2\right) \quad \text{(m3/s)} \qquad (6)$$

The remaining component is that of the exit losses. For this we define the exit loss factor Kw:

$$K_w = \left(\frac{\varnothing_{pls}^2 - \varnothing_{rope}^2}{\varnothing_{tub}^2 - \varnothing_{pls}^2}\right)^2 \qquad (7)$$

$$(P_1 - P_2) = \frac{K_w}{2g}\left(\frac{Q_{loss}}{\frac{\pi}{4}\left(\varnothing_{tub}^2 - \varnothing_{pls}^2\right)}\right)^2 \quad \text{(N/m2)} \qquad (8)$$

We have now defined a system of 4 equations (equations (3), (4), (5) and (8) with 4 unknowns: (P0 – P1), (P1 – P2), Qloss and Qpres. This system can be resolved manually (although it demands perserverance) or numerically with a microcomputer. Some results are reflected in the figures 7.1 – 7.3

Discussion of the model's validity.

The model presented here starts with the following premises:

- The tube has a constant interior diameter. All the pistons are of equal form and diameter and are equidistant.

There are neither entrance nor exit effects.

- The flow through the ring between the piston and the tube wall is laminated (Reynolds number less than 2,300). This limits the applicability of the model to cases where neither the speed nor the motion are very great. For example, the following combinations: Vpis ≈ 2 m/s and δ ≈ 0.65 mm., or Vpis ≈ 1.4 m/s and δ ≈ 1.1 mm. We have not discarded the model for other cases, but neither has it been proved. Likely the real losses would be greater than those calculated in the model.
- Also neglected are the dynamic effects of the water flow such as the acceleration of water and the friction between the water and the tube. This is acceptable because it is less than 1% in our conditions.
- The losses between the rope and the piston are not taken into account.

The model was verified in 53 field tests at 4 different depths. The standard deviation of the relative difference between the theoretical results and the field tests (ηhyd, model /ηhyd, real) was somewhat high (10%) due to measuring limitations. Nonetheless, the average relative difference was only 1.3%, so we accept the model as valid.

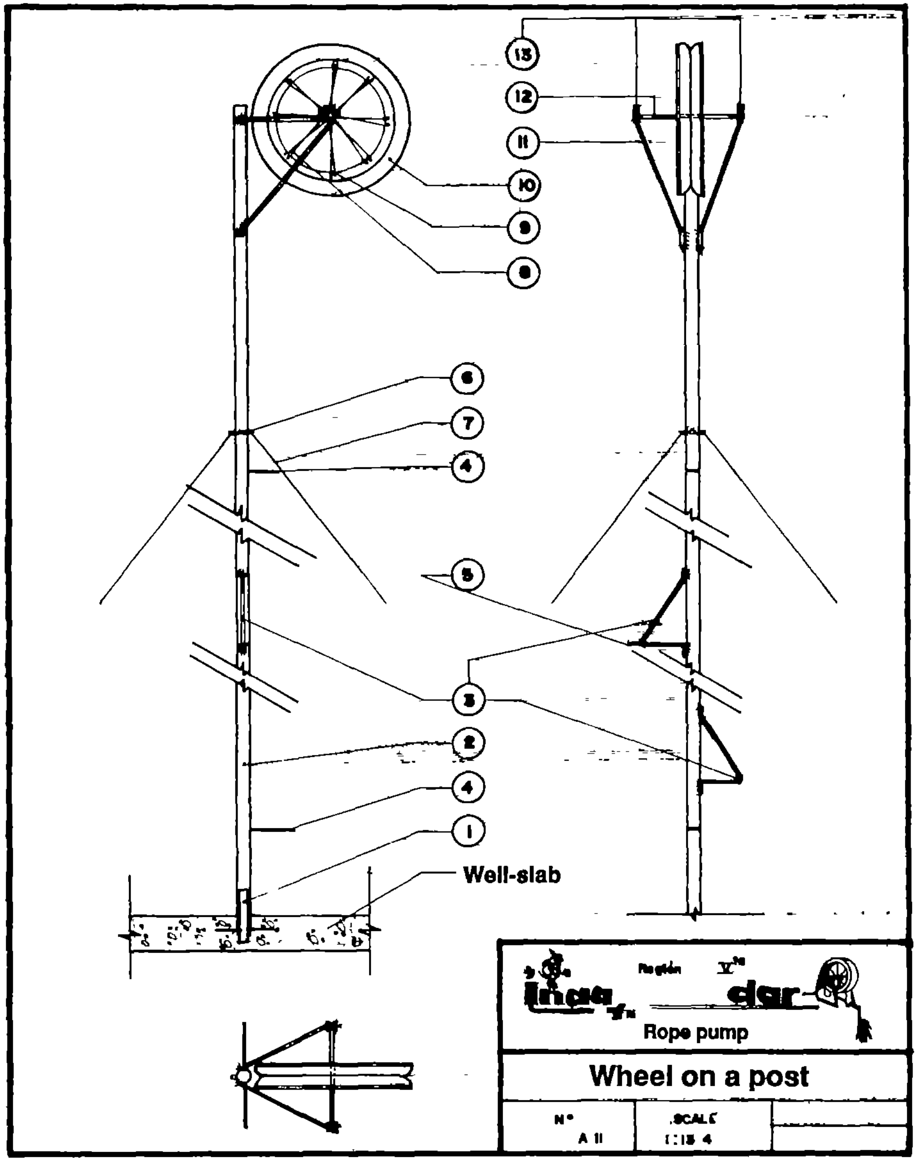
The only similar study that we have found in the literature is that cdragied out by Faulkner and Lambert, 1990, which did tests using a high discharge rope pump with Øtub = 71 mm, Øpis = 69 mm (flat pistons), and 2.4 mm Hhead 5.5 mm. The results coincide with those of Heuthorst in that efficiency increases with piston speed and (of less importance) with the quantity of pistons. There are two differences: Heuthorst found an optimum speed of around 2 m/s, while Faulkner found it to be around 0.7 m/s. This difference is explained by the water acceleration effects and entrance and exit losses that are relatively muchlarger at lesser depths. Faulkner and Lambert also found a slight drop in efficiency at greater depths, a phenomenon that Heuthorst did not encounter in his tests. We do not have an explanation for this discrepancy. What does stand out is the great difference in pumping heads (5.5 m versus 32 m). Moreover, the quantity of pistons that is found simultaneously inside the raising main in Heuthorst varies from 5 to 30, while the variation found by Faulkner and Lambert is only 1 to 5.

Appendix H:
Materials for the wheel on the post.

Part No.	Material	MM	Quant.
1 Anchor	GI 1 1/4" Tube	150	1
2 Post	GI 1 1/2" Tube	6,000	1
3 Ladder	Iron "	430	9
4 Raising main securing	Iron 1/4"	400	3
5 Discharge tube securing	Iron 1/4"	100	3
7 Strut	#12 Wire	12,000	3
6 Strut securing	Iron 1/4"	40	3
8 Spoke	Iron 1/4"	190	16
9 Pulley wheel support	Iron 1/4"	80	16
10 Pulley wheel	15" Tire		1
11 Support	Iron 1/2"	800	2
12 Axle	1/2" Tube	400	1
13 Bearing conjunction			2

Materials total:

Material	MM	Unit
1 1/2" Tube	6,000	
1 1/4" Tube	150	
1/2" Tube	400	
1/2" Iron	1,600	
3/8 Iron	3,870	
1/4" Iron	5,940	
#12 Wire	36,000	
15" Old tire		1
Bearing conjunction		2


13
12
11
10
9
8
6
7
4
5
3
2
4
1
Well-slab
Rope pump
Wheel on a post
SCALE

List of symbols

f	s–1	Frequency of axle revolutions	0.5 – 1
Fhandle	N	Real force on wheel handle (= Fhandle, teor * rope)	
Fhandle, teor	N	Force on pulley wheel handle without friction.	
g	m/s2	Gravity acceleration	9.81
Hhead	m	Pumping head	
Hpis	m	Distance between pistons	2
-	mm	Diameter	
-handle	mm	Pulley wheel handle diameter	500
-rope	mm	Rope diameter	5
-pis	mm	Piston diameter	
-pul	mm	Pulley wheel diameter	
-tub	mm	Raising main diameter	
Pin	W	Input power,developed by user	30 – 150
Psal	W	Exit power, resulting in pumped water	
Qdrag	m3/s	Component of loss flow due to dragglng of piston	
Qloss	m3/s	Loss flow (= Qpres – Q drag)	
Qpres		Component of loss flow due to pressure	
Qreal	m3/s	Real flow	
Qteor	m3/s	Theoretical flow	
Vpis	m3/s	Piston speed	
VOLrev	Ltr	Theoretical volume per revolution	
	mm	Play between piston and tube (= -tub – -pis)	0.2 – 1
		Pump total efficiency (= hyd * rope)	
hyd		Hydraulic efficiency (= Qreal / Qteor)	80–95%
rope		Mechanical efficiency, defined as lossfactor due to friction (= Fhandle, teor / Fhandle)	80–90%
		Pi	3.1416
	kg/m3	Specific weight of water	1,000
	m2/3	Kinematic viscosity of water	1 * 10–6

List of abbreviations

VLOM	Village Level Operation and Management
CITA–INRA	Appropriate Technology Research Center – Nicaraguan Agrarian Reform Institute
COOPINIC	Nicaraguan Innovators' Cooperative
CEPAD	Ecumenical Pro–Development Committee
DAR	Rural Water Institute
INAA	Nicaraguan Water Utility
PAHO	Panamerican Health Organization
PE	Pulyethylene
PP	Pulypropylene
UNI	National Engineering University

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Watt, S., 21 **Chain and washer pumps.** IT publications, Londres, Inglaterra, 1976.

Addresses in Nicaragua

Name:	**CEPAD**, Department of Appropriate Technology
Description:	Ecumenical development organization, works in latrine (traditional and compost), water tank and rope pump construction.
Contact:	Cristy Stickney, adviser.
Address:	Del cementerio occidental, 2 c. al norte. Apartado Postal 3091, Managua
Tel:	Offices: 505–2–664507 / 666102 / 664212 Workshop: 5052–50389
Fax:	505–2–664326

Name:	**CICUTEC**
Description:	Non–profit popular communications association. Edits, among other things, the ENLACE magazine. Counts among its collaborators several worked with rope pumps for many years. Edited and distributed this book.
Contact:	Antonio Belli, coordinator; Eduardo Orozco and Boris Engelhart, collaborators.
Address:	De la CST, 1 c. abajo, 1/2 c. al sur. Apartado Postal A–136, Managua
Tel:	505–2–662643

Name:	**COOPINIC** (Nicaraguan Innovators' Cooperative)
Description:	Cooperative that produces various products based on appropriate technology, including hydraulic ram pumps and rope pumps. The adviser, Jan Haemhouts, is co–author of this book and has been involved in the development of rope pumps in Nicaragua since 1983, serving prior to that as an adviser in Haiti.
Contact:	Jan Haemhouts, adviser.
Address:	Del cine Salinas, 1 c. al sur, 1/2 c. abajo, Mga.
Tel:	505–2–23947 (CEDIN) 505–2–661366 (Jan Hamehouts)
Fax:	505–2–23947

Name:	**DAR–Region V**
Description:	The regional representation of the NicaraguanRural Aqueduct Directive of the national water utility (INAA) in Region V. With its 60 employees, it is dedicated to rural water supply and sanitation programs and education. It began using the rope pump in 1988, and has worked in its development, particularly in terms of the design of the wheel and in rope pumps used with drilled wells. It took the initiative to make thispublication a reality.
Contact:	Osmundo Solis Orozco, head of community participation.
Address:	Contiguo al BND, Juigalpa. Apartado Postal 24, Juigalpa.
Tel:	505–81–351 / 740
Fax:	505–81–369 / 505–2–763205

Name:	**"Guadalupe Carney" Cooperative**
Description:	Women's cooperative producing, among other things,molded glazed ceramic guides.
Contact:	Ervin Torrez, manager; Ron Rivera, adviser.
Address:	De la Normal, 200 m al Norte, Esteli.
Tel:	(Ron Rivera: 505–2–73807)

Name:	**HUTECNIC**
Description:	Rubber, PP, PE, PVC, etc., injection workshop. Has worked making pistons since 1985.
Contact:	Celimo Morales Novoa, owner–manager.
Address:	Puente Larreynaga, 2 c. abajo, 25 v al norte, Managua.

Name:	**Ignacio Lopez Workshop**
Description:	Private metallurgic workshop that has produced wheels for different models since 1990. Working on developing a motorized rope pump as well as a rope pump that works with a windmill.
Contact:	Ignacio Lopez and Reynaldo Erlach, partners. Henk Holtslag, windmill development.
Address:	De los semaforos Repuestos La 15, 100 v. al sur. Managua.
Tel:	(Henk Holtslag, 505–2–74952).

Name:	**Jose Evaristo Talavera**
Description:	Micro–workshop of PE and PP injected pistons.
Address:	Frente al antiguo Mercado Periferico, Managua.

Name:	**"Palo de Hule"**
Description:	Foundation of social projects in the town of Nueva Guinea, founded in 1990. Carries out minisocial projects, and own a shop of sanitation and other materials to improve wells, including rope pumps.
Contact:	Donald Rios.
Address:	Frente a la alcaldia municipal, Nueva Guinea.
Tel:	(via DAR–Region V: 505–81–351 / 740)
Fax:	(via DAR–Region V: 505–81–369 / 505–2–763205)

Name:	**Puente de Paz.**
Description:	US solidarity organization. Finances and executes small development projects. Works with rope pumps at the level of local construction.
Contact:	William Torrez, promoter; Dorie Bargmann, adviser.
Address:	Colonia Centroamerica, #441, Managua.
Tel:	505–2–7–350
Fax:	(via CEPAD; 505–2–664236)

Name:	**Rafael Castilla Castro**
Description	Metallurgic workshop with 3 workers who have been involved in the development of appropriate technology projects since 1984. Produce wheels for rope pumps of different types.
Address:	Del INAA, 1/2 c. al sur, 1/2 c. dragiba, Juigalpa.

Name:	**Society for the selling and installation of rope pumps.**
Description:	Founded in mid–1990, this society sells and installs rope pumps throughout Nicaragua, particularly in the country's Pacific region. The society sells between 5 and 10 rope pumps weekly. Moreover, the society is dedicated to thetechnological development of the pump, and in particular, improving of the pistons and the glazed ceramic guide, the pump for a raised tank and a motorized pump.
Contact:	Rene Mesa, coordinator; Henk Alberts, adviser.
Address:	Reparto Los Cedros, Cdragetera Vieja a Leon, Km.29, 100 v. dragiba, a la orilla de la cdragetera.
Tel:	505–2–51236

Name:	**Alan Gallegos**
Description:	Ceramic workshop that produces glazed ceramic guides molded with extruder.
Contact:	Alan Gallegos, coordinator; Ron Rivera, adviser.
Address:	Del Hotel Estrella, 2 c. al lago, 3 c. arriba, casa no. 21, Managua.
Tel:	(Ron Rivera: 505–2–73807.)

Addresses outside of Nicaragua

Name:	**Bernard van Hemert**
Description:	Principal author of this book. Has worked with appropriate water technologies and pumps since 1982, and with rope pumps since 1987.
Contact:	Oude Velperweg 50 6824 HE Arnhem, The Netherlands
Tel:	31–85–617817
Fax:	31–85–644909

Name:	**Mennonite Central Committee–Technology for Health (CCM–Tecnologia para la salud)**
Description:	This NGO works in conjunction with ECOTEC in the development of the rope pump in Guatemala. Although it has little experience to date, its emphasis on transference of technology is interesting. Contact: Edgard Caceres, director; Raymundo Helmuth, technical adviser
Address:	Apartado Postal 1779 Ciudad de Guatemala 01901 Tel: 030–4308

Name:	**ECOTEC**
Description:	This organization works together with the Mennonite Central Committee in the development of the rope pump in Guatemala. Although it has little experience to date, its emphasis on transference of technology is interesting.
Contact:	Bayron Rosales Amado
Address:	7a. avenida 8–90, zona 2, Ciudad de Guatemala.
Tel:	22471/24871

Name:	**DEMOTECH**
Description:	A small Dutch NGO that is dedicated to development and the transfer of appropriate technology. It has worked for more than 10 years with user-built rope pumps in many places, including Indonesia and Peru. It emphasizes technology transfer and user participation.
Contact:	Reinder van Tijen, coordinator
Address:	A.P. 303 6950 AH Dieren, Holanda
Tel:	31–8330–15777

Name:	**Center for technological advice on water pumps (Centro de asesoría para bombeo de agua)**
Description:	This center has introduced the large flow rope pump for low depths with technical and financial (GTZ–Germany) assistance.

Annex 1:

During a technical evaluation of the 60 ropepumps, installed 2 or 3 years ago by the proyect of INAA-SNV in Nueva Guinea, Nicaragua, some weak points were found.

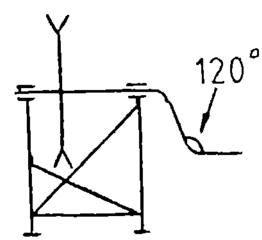
The problems found are:

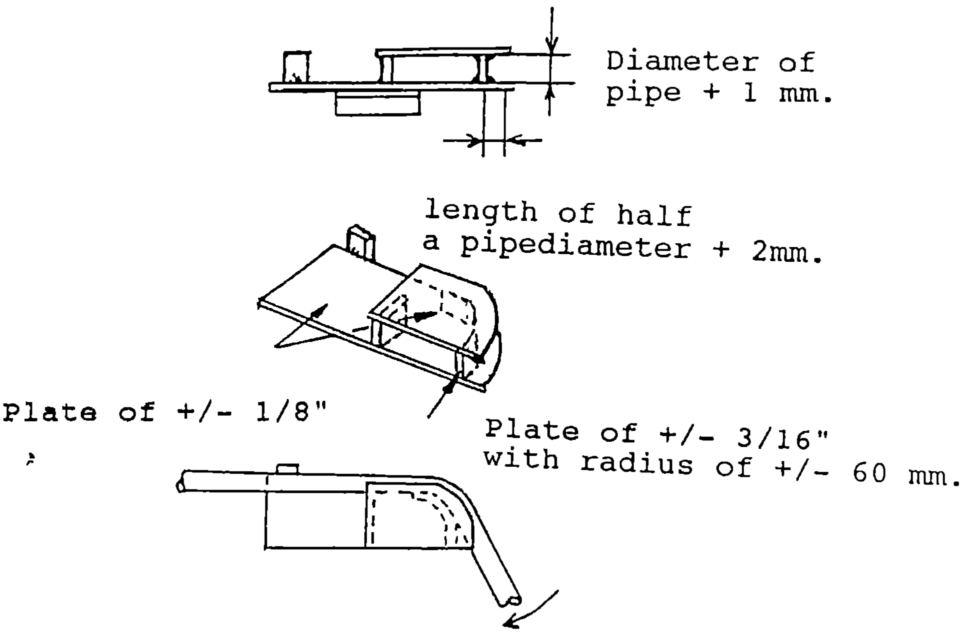
1. THE AXLE (p. 92)

In Nueva Guinea we have the experience that the axle regurarly breaks where it is bended.

Reasons:
- Small radius.
- Bad quality of the bendings. (see photo 23)

Suggestions:
- Make the bends with bigger radius.
- Make the bends of 120 instead of 90 degrees (this is easier if pulley wheel is mounted between supports).
- Bend the pipe with adequate tools (for instance a tool like in the illustration). Pumps made like this 3 years ago and bend with this tool had no problems.





2. THE BEARINGS (p.147-149)

Of the mayority of the pumps of this design, the bearings are getting loose (for example like on page 149) or the bearings got lost, causing worn out and breaking axles.

Reasons:

• Some pumps were installed with a pin instead of a safety bolt.

• The safety bolt got lost or got removed and a small pin was placed. In this way the upper-bearing gets loose and after that the lower-bearing.

• Incorrectly installed bearings (see p. 149).
• Lack of knowledge, maintenance and back-up of the water committees and the users.

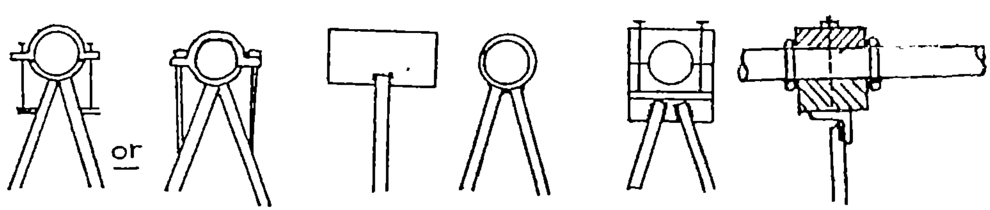
Suggestions:

• If design of page 147 is used, weld the lower-bearings with some points if it is felt neccesary that axle and pulley wheel should be removable. (the experience is that the bearings and the axle hardly wear out when they are lubricated). When the bearings have to be changed, the lower-bearing can be removed with a hammer.
• Oil is better than grease because it "cleans" the bearings.
• Lubrificate the bearings with regular oil every 4 weeks.
• Use axles and bearings of galvanizad pipe if possible. (The galvanizing works as a lubrication.)

Construction when you want the possibility to remove the pulley.

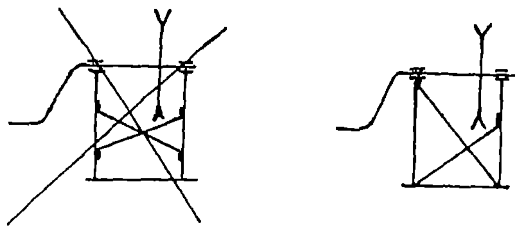
Fixed bearings. Installed in some 1500 pumps; no big problems. (pulley not removable)

An other possibility is to use bearings of wood. (pulley and bearings removable)



3. SPOKES AND DIAGONALS

In the several pump designs, sometimes there are problems with broken diagonals or spokes.



Reasons:

• Welding is of bad quality and/or material is "burned", there is corosion, especially on the welds.
• The diameter of the spokes is to small. (5 mm.)
• Diagonals are not welded "triangular". (if pump structure can move, parts and especially welds can break.)

Suggestions:

• Use spokes of minimal 1/4' (6 mm), but even better a larger diameter, for example 3/8'. (8 mm)

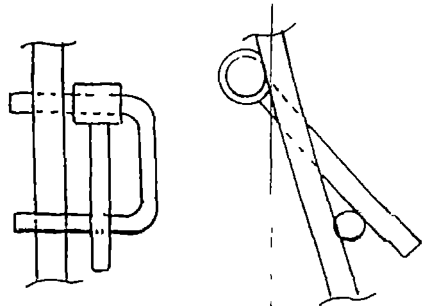
4. THE BLOCKING-SYSTEM (fig. A3, page 193)

Of several pumps the mounting/welding (as on photo 15) is broken. Almost all alternative systems (see photo 16) are broken.

Reasons:

• The welding in this way don't resist the big forces.

on the blocking systems.
• If the blocking-system is close(r) to the axle, the forces become big(ger).



Suggestions:
• **Use the system shown here.** (used since 2 years and has not given problems).
• Strengthen the pumpstructure (legs) where it receives the forces. (see illustration)
• Eventually use bars of 1/2' instead of 3/8' (in case of community pumps/deep wells).

5. PISTONS AND ROPE

The pumps installed 2 - 3 years ago often have original pistons, mounted every 1.5 - 2 m. The efficiency has decreased.

Reasons:
• In practice people change the rope, when it is worn out/starts breaking, and leave the worn pistons. This causes lower efficiency. The pumping-time is longer to get the same amount of water. This causes extra wear out of pistons and rope.

Suggestions:
• Put the pistons with less distance. (0,5 - 1 m) Though the investment at the beginning is higher, in the long run it is cheaper, because the pump is more efficient and the rope and pistons last longer. Fastening the pistons with knots seems the easiest.

• The wear-out of the PVC-tube appears to be "little". Of all pumps installed in Nicaragua (about 2000)in the last 3 years only some 20 are known, where it was neccesary to change the tubes. (about 70% is installed on private wells)

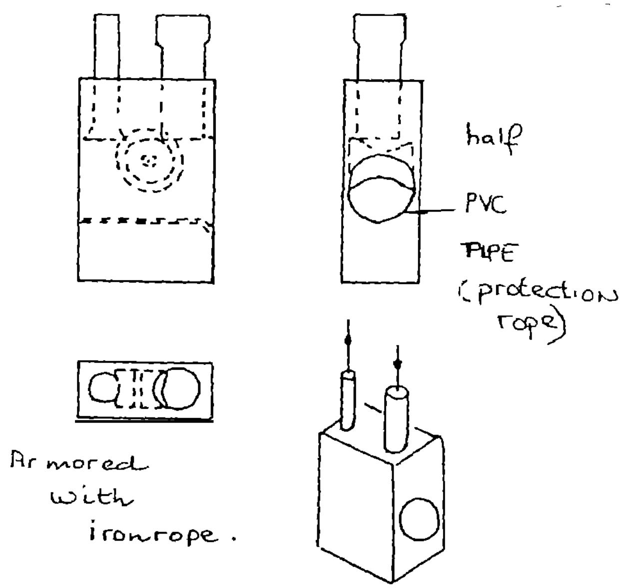
6. THE GUIDE (page 201-203)

The guides as demostrated have several problems like breaking (especially the hollow type), defects in the glazing or breaking during instalation or maintenance. Also these types of guides are relatively complicated in production and distribution.

Suggestions:

• Use an insulator (like the ones used in high-power electrical systems) installed in concrete (or wood). Right now almost all guides in Nicaragua are made with an insulator installed in concrete.

• For drilled wells up to 3" the guide can be made in a round form.



7. CORROSION

On all types of pumps there are problems with corrosion at the base and the wheel-spokes.

Reasons:

- Quality of handling, cleaning and painting in general is low.
- In general users don't maintain the painting of the pumps.

Suggestions:

- Mount a piece of galvanizad pipe 3/8" or 1/2" to protect the lower parts of the pump-structure.
- Use as much as possible galvanized materials and treat the welded parts. Clean thouroughly, especialy the weldings, and paint with anti-rust and "oil" painting.
- Use non-corrosive materials e.j. wood, plastic, cast iron, others?

8. NOISE

The pumps make a noise in the blocking-system and the handle.

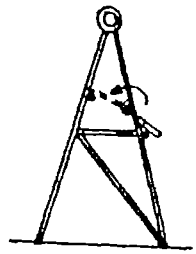
Reasons:

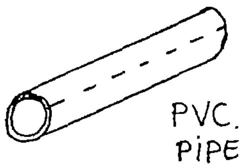
- The materials mounted as brake absorption (plastic tube or rubber) get loose.
- In the case of the handle: in general it is not lubricated. (dirtens the hands)

Suggestions:

- Give an option to remove the brake lever (children have to take more care!), making a "stop". (see illustr.)

• Mount a PVC tube instead of a steel tube. (if cut lengthwise it can be changed)





9. MOUNTING OF THE PUMP TUBE (rising main)

In many pumps installed in Nueva Guinea, the PVC-tubes are not mounted straight in the cover of the well, causing wearing out of rope and tubes. (e.j. photo 22). The mounting demonstrated on page 109 and 136 functions well if made in this way, but many of the pumps are installed with other materials.

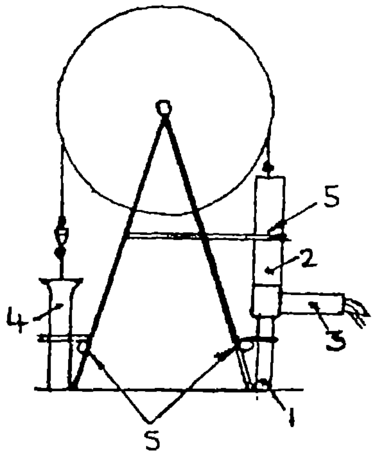
Reasons:

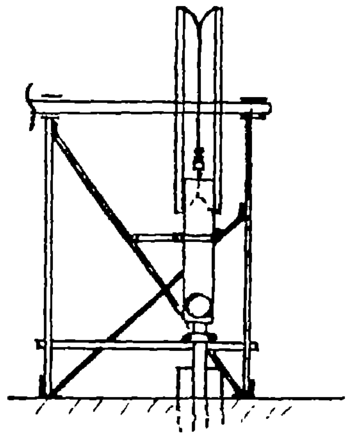
• Lack of adequate materials and knowledge/techniccal control during installation.

Suggestions:

• Line out correctly the discharge and return tube, using a plummet, and use the materials as indicated.

• Assemble a support in the structure of pump so that the pump tube is centralized automatically (see illustration, at number 5).





Tube 2 is 2x diam. of tube 1 e.g. 1=1" and 2=2".
Tube 3 is of same size as tube 2.
Tube 4 is 1 size bigger as tube 1, e.g. 1=1", 4=1, 25" (min).
In drilled wells it is better to use a return tube (in handmade well less necesary).
It is likely that a small booklet will be made by COSUDE/Bombas de Mecate S.A. about production/instalation and maintainance of the (recent) Rope and Washer pump.

	We wrote it several times, but received no response.
Address:	Jiron Bolognesi 165 Puno, Peru.

Name:	**Loughborough University of Technology, Dep. of Civil Engineering**
Description:	The contact people have developed and researched a low depth rope pump for irrigation use in Zimbabwe and Tanzania; they have published various articles, as well as a construction manual.
Contact:	Robert Lambert and Richard Faulkner.
Address:	Leicestershire LE11 3TU, England

"The success of the rope pump relies on the manner in which it is introduced into a marginalized community, with the only resource being the community's desire to participate within a group project, because the process must involve a program based on the community's social organization and self–management. The only methodology that results in the successful transfer of technology is that which takes into account the subjects of development, providing for their collective participation and unlimited creativity."

Nemesio Porras Mendieta

"It is popular because in the first place, it is made from our own materials. It isn't necessary to bring in parts from somewhere else, and its cost is within reach of people with few economic resources. It is democratic because practically everyone has the right to participate in the installation and reparation, including the women and children. There is nothing difficult as I see it."

Concepción Mendoza Castro