EXPERIENCES AND TOLERANCES

IN ROPE PUMP

PRODUCTION

Bombas de Mecate S.A.
Technology Transfer Division
P.O. Box 3352
Fax: 00-505-2784045
E-mail: sdc-agua@ibw.com.ni
Managua, Nicaragua.

MANUAL OF EXPERIENCES AND TOLERANCES IN ROPE PUMP PRODUCTION.

I. PRESENTATION.

This document, which includes experiences and tolerances in the rope pump production process, is part of the Rope Pump Technology Transfer program and is a supplement to the production photo-manual as well as the technical drawing manuals.
At first glance, production appears to be relatively simple. This document reflects the various steps in the production and also includes positive as well as negative experiences encountered in the countryside. It includes the tolerances for materials, which must be met in order to ensure the proper functioning of the pump and also indicates alternatives, which may be used in production without posing any risks.
This document has been elaborated for future producers with the aim of indicating the limits in quality, of preventing errors and also the duplication of errors already committed by others.

The document provides a characterization of the design including all of the parts of the rope pump, such as the rope, the guide, the pistons, the structure, the use of devices, etc. Although this is not a production manual, together with the technical drawings and the photos it gives the guidelines that will prevent unnecessary errors. Reference to these two documents will be made in the text.

In March of 1996, the governments of Nicaragua and Switzerland, through COSUDE, signed a bilateral aid agreement, which would continue activities of the INAA-COSUDE program for a new three-year phase (1996-1998). The rope pump Technology Transfer was specified within the framework of the INAA-COSUDE agreement in order to promote production both regionally and internationally. This activity is being carried out by the Technology Transfer Division of Bombas de Mecate (the rope pump company). The Dutch ecumenical aid organization for technical cooperation known as "Overseas Service" or DOG (Dienst Over de Grenzen) provides technical assistance to the division.

This easily understood document is directed at future producers, aid organizations working in the field of water and sanitation and all other persons interested in rope pumps.
Together with the production photo-manual and technical drawings, this document provides the complete information for carrying out international technology transfer.

Los Cedros, Department of Managua, Nicaragua, November 15th, 1998.

II. CHARACTERISTICS OF THE EQUIPMENT.

Rope pumps represent a simple and low cost technology, which is efficient at 50 meters in depth and is categorized as technology appropriate for use in rural areas.
It is produced locally with materials that are easily obtained, such as: used tire rims, injected plastic, hand-made ceramics, angle iron and rods used in construction, polypropylene rope and PVC pipes.
Equipment repair and maintenance is carried out by the user, as its design allows full mastery of the technology and does not require the use of unavailable or complex tools, which allows the pump to remain active.
Handling this technology is very simple; the wheel is turned with the crank – even a child can do it. On conclusion, the brake must be put on the wheel in order to equilibrate the force of the water column. The pump is accessible to the rural population as it can be acquired with their own economic resources. Its cost is between 3 and 10 times less than imported equipment.
With the use of the rope pump, there is an increase in the amount of water available with less effort, and quality is maintained thus preventing diseases and improving the quality of life.

II.a. WARNING.

The rope pump is in its installation, use and maintenance, an appropriate technology, which does not require any special tools. However, its production includes high quality parts.

THE ROPE PUMP at its current technological level:

- ► Does not have a rope with pieces of rubber acting as pistons!
- ► Does not have a crank with screwed in pipes and elbows!
- ► Does not have a siphon in the bottom of the well acting as a guide!
- ► Does not have a wheel made from wood or a bicycle wheel!

III. PUMPING CAPACITY.

PUMPING CAPACITY

Depth (Meters)	Adults (Liters/min)	Children (Liters/min)	Time needed for an adult to fill a barrel (min)
5	70	39	3
10	41	19	5
15	27	13	8
20	20	10	10
25	16	8	13
30	14	6.5	15
35	12		18
40*	15		14
45*	15		14
50*	15		14

* At these depths, two people are required to pump the water using a double crank pump.

The pumping capacity depends primarily on the power with which the user can pump. The chart is based on field tests and coincides with a physical-mathematical model elaborated for this process.
Losses due to friction on the wheel and the guide are unknown, but are estimated at approximately 15% of the power applied.

Friction between the pistons and pipe must be minimal

The depth of the well determines the diameter of pipes and, therefore, the volume of water to be extracted.

All these factors are related and establish the efficiency of the pump.

The maximum depth that can be reached with the double crank pump is 50 meters. A design based on a double bicycle ridden by two people has been elaborated for depths between 50 and 80 meters.

A. PISTONS, ROPE, PIPES AND EFFICIENCY.

The pistons are one of the most sensitive parts of the pump. Together with the rope they form an endless chain. When the rope rotates it leads the piston through the pumping pipe, pushing the water inside upwards.
The piston is a cone shaped part with a hole on its top and must meet the following norms:

- Exact dimensions.
- Cone shape to reduce friction.
- Strong and water-resistant material.

The chart called "Variations in Measurements of Pistons and Rope" in Section III-A of the technical drawing manual indicates the diameter of pistons that can be used. Pages 8 through 11 of the production photo-manual show the various steps for producing the pistons.

SEMI-INDUSTRIAL PRODUCTION.

For semi-industrial production of pistons, experience and basic knowledge of the injection process are required. The most rudimentary method is with a machine wherein a piston manually injects the heated material into a mold. When the heated piston is removed, it can be left to cool off or placed in water. The means used to cool off the piston has no noticeable effect on its final diameter. The practice currently being followed is injection one at a time using a cylinder with a spiral wheel inside and which is activated by an electric motor and heated with electric resistors.

A.a. PISTONS.

Raw material used for pistons: This should be resistant and of good quality in order to ensure it does not suffer wear during use. The most appropriate material is plastic, and in this case Polypropylene or Polyethylene. Polypropylene has better resistance characteristics than polyethylene. The fusion temperatures are 165 °C and 134 ⌒C respectively, which makes the processing of polyethylene easier due to the lower temperature required. Polyethylene is much more easily obtained on the market and is what is used most. It must be high-density polyethylene as the other types are softer and less resistant.
The raw material can be unprocessed or reprocessed polyethylene. In this case, discarded pieces of polyethylene are reprocessed in order to be used in the injector machine as shown in the last photo.
When using reprocessed material, care should be given to ensure that it has not been mixed with other types of plastic such as polypropylene or PVC. Dirt mixed in with the material can significantly decrease its quality. Only clean material without foreign

substances must be reprocessed. The contraction of the piston on hardening depends on the type of material. A mixture of different materials or of materials with different densities can cause distortion in the diameter of the piston and decrease resistance.

It has been proven that a plastic piston in a pump that has been properly installed and which has met these specifications should last four years.

ALTERNATIVE TECHNOLOGY:

The use of flexible PVC was also tested in Nicaragua, resulting in injected pistons that were similar to polyethylene pistons but which resembled the flexibility of rubber. These pistons create excessive friction in the pipes and cause excessive wear to the piston. These pistons can be used for a much shorter time than the plastic pistons.
Rubber or wooden pistons are sometimes found. For shallow wells (six meters), it is possible to pump water during only a limited amount of time with these pistons because of wear to them.
These pistons are usually hand-made and do not have exact dimensions. They are also generally flat and round (like coins) with a hole in the center. Friction and deformities are excessive and produce a great loss of water.

A.b. MOLDS FOR PISTON INJECTION:

For semi-industrial production, the injection process, in which the mold plays an important part, is used.
The function of the mold is to give an exact form to the piston; thus the final diameter of the pistons depends on the quality of the mold.

Each mold consists of two parts, as shown on page 9 of the photo-manual. The most logical design for these two parts is a bottom piece with the inside cone-shaped part of the piston and a pin on top with the diameter of the hole in the piston, and a top piece consisting in the outside shape of the piston. However, during the injection process, a seam is formed where the two pieces meet. A seam on the bottom part of the piston will cause friction in the pipe. The bottom part of the piston is slightly conical with a radius that is slightly inferior to the top part. (See Drawing A-03 in the technical drawing manual). A small seam on the higher part of the piston will not cause friction in the pipe and will disappear with use. This means that the separation between the two parts of the mold is not located at the bottom of the piston, but a little higher at the point where the piston becomes conical in shape.
Injection is done preferably through a central hole or canal and not from the side. The inside bottom part of the piston should have a rounded edge as shown in drawing A-01 of the technical drawing manual. This inside edge touches the rope when it passes though the guide and the wheel, and may cause the rope to wear.

TECNOLOGICAL ALTERNATIVES FOR THE MOLD:

There are molds which require injection through a side canal, producing a piston with a shorter life span and which do not permit intensive use.
Injection from the side will cause the injected material to enter the mold and separate into streams, which meet, again on the opposite side of the injection orifice. An almost invisible scar occurs at the spot where these streams meet, where the pistons tend to break with use. In fact, there are pumps installed with rope, but missing pistons where this type has been used. This occurs most frequently when slightly contaminated material has been used in reprocessing.
In high capacity injection machines, the molds can produce six or more pistons in one cycle, since the injection canal is a network. Injection in these cases is through the side and the material must be of good quality.

PISTON DIAMETER:

Piston diameter is determined by the inside diameter of the pipe. Together with the rope and water, the piston takes up the entire space inside the pumping pipes.

PISTON, MOLDS AND PIPE MEASUREMENTS.

Nominal diameter of the piston	Diameter of the piston	Inside diameter of the pipe	Space between the piston and the pipe	Maximum diameter of the mold
1/2”	17.90	18.20	0.15	18.5
3/4”	22.70	23.53	0.42	23.6
1	29.60	30.36	0.38	31.2
1 ½”	43.40	44.56	0.58	45.3
2	52.80	55.71	1.46	55.0

Inside diameter of pipes according to ASTM D-2241 norm.

Volumetric efficiency of the rope pump depends largely on the space between the piston and the pipe. This empty ring should be large enough to avoid friction and small enough to avoid loss of water. The ¾ diameter of the piston is relatively small, while the space between the piston and the pipe is relatively large. This is due to the quality of production of the PVC pipe, which often does not meet standards. The standard deviation of the diameter of the pistons is in the order of 0.4 % of its diameter and tends to be larger for larger pistons. Extremes in diameters are caused by impurities in the raw material and may be up to 1% above the average diameter. In practice, installation technicians solve these problems after installing the pump by filing the pistons that cause friction in the pipe. The observation of these technicians can be seen as quality control of production.

A.c. THE ROPE.

The rope, together with the pistons, functions as an endless band transporting water. The pistons are located the entire length of the rope and are attached with two knots, one in front of the piston and one directly behind it. The knot behind the piston is tied first as it allows the second one to be tied more easily right next to the piston. Normally, the knot would be tied in front of the piston first.

The rope must have the following characteristics:

- Be sufficiently strong and durable.
- Must not be stretched during use. Rope that is stretched over time will cause a lack of tension on the wheel resulting in the pump beginning to slide.
- Must not be too smooth to avoid sliding on the wheel.
- Must be water-resistant.

THE MOST APPROPRIATE ROPE.

The rope that has worked correctly, meeting all requirements has a diameter of approximately 5 millimeters indicated with the 1/8" nominal measurement. (4.5 mm should be considered as the minimum diameter)
A polypropylene fiber rope has been used. This is the same material from which sacks are made. This material is twisted into strands and the rope consists of three of these strands twisted together. The advantage of this raw material is that this rope does not become smooth with use, which avoids sliding on the wheel.
When installing, the ends are attached by braiding (See installation manual, drawings k1 and k2). Knots are not used as they are difficult to untie when tautening the rope or for repairs.

It has been noted that the rope tends to break immediately before or after the knot. The following causes this: When the rope goes through the guide, the inside part touches the guide and the outside part makes a wider turn. The difference is minimal, but significant. The inside part contracts a little while turning and the outside part stretches. This causes the fibers to bend, especially right past the knot, resulting in breaks in the rope just past the knot for no apparent reason. To avoid this problem, ensure that the diameter of the part of the guide where the rope turns is sufficiently large. This process is evident in 1/8" rope after several years of use. However, in community wells, where 1/4" rope is used with knots, and ¾ pumping pipes were used for better security, it was noted that in a period of several weeks the extra thick rope had already “broken”. This effect was specifically seen in drilled wells using guides with a total diameter of 4 inches and a relatively small ceramic piece. In the case of 4 inch-drilled wells, the 1/4" rope is used without knots and the pistons are attached with pieces of rope intertwined with the thicker rope.

In all wells with depths above 29 meters an extra large 1/4" or 7 millimeter rope is used as standard, with the pistons attached with pieces of rope intertwined. Using a larger rope means that part of the water in the pumping pipes will be replaced by the rope, which will help to decrease the weight of the water column and therefore reach more depth with less water per turn.

CHART OF NOMINAL AND REAL DIAMETERS OF THE ROPE.	
Nominal	Real
1/8"	4.5 mm
1/4"	7 mm

The different types of rope deteriorate with sunlight, but since only a small portion of the rope is exposed while the rest is in the shade of the well, this has not been a determining factor on the life span of the ropes.

TECHNOLOGICAL ALTERNATIVES FOR THE ROPE.

There is another very good quality rope on the market made of polyethylene, but the material is a phylum instead of a fiber, causing the rope to be smoother. There is also a white rope made of very fine braided nylon fibers. It is an excellent rope used for sailboats and mountain climbing, but not applicable to rope pumps. This material stretches and becomes very smooth.

EXPERIENCES WITH INJECTED KNOT.

Intertwined pieces of rope are used to attach the pistons to extra large 1/4" or 7 millimeter rope. There has also been success using injected knots. These are small round balls made from the same material as the pistons, which are injected, into a mold using the same rope. The diameter is slightly smaller than the ½ inch pistons. Injection is through the side and the mold consists of two plates, with a canal through the center through which the rope passes. There is also a round hole, which forms the ball.

A.d. THE PIPES.

The pipe is a conduct in which the column of water to be extracted is formed, and has the following characteristics:

- Made of PVC.
- Designed for pressure.
- Meets ASTM D2241 standards.

CHART OF NOMINAL AND REAL DIAMETERS OF THE PIPE.

PVC pipe Outside diameter	
Nominal	Real
1/2”	21.34 mm
3/4”	26.67 mm
1"	33.40 mm
1 ¼”	42.16 mm
1 ½”	48.26 mm
2"	60.33 mm
3"	88.90 mm
4"	144.30 mm

The recommended pipe should meet ASTM D-2241 standards. All piping is the pressure type used for potable water.

In Nicaragua, measurements are in inches, whereas other countries use millimeter measurements, requiring adaptation.

In the technical drawing manual, there is a table entitled “Variation of Measurements for Pistons and Rope” in chapter 4 and in chapter D is “The Installation Accessories” chart.

Pumping pipes vary according to the depth of the well. The deeper the well, the smaller the diameter of the pipe. The combinations of types of pipes according to depth are based on experience. Going beyond these limits can cause the rope to slide on the wheel over time. The rope with pistons can support the weight of the water column in the pumping pipe. The maximum weight of the water in the pipes is 10 kilograms and should not be exceeded. Therefore, if pipes with different measurements are used, the maximum depth should be adapted to the maximum weight of 10 kilograms.

Deficiencies have been encountered in the pipes depending on their origin of production. Examples of these, which can affect the pumping pipes, are:

- The inside diameter does not meet standards. This causes a problem when the diameter is smaller than what has been established because the piston will not fit or will fit but cause friction.
- The inside walls of the pipes are rippled, which can cause unforeseen friction.
- The jacket is not made correctly. Some jackets are found to have a narrowing, right before the widening, where the pistons stick.

These problems are more sensitive in the case of ½” and ¾” pipes.

Care must be taken in the handling of ½” pipe. Heat from the sun can cause contraction and deformations in the pipes causing the pump to malfunction or function with friction. Handling and tying up during transportation, together with the heat from the sun can ruin the pipes.

Dust and dirt in the pipes are always obstacles when installing. Storing of the pipes, therefore, requires some care.
The type of pipes used for irrigation or drainage is less expensive but with a smaller wall thickness and is not used for rope pumps.
Metal or flexible pipes are never used in rope pumps, as they are not appropriate for this type of equipment.

A.e. EFFICIENCY.

Pumping capacity depends firstly on the pumping power of the user, which can be between 40 and 100 watts. However, the diameters of the piston and its distance, the depth of the well and the diameters of the pipes and mechanical loss of the guide and in the bushings box are also determining factors. The chart in chapter III is based on field tests and coincides with the physical-mathematical model elaborated for this process.

ASPECTS RELATED TO THE PUMPING PROCESS:

When the crank is turned and the pumping pipe is completely filled with water, the pumping process has begun. Air never enters the pipes. The total weight of the water column is distributed equally over each of the pistons, as long as they have the same diameter, creating a downward pressure. Each piston pushes the water upward.

It is a process involving pushing and suctioning which depends on the position of the piston next to the exit (at the reducer) at the well cover. Immediately before the water reaches the reducer, this piston feels the water suctioning it downward. At the same time, water is entering the pumping pipes from the bottom while the next piston has not yet arrived, or in other words, the water is suctioning toward the inside of the pipe. This distribution of pressure and drops in the pressure is redistributed along all of the pistons. Overall, this process can be described as a column of water on each piston with the length of the distance between the pistons. This column filters downward around each piston at a certain speed. The speed at which the water filters downwards is approximately proportional to that of the distance between the pistons and to the power of 0.65 and is directly proportional to the surface of the opening between the piston and the pipe. Therefore, in order to minimize this loss or filtration, the diameter and number of pistons must be increased.

The tension in the rope is constant during the pumping process and independent from the power with which water is pumped. More power means more speed and more water, but always the same tension or force in the rope.
The relationship between volumetric losses and the power of 0.65 of the distance between pistons was determined through a series of tests in a ten-meter deep well using 1" pistons at distances ranging from 20 centimeters to three meters between each. It is a mathematical description of the process of the mechanics of the fluids,

which surround the pistons. Included in the physical description of this process is the role of the currents around the piston and the laminar layers on the inside surface of the pipe, which intervene in the turbulent flows.

It is easy to obtain a first estimate of volumetric losses and efficiency, considering that the filtration is constant and does not depend of the pumping speed. By pumping water and decreasing the speed of rotation, a speed is reached wherein water filters downward at the same speed as upward pumping, and at that very moment no water is pumped out. The water column remains semi-stable up to the height of the reducer and the volumetric efficiency is zero. To achieve this, six turns per minute are required, whereas normal operating conditions require 60 revolution per minute with a loss of six in every 60 and therefore a volumetric efficiency rate of 90 %. A volumetric loss of 20 % is considered acceptable while a new pump should have a loss in the order of 10 %.

The losses caused by friction in the wheel bushings and the guide are unknown. The minimum force required to move the pump system from its point of equilibrium when there is no water obtains a first estimate of losses due to friction. This force is applied to the rope and then compared to the weight of the water column. The force is only 2 Newton or 0.2 Kilograms. For a water column weighing 10 kilograms, this means that mechanical losses are lower than 2 or 3 %. In other words, these losses are very small compared to hydraulic losses. They increase when the pumping pipe fills with water and there will, therefore, be increased pressure and friction in the bushings. However, a simple method for measuring these losses caused by friction in the bushings has not been found.

The friction between pistons and pipes should be minimal although it may be significant in a newly installed pump, which is felt when the pumping process is begun. This friction disappears over time as the seams in the pistons wear.

The Kinetic energy of the water column in the pipe, which is proportionate to the speed squared, and with which the water reaches the surface, is also a loss of energy. It also influences slightly the volumetric losses as it increases the pressure on each piston. However, kinetic losses are, under normal operating conditions, less than 1 % of the applied power, while reaching 5% as a maximum, when the pump is used at its maximum speed.
Therefore, the total efficiency of the rope pump is in the order of 75 to 85 %.

THE GUIDE.

The guide is installed at the bottom of the well and is where the pumping process is initiated. It function consists of guiding the rope with pistons attached so that it enters into the pumping pipe from below, as well as maintaining it taught (plumbed) with the appropriate tension. Therefore, the guide has various functions integrated into one piece.
It serves as a counterweight to tauten the rope in order to avoid sliding on the wheel. The weight of the guide is between 8 and 9 kilograms, as a weight lower than 7 kilograms would cause sliding. This sliding occurs in cases where depths approach the maximum in range or its application, as is 11 meters for 1" pipes and 19 meters for ¾" pipes, when the weight of the water column is close to 10 kilograms.
The weight can be lower in drilled wells where double piping is used, since two pipes used together help to stop the guide from lifting when the rope tautens.

SEMI- INDUSTRIAL PRODUCTION:

The guide is a concrete box with a base piece, an entry pipe, a pumping pipe and support pipe, and a ceramic piece inside.
These parts of the guide must be made in such a way that the rope never touches the concrete, which would cause wear to it as well as to the pistons. Around the pumping pipe is a small protective piece. See drawing B1-04 in the technical drawing manual. This piece is used to stop the pumping pipe from contracting during assembly when the pieces are mounted together. Experience has shown that it is the most sensitive point. Galvanized wire is used to assemble the guide, but in the finished product this wire does not come in contact with the water. Therefore, the rope pump is not susceptible to rust problems and can be used in very corrosive water.

The entry and pumping pipes on the guide have a wide mouth to facilitate the entry of the rope and pistons. This process is located in section B.2.1. of the photo-manual and is very simple. However, many precautions must be taken when PVC pipes are being used. When PVC is burned, it produces an extremely dangerous poison called "dioxin", which in even small concentrations can have long term negative effects to one's health. In some countries plastic pipes have replaced PVC for this reason. When heating the pipes, care must be taken to ensure that the PVC does not burn. A temperature slightly above 100 ^oC is required; therefore it is not necessary for the PVC to be placed in the flame. It simply needs to be heated from a prudent distance from the fire. Another option for heating the material is placing the pipe in hot oil.

The coil of wire underneath the base piece helps maintain the parts at a certain height from the bottom when filling the mold with concrete. In the guide's concrete, reinforced or construction iron is not used.

The water enters the guide through the base piece (2" PVC pipe) located at about five centimeters from the bottom of the guide. The guide itself is placed on the bottom of the well. This allows practically all of the water to be drained from the well. This is important when a well has very little water, as water can still be extracted, which would not be the case with a bucket and rope.

B.a. THE CERAMIC PIECE

The ceramic piece in the center of the guide has a design that was developed based on practical work and corresponds to various needs at the moment of assembly. See photos B1, B.2.1., B.2.2. and B.2.3. of the photo-manual and B1-02 of the technical drawing manual.
The ceramic piece is shaped like a packsaddle to stop the rope from leaving the canal formed by the packsaddle. The diameter or thickness of the cylinder part through which the rope passes is 3 centimeters. It is important for the diameter to be as large as possible so that the rope does not have to make such a narrow turn. A narrow turn would cause the rope to break after each knot that goes through the guide. The ceramic pieces for drilled wells of 4 inches in diameter (10 centimeters) are smaller so they can fit into the casings for these wells. In this case, pistons are not attached to the rope with knots. Instead, small pieces of rope are intertwined with the main rope immediately before and after the pistons, to attach them. A mold can also be used to inject material to be placed before and after each piston and function as knots.

The ceramic piece is made of refractory clay obtained locally. It is similar to white porcelain, but is less expensive. Its vitrification temperature is between 1250 ^{o}C and 1300 ^{o}C. The clay is mixed with water then sieved to remove small stones and sand. Number 40 to 80 (the number of holes per inch) screen is used to sieve the clay. The clay must be kneaded in order to remove air bubbles and homogenize it. Before the material is fired for the first time, it must be dried, a process, which requires time, as the piece is solid. A piece that has not dried properly will crack on the first firing. This drying process can be done in three days during the dry season at a room temperature of 35 ^{o}C. During rainy season, it is not possible to dry the pieces properly, causing them to crack when they are first fired. The most critical phase during the first firing is when the temperature reaches between 360 and 400 ^{o}C as this is when the clay looses its chemical water. The water and chemical water in the pieces can cause cracks during the first firing.
The ceramic piece has a coat of enamel, which makes it completely smooth where it touches the rope. This enamel does not wear. In Nicaragua the piece was developed using raw material and technology available locally. It of course requires a ceramic workshop to carry out the process, but when the process is learned, it is not difficult to carry out independently as it does not require the same precision as ceramic utensils. Vitrification of the enamel as used in Nicaragua requires a temperature of 1236 ^{o}C. The enamel used is a mixture of 50% lava rock and 50% feldspar. This material must be ground into a fine powder, then mixed with water and passed through a number 120

screen. Depending on the country, this enamel mixture can be purchased by the quintal in workshops or manufacturing plants where toilets or ornaments are produced.
In ceramics it is common for the pieces to break during the process of firing, due to incomplete drying or sudden changes in temperature. In the case of defective pieces, the cracks are filled in with clay and covered with a new coat of enamel. The finish result is identical to the original piece.

The most appropriate oven uses liquefied gas as fuel, has four burners and a capacity for 50 pieces. The temperature required for the enamel is reached in 10 hours.

TECHNOLOGICAL ALTERNATIVES FOR THE GUIDE:

Previous designs for a guide made of ceramic had a weight tied underneath them and the water entry higher up. During the dry season, users complained that the pump did not pump water but that they could extract water using a bucket, creating rejection for the product. A well should preferably have more than one meter of water, but the rope pump requires only 10 centimeters of water.

There are some ceramic pieces used on the guide, which are similar to the material used as insulation on posts where electrical wires run. Thus it is possible in the initial phase of production to use this type of insulators in the guide as an alternative. Assembly is a little more complicated but it can work. Another alternative that has been used is small bottles instead of ceramic pieces. The bottle is filled with cement to avoid easing breaking. Glass does not break easily under water making it an alternative for the initial phase of production. A disadvantage to this solution is that a cylinder bottle can cause the rope to slip to one side and touch the protective pipe or the concrete. In any place where the rope touches the PVC pipe there will be wear to the pipe over time.
There are cases where the guides are made from clay for making bricks at a low temperature. It is a lower quality alternative wherein the clay is poured into plaster molds. It is important to note that this technology is commonly used in many countries for producing ornaments or religious pieces. This product did not produce good results due to the fragility of plaster and the enamel that vitrifies at a low temperature.
Wooden guides are good quality, hard, water-resistant and have good results for a limited time of, for example, one year. However, over time the rope wears the wood, making a groove in which the knots get stuck. It is also difficult to process this type of wood, making it less appropriate for the process of semi-industrial production.
There are examples of guides that use a curved siphon-type pipe at the bottom of the well. The friction between the rope causes wear making its life span only three months.
Some producers have substituted the ceramic piece with a 12” galvanized pipe about 10 cm long attached transversally between the entry and pumping pipe. This surface is smooth enough but when the rope rotates it moves along the pipe and touches the concrete because of the lack of ends on the packsaddle, thus decreasing its life span. Another problem is the fact that over time the pipe corrodes causing wear and water contamination.

There is also experience in Nicaragua with ovens that use kerosene or diesel as fuel. The photo-manual shows an electric oven that is not recommended because its resistances burn out or break relatively easily. To reach the high temperatures necessary for the enamel, up to 20 hours can be required. Handling and maintaining an electric oven is also somewhat complicated and the electricity supply is not assured in this country.

The guides with a ceramic piece that are currently being used will last practically forever. The entry and exit pipes are more likely to become damaged.

B. THE ROPE PUMP STRUCTURE

The function of the rope pump structure is to support the efforts of the axle, wheel, and crank, as well as fix the pumping pipe, both entry and exit sections. It is the esthetic part (Visible) of the pump and is installed on well cover. The types of materials and their diameters depend on the use given to the equipment.
The structure of a semi-industrially produced pump is made of pipes, iron rods, iron strip and angle iron. The wheel is made of cut up truck tires with clamps and spokes.

There are essentially three types of pumps: the family rope pump, the extra-strong rope pump, and the community rope pump. (See technical drawing manuals).

Family pump:
For family wells, family plots.

Extra-strong pump:
For community wells serving three to ten families, school wells, water and sewage projects, family plots, with an extra strong structure. This pump generally has a protective cover, which covers part of the wheel.

Community rope pump.
For community wells, school wells, water and sewage projects, 100% galvanized structure, protective cover covering part of the wheel.

The family pump is the product of a search for the most inexpensive equipment possible, while maintaining a high degree of reliability for the user. The extra-strong pump is more resistant with regard to the materials used in the production of its structure and wheel. The other parts, such as the rope, pistons and pipes are the same as for the other types of pumps.

In the case of the community pump, the wheel is mounted on the outside of the structure to provide better stability when the equipment is in operation, as the two bushings on the axle are connected. On the other hand, the bushings on the structures of the family and extra-strong pumps require triangular supports to ensure stability.

Each support and tensor requires soldering which is susceptible to damage and the result is an esthetically less attractive structure than in the case of the community pump. With regard to the strength of the bushings and consequent wear, the community pump also has slightly better characteristics.

The rope pump was developed in response to demand from the family sector. The advantage of the family and extra-strong pumps' structure is that the wheel is located inside the structure, which gives them more stability when installing. The great majority of pumps are installed in wells with wooden covers or lumber frames. The community pump would fall if installed on the pieces of lumber due to eccentric weight of the wheel which must support not only the weight of the water column, but also the force of the crank which halfway through a turn moves upward. Therefore, the use of designs with the wheel on the outside of the structure is limited to wells with a concrete slab on which the wheel structure can be fastened. This sector of the market is very limited.

Corrugated iron is often used for the structure (Construction iron) instead of smooth iron. Corrugated iron is less attractive esthetically and is more susceptible to rust. However, corrugated iron has different characteristics than smooth iron; it has a hardening component and is tempered in the corrugation process. This is the reason for its use in rope pump production.

One quarter inch-smooth iron with a diameter of 6.4 mm is used in several parts of the structure. On occasion only iron with a diameter of 6.0 mm can be found in the market. This iron cannot replace 1/4" iron as it has proven to be too weak for application in the wheel structure.

CHART OF NOMINAL AND REAL MEASUREMENTS (IRON MATERIALS)

Black or galvanized iron pipe	
Nominal	Real
½"	21.8 mm
¾"	26.8 mm
1"	33.5 mm
1 ½"	48.0 mm
2"	60.5 mm

Rod	
Nominal	Real
1/4"	6.4 mm
3/8"	9.4 mm
½"	12.5 mm

Thickness of the angle irons	
Nominal	Real
Normal 1" x 1/8"	3.2 mm
Extra-strong 1 ½" x 1/8"	3.5 mm

Galvanized sheet: Caliber 24. Coincides with the 0.6-mm width.

TECHNOLOGICAL ALTERNATIVES FOR THE STRUCTURE.

There are rope pumps where galvanized pipes have been used (see drawings of the community pump in the technical drawing manual). This increases their life span, give them a better presentation, but increase costs.
The community pump is shown in the technical drawing manuals. This pump has already been replaced by a design which is 100% galvanized, with leg support made of galvanized pipe. The wheel is inside the structure and there are protective covers, both at the top and bottom, which cover it completely. The top cover can be lifted as it is attached with hinges.

C.a. THE CRANK

The function of the crank is to turn the wheel by means of power applied by the user. It consists of an axle with two 90-degree bends. The crank or axle is made of ¾" pipe, which is black pipe for the family and extra-strong pumps and galvanized pipe for the community pump. The diameter of this pipe is 27 millimeters, while the thickness of the material is 2.0 millimeters. It is possible to use 1/2" pipe for the crank, but it is not recommended. The 1/2" pipes were the weakest part of the family pump after several years of use. The difference in price between 1/2" and 3/4" pipe is not that large, which has led to the use of 3/4" pipe in all designs.

On pages 56 and 60 of the photo-manual is a photo of a relatively rustic pipe bender. The channel in the bender pulleys should have the same or slightly smaller width than the diameter of the pipe and a slightly larger depth in the middle of the diameter of the pipe. The bend can be made in either of two ways: by holding the pipe and stretching it at the bend, or by letting the pipe slide slightly until the fixed pulley rotates also, which produces better results in the bend. However, the method to be used depends on the material used or available. Pipe made of a relatively soft material and which has a smaller thickness will bend more easily without stretching the material, whereas more rigid pipe tends to wrinkle inside the turn and should be stretched while bending. The minimum thickness of the material used to make the pipe is 1.9 mm.
The bender's pulleys have an minimum inside diameter of 11.5 cm, which is also twice the size of the inside radius of the bends on the crank.
The radius or distance between the axle and the handle of the crank is 33.5 cm (see C-GENERAL-05 in the drawing manual). This radius is large for children doing the pumping but is necessary in order to exert the maximum force related to the weight of the water column, which has a maximum of 10 kilograms. The radius can be a little smaller for adults because of their strength or larger because of the length of their arms. This maximum strength also depends on the depth of the well in which the pump is being used.
An important detail is the first bend at the axle. Care must be taken to ensure that the bend begins past the bushing. Beginning the bend right at the bushing will wear the axle causing it to break.

The roller and the handle are 15 centimeters in length, long enough for two children's hands or one adult hand. The spacers on the handle are made of the same pipe as the handle without any space between them so as to avoid the hand getting caught between the handle and spacers. Experience has shown that despite their short life span, PVC can be used and replaced by opening the pipe lengthwise. There may be a need to seek alternatives for the bushings and handle should the pipe not be available on the market. These should fit snuggly around the axle pipe. Bushings can also be made of iron strip.

As indicated in the drawings, the angle of the bends is 90^{o}, although they can be a little wider causing the handle to be further from the wheel structure, making the distance or radius between the axle and handle decrease slightly, which should be corrected. At the same time there is an increase in the distance between the handle and the wheel structure. This distance between the handle and the structure is important when installing the pump. The rope must be able to descend freely into the well without touching the wall, therefore the pump should be as centered as possible on the well. On the other side, the handle should remain outside the well wall so as to make the pumping process as comfortable as possible. Depending on the infrastructure of the well and the thickness of the well wall, it may be advisable to leave the handle farther from the structure using a less pronounced bend. This situation, of course, depends on the local customs regarding the production of well walls.

Depending on the depth of the wells, pumps with one or two handles are used. Pumps with two handles are used to increase power and the work becomes social for users.

Pumps used for 0 - 37-meter depths require one handle.

From 37 - 50 meters, special pumps with wooden bearings and double handles are used.

MATERIALS FOR THE CRANK

Quantity	Material	Measurement	Section
1	Black pipe	3/4" x 100 cm.	Shaft
1	Galvanized pipe	1" x 15 cm	Roller
2	Galvanized pipe	1" x 1 cm	Spacer

TECHNOLOGICAL ALTERNATIVES.

In several parts of the world, including Nicaragua galvanized pipe with a screw-thread and elbows were used to build the crank (Axle with handle). The result has always been negative, as the pipe screwed into the elbow, in the end always cracks as it cannot

resist the alternate forces occurring in pump operation.
The use of solid axles was reported in some countries (i.e. Zimbabwe) but had no real raison d'être.
Instead of the bend, a pipe can be cut at a 45^{o} angle then resoldered in order to obtain a 90^{o} angle. This is more work and as long as 3/4" pipe is used, there should be no problems.
Connected with this are the rustic rope pump designs in which the axle must cover the entire space between two posts on both sides of the well. The length of the axle, the momentum involved, as well as the modular forces received by the axle make it difficult to predict its long range behavior, especially when soldering is used to fasten the wheel. In Nicaragua and El Salvador, experimental tests are being carried out with axles made from 1" pipe. This pipe can work in these designs when the distance between the posts is not extremely long, while it would be worth considering using axles made from 1 ¼" or 1 ½" pipe to provide a long term solution.

C.b. LEG ASSEMBLY.

The difference between the family pump and the extra-strong pump is mainly in the structure and thickness of materials used. The leg supports of the family pump are made from 3/8" or 9 mm corrugated iron. This diameter can be considered as the minimum thickness to be used. There have been cases of damaged structures after several years of use of the family pump with legs this diameter. They were without exception pumps that had undergone intensive use. This more than justifies the family and extra-strong models.
There is a "horizontal cross" support between the two legs beside the brake, which is necessary to lessen the blow from the brake.

BUSHINGS

The crank axle is inserted into the bushings, located at the top of the legs. They are preferably made from galvanized pipe as this cuts down on the wear on the axle. It is 43 millimeters long, but can be as short as 35 millimeters, to avoid premature wear.

The spacers placed before and after each bushing are 1" pipe, but can be made of heavy galvanized wire. The 1" pipe is used for esthetic reasons. No significant wear on bushings or separators has been observed.

LIST OF MATERIALS

Quantity	Material	Measurement	Section
4	Corrugated rod	1/2” X 70 cm	Leg
1	Corrugated rod	3/8" X 13 cm	Horizontal cross bar
2	Pipe	1" X 4.3 cm	Bushing
4	Pipe	1" X 1 cm	Spacers

TECHNOLOGICAL ALTERNATIVES FOR THE BUSHINGS.

For special pumps used in deep wells, wooden bearings consisting of a square wooden peg about 75 mm long on either side, are used. The peg is cut through the center so as to produce a mold made up of two parts.

There are holes in the center of the mold so that there is a space the same diameter (3/4) of the crank axle. These bearings are removable and rest on a flat metal plate attached to the leg, which fixes them with the help of two bolts or hinges and a metal strip at the top. This type of bearing reduces mechanical friction. The wood recommended for this must be hard and resistant. In Nicaragua the following species are used: Coyote, Guava (Guayabon), Nanciton etc. Soft wood that is not water-resistant will cause rapid deterioration of the bushings and the pump. These bearings permit the removal of the axle, crank and wheel, facilitating some repairs.

In the case of pumps that are embedded in concrete, removable bearings are used in order to be able to change the wheel and bearings. This technological alternative to the removable bearing consists of a 1 X 1/4 “U” shaped support with holes in the top for the bolt. It is attached to the legs and has a bottom bearing inside, which is a 3/4 pipe, cut in the middle. All of this supports the axle, which is a 1/2” pipe, and there is an additional bearing at the top to complement the 3/4 pipe. There are also two 3 cm x 1/4" wedges, which apply pressure to the bearings when the 5/16" security bolt is inserted. Producing these bearings is complicated, and does not reduce mechanical friction, such as that of wood. This design was rejected since the half-moon bearings caused wear and are easily lost.

A variation on the design with additional aluminum bearings had very negative results as they produced wear after a period of only a few months.

Rope pumps using ball bearings instead of flat bearings are also built. However it is difficult to find ball bearings that are the same diameter as that of the axle, making it necessary to adjust them. The use of ball bearings with pillow blocks on the family pump increases the price too much. It is not advisable to use ball bearings on community pumps as they cause maintenance problems. Moreover, once they are installed in the countryside and a ball bearing breaks, it is difficult for the user to repair. The combination of water and ball bearing always implies wear problems. However, the use of ball bearings should not be discarded totally in special designs that require minimal friction and maximum efficiency.

C.c. LEG SUPPORTS

Leg supports are necessary in order to provide stability to the legs and keep them vertical. Experience has shown that one of these supports requires a diameters of 3/8" instead of 1/4" because it would break due to problems with materials or soldering. The support in questions is the cross bar located at the bottom next to the crank and the pumping pipe. During the pumping process, the force applied to the crank causes tension in this bar, which can over time lead to breaking.

LIST OF MATERIALS.

Quantity	Material	Measurement	Section
1	Smooth rod	1/4" x 77 cm	Cross bar
1	Smooth rod	3/8" x 77 cm	Cross bar
2	Smooth rod	1/4" x 53 cm	Cross bar

C.d. ANGEL IRON

The angle iron used for the family pump are 1/8 x 1" x 41 cm and those for the extra strong pump are 1/8 x 11/2” x 60 cm. The width of the angle iron used for family pumps is 1" is the minimum necessary, as they require holes in order to fasten the wheel. The length is related to the stability of the wheel. Activating the pump causes an upward force and another parallel to the angle iron, therefore the longer it is the more stability it gives to the wheel. The reinforcement gives rigidity to the structure when it is installed on a wooden frame or cover. It also makes the structure easier to handle when transporting. For extra-strong pumps installed on a concrete slab, this reinforcement is not necessary and only serves a purpose when transporting.

LIST OF MATERIALS.

Quantity	Material	Measurement	Section
2	Angle iron	1/8 x 1 ½” x 60 cm	Angle irons for base
1	Corrugated rod	1/4" x 54 cm	Reinforcement bar
2	Corrugated rod	3/8" x 34 cm.	Reinforcement bar

C.e. THE WHEEL.

TIRE RIMS AND THEIR DIAMETER.

The wheel is made from the two rims cut from tires with 20” hubcaps, usually used by buses and trucks. The rims are from the part of the tire that is mounted on the hubcap and always has steel wire in it for reinforcement. They are not the sides of the tires, which have been used in some previous rope pump designs. These tires always have wire in the part that is in contact with the road and in the rims used for rope pumps. Some brands also have this wire in the sides of the tires, making them inappropriate for the pumps as they are nearly impossible to cut and will always have wires protruding from the cut section.
Cutting these rims is an art. Experts in this activity need five minutes to cut two rims from a tire using a very sharp knife, a mallet and water for lubrication. Tire rubber is used for producing shoes, rocking chairs, beds, etc, causing tire rims to be known as waste from this industry. The cost of this material is minimal, less than a third of a dollar and with a little incentive the rims are cut correctly for use in rope pumps.

The rope touches the rubber on what was the inside part of the tire. This rubber often has an engraved design, which helps to avoid the rope sliding on the wheel. After a year or more of use, this design disappears leaving the surface smooth. After about three years of use the rubber becomes worn where the two rims meet and where the rope moves along it, exposing the wire threads.
The steel wires are located under this layer. As the rubber becomes worn with the movement of the rope, the surface becomes smoother and the rope tends to slide. This depends on the weight of the water column and the tension in the rope. Therefore, it is important to look at the functioning of the rope pump after several years of use.

The rims from these specific-sized tires are used for the following reasons:
1) A large wheel implies more contact between the wheel and the rope than a smaller one (i.e. 16" hubcap) and therefore less sliding. The limits of 11, 19 and 29 meters are also based on sliding problems, which appear over time.
2) Using rims from smaller tires implies that the force to be applied to the crank will

be smaller and at the same time less water will be pumped. To compensate for this, the crank must be turned more rapidly, which is less comfortable.
3) Rims with smaller diameters (20") have less consistency, are more flexible and require more clamps and support when used in a rope pump.

Using a tire for a 20" hubcap leads to an optimum use with regard to :
- The ergonomic functioning of the body with respect to the maximum force to be applied, the radius of the turn of the crank, and speed.
- Stops sliding that occurs when using smaller tires.

This situation is coincidental and moreover, the 20" diameter is the size most commonly found on the market. A smaller wheel could result in a more esthetically pleasing image. The pumps are used on different ranges of depth and therefore it is impossible to speak of an optimum situation for each depth. What is true for a rim from a tire using a 20" hubcap is true for those from larger or smaller-sized hubcaps at different depths. The problems arise in the limits of the ranges. Smaller rims are used for deeper wells with the same size pumping pipe, while the problems of sliding indicate the need for an application at less depth.

There are also 22" hubcaps whose tire rims require even more force to be applied, therefore their use is less advisable with regard to force and more advisable when avoiding sliding. Another design aspect that plays a role is the speed of the rope. If the rope moves very rapidly, it carries large amounts of water, which splashes off the wheel. This occurs when the pumping pipe is small compared to the depth of the well.

SPOKES ON THE WHEEL.

The wheel has six clamps made of 1/8" x 1" iron strips. These clamps squeeze and join the two rims together. The rope tends to get between the two rims due to the tension in it, a situation, which must be avoided. Smaller clamps than what is indicated will open during use. The clamps are not all the same length and must be produced (cut and bent) specifically for each tire since each brand of tire has different measurements. In practice it is enough to have three lengths of strips. The supports between clamps are smooth rods required to lessen the blow to the brake pins and avoid deforming the wheel. Two spokes are used on each clamp, crossed in an " X". It is necessary to use two in order to provide rigidity and help lessen the blow of the brake to the pins, which apply torsion to the spokes. The device shown on page 57 of the photo-manual, is for soldering spokes of the #20 wheel", must be used to attach the clamps and solder the spokes. The spokes are soldered at the center on the two bushings, then at the axle.

LIST OF MATERIALS.

Quantity	Material	Measurement	Section
12	Smooth rod	1/4" x 25 cm	Spokes
6	Smooth rod	1/4" x 25 cm	Reinforcement bars
6	Steel strip	1/8" x 1"x 10 cm	Clamps
2	Pipes	1" x 2.5 cm	Bushings
2	Tire cuttings	Hubcap # 20"	Wheel

- Tires using # 16 hubcap are used for deep wells from 29 to 50 meters with wooden bearings, double crank and installed as in the case of a drilled well.

TECHNOLOGICAL ALTERNATIVES FOR PUTTING THE SPOKES ON THE WHEEL.

There are cases in which the clamps have been made from construction rods bent in the shape of clamps or other similar designs, which have not been successfully used as they tended to unbend easily.

It is possible to solder the spokes directly onto the axle without using bushings although this complicates the process of assembling the wheel structure and weakens the axle because of the large number of points being soldered onto it. On the other hand, it saves the use of two additional bushings. It does not improve the appearance of the pump. The thickness of materials indicated should be considered as the minimum thickness necessary for proper functioning.

C.f. THE BRAKE.

On each of the clamps there is a soldered pin which is part of the brake system. This 3/8" thick corrugated iron pin is soldered directly before each of the spokes in order to help to damp the blow to these pins. The pins are 10 centimeters long, but the length of the clamps is not specified, as it will depend on the thickness of the two tire rims when joined. The important part of the pin is that which projects from the clamp and touches the lever. This should project between 3.5 cm and 4.5 cm from the clamp. The total thickness where the two tire rims meet next to the brake plays an important role. A thick rim will cause the wheel to be farther from the legs of the structure and will require pins to protrude more in order to reach the brake lever. Nevertheless, the pins cannot project more than 4.5 cm in order to avoid bending during rough or intensive use. Therefore, the measurements indicated in the technical drawing manual, with regard to the brake, are somewhat flexible depending on the raw material; the rim. When assembling the wheel, the brake pins are soldered to the wheel when the axle, wheel and structure have been assembled.

The lever projects three centimeters below its frame. It is made from 3/8” corrugated iron so that it is sufficiently strong. The fact that the brake is located opposite the crank is related to the distance required between the wheel and the crank. The roller or handle of the crank must be outside the well and the wheel must be centered enough so that the rope does not touch the wall of the well. This automatically indicates the position of the brake. The fact that the clicking sound of the brake lever attracts children and invites them to put their fingers between the lever and the pin when braking should be taken into consideration. It is therefore convenient for the brake to be placed in a not-so-accessible location. (To date no jammed fingers have been reported).

The clang-clang made by the brake, a sound that has become part of nature in rural Nicaragua, is relatively irritating. The user can lift the lever until it is lying against a small pin called the “brake stop”, which is soldered onto the other leg, see drawing C-b-C1 of the technical drawing manual. When the pump is activated at a relatively fast speed, the lever will spring upwards until it is lying against the brake stop. When the pumping process is finished, it should rest against one of the pins, as the weight of the water column in the pipe causes the wheel to reverse and stick.

This sound can be avoided by covering the lever with a piece of hose before delivery to the client. However, this hose will wear after several months of use and the clanging sound will return.

A more long-term solution to reduce the noise would be to cover the lever with polyethylene using an injection process to produce a mold (tube) in which the lever is inserted. This solution will still last less time than the total life span of the pump, which is ten years.

LIST OF MATERIALS.

Quantity	Material	Measurements	Section
6	Corrugated rod	3/8" x 10 cm	For the stop pins
1	Corrugated rod	3/8" x 15 cm	For the brake
1	Corrugated rod	3/8" x 10 cm	Lever
1	Pipes	1/2” x 2 cm	Bushing
1	Smooth rod	1/4" x 4 cm	Brake stop pin

TECHNOLOGICAL ALTERNATIVES FOR THE BRAKE.

In water and sewage projects, hermetically sealed covers are often used for the wheel.

In these cases, a brake with an "L" shaped mechanism is used (see brake in the drawings manual for community pumps). This mechanism causes the blow of the spoke in the direction of the turn of the wheel to propel the pin. The stop on the mechanism serves as a return. To neutralize the noise, the previously described methods are used.

C.g. LOWER AND UPPER SUPPORTS

The function of the upper and lower supports is to fasten the nipple, exit and pumping pipes.

The upper supports are made up of a band with clasps, which are easy to put on and remove, and don't require the use of tools. When installing the pump, the gripper of the clasp is closed on the support so that it does not slip off, thus avoiding children taking off the clasps. With the current design for fastening the pipes, an easy operation was sought in order to avoid the use of tools, and thus bolts and screws. A disadvantage of this is that the clasp can fall into the well and is difficult for the user to replace.

The diameter of the return pipe (or protector) is consistent in the extra strong and community pump, thus requiring only one clasp for the upper support, which has a standard diameter for 1 ½" PVC pipe.

A 1 ¼" pipe could also have been standardized, but it is not always available.

In the case of pumps on shallow wells, 2" pipe is used; requiring 3" return pipe.

The diameter of the nipple pipe varies according to the depth of the well (See section D of the technical drawing manual). Because of this, three different sizes of clasps are used depending on each case: 2" (0-11 meters), 1 ½" (11-19 meters) and 1" (19-50 meters), which is the nominal diameter of the PVC pipe.

The nipple is fastened to the top of the T with the same sized clasp. The lower support is standard size while the clasps as selected depending on the diameter of the nipple.

The lower support is a hoop that is used to fasten the claws, reducers, and pumping and return pipes. The return pipe is easily fastened as the pipe is an exact fit for the lower support, which has a nominal diameter of 1 ½" at its center and is soldered to the structure.

The lower support for the pumping pipe has an inside diameter equal to that of the outside diameter of the 1 ¼" PVC pipe. Different accessories and wedges are used to fasten the pumping pipe, depending on its diameter. These accessories are explained in chapter D, Installation Accessories.

The PVC return pipe, with wide-mouth 1 ½" diameter, is embedded in the well cover and is a protector.

LIST OF MATERIALS.

Quantity	Material	Measurement	Section
1	Iron strip	1/8" x 1" x 70 cm	Upper supports
2	Smooth rod	1/4" x 10 cm	Upper support buckles
2	Iron strip	1/8" x 1"x 10 cm	Clasps
2	Iron strip	1/8" x ¾" x 6 cm	Clasp grippers
2	Iron strip	1/8" x 1" x 30 cm	Lower supports
1	Black pipe	1 ¼" x 2.5 cm	For pumping pipe
1	Black pipe	1 ½" x 2.5 cm	For return pipe

The previous explanation can be summarized as follows:

- The extra-strong pump has two upper supports and two lower supports, which fasten the pipe on installation.
- The diameter of the nipple varies depending on the depth, which implies the possible use of three different sized of clasps on the upper support: 2" (0 - 11 meters), 1 ½" (11 - 19 meters) and 1" (19 - 50 meters), which is the nominal diameter of the PVC pipe.
- The diameter of the return pipe is always the same, which is why only one clasp is used for the 1 ½" PVC pipe in the upper support.
- The center of the lower support for the pumping pipe has a nominal diameter of 1 ¼"
- The center of the lower support for the return pipe has a nominal diameter of 1 ½".

TECHNOLOGICAL ALTERNATIVES.

The supports currently being used are the result of several years of innovation. For many years a ¼" rod hoop has been used as the upper support. It was soldered onto the legs. The lower support was a ¼" rod hook soldered onto the base support. Strips of rubber cut from tires are used to tie the pipes to the supports soldered onto the structure. This works well as an interim solution. However, the assumption that pieces of rubber are readily available in rural areas is somewhat erroneous. After years of use, the rubber and pipes become loose and dangle from the structure.

C.h. THE COVER FRAME.

LIST OF MATERIALS.

Quantity	Material	Measurement	Section
2	Angle Iron	1/8" x 1"x 80 cm	Frame
2	Angle Iron	1/8" x 1"x 20 cm	Frame

C.i. THE WHEEL COVER.

The wheel covers are made from smooth sheets of 24 caliber galvanized zinc, which coincides with a thickness of 0.6 millimeters. In production, it is a sheet that can be processed (cut and folded) with a certain degree of ease, while it has also been shown to be sufficiently strong. Thinner sheets have not had the expected results and should not be considered acceptable. The galvanized sheet to be processed always has some scratches and therefore must be painted to improve its presentation. Ordinary paint comes off the galvanized sheet very easily, whereas "fast dry" paint has given satisfactory results. To improve the presentation of the paint, the galvanized sheet must be sanded and covered with a coat of white water-based paint, followed by a coat of the fast dry paint. Four-millimeter aluminum rivets are successfully being used for assembling the cover. In the rope pump design, the use of bolts has been avoided because they get lost and the user will not have the tools necessary for tightening or loosening. However, when fastening the cover to the frame, bolts are used because aluminum rivets tend to get cut during transportation over rough roads as they make their way towards their destinations. For application in community wells, the water and sanitation project promoters or the pump producer’s installation technicians are present and have the necessary tools. It is convenient for them to have a detachable cover to facilitate installation and subsequently the fastening of the cover with bolts. The users do not need to remove the cover for repairs or maintenance and therefore the bolts can remain in place as long as they do not become unscrewed

LIST OF MATERIALS.

Quantity	Material	Measurement	Section
1	smooth zinc sheet caliber 24	40 cm. x 125 cm	Cover

D. INSTALLATION.

D.a. INSTALLATION ACCESSORIES.

The installation and fastening accessories have always been the topic of discussion and innovation. The use of different sized pumping pipes depending on depth is an obstacle to the standardization of one single structure, which can be used for any depth. It is, however, a condition that the structure of the pump can be used for any depth. The technicians carrying out installation always carry a load of, for example, ten pumps, but never know beforehand the exact depth of wells, and therefore the diameter of pipe, which they will find. Therefore, the structures should be applicable to any depth as long as they have enough additional accessories and pipes required to adapt to the situation. The alternatives with regard to fastening the pipes must, therefore, comply with the criteria of being "multi-use".

An important alternative is the standardization of all T accessories, exit pipe and nipple. They all have a diameter of 1". 1 ½" or 2" using a 1/2", 3/4" and 1" pumping pipe. Standardizing these accessories to one single measurement of 2" is possible but also has certain inconveniences. (The exceptional cases with 1 ½" and 2" pumping pipe and 3" exit pipe will not be addressed here.)
For the standardization of a 2" exit pipe, the pumping pipe is cut just below the cover of the well, a reducer is fitted to it, and 2" pipes follow regardless of the diameter of the pumping pipe. Therefore, all of the accessories in the wheel structure can be standardized to one diameter. The fact that the pumping pipe is slightly shorter does not affect pump efficiency or only to a very reduced degree. A disadvantage is the cost of the pumps, as larger diameter accessories are being used when smaller diameter accessories were used in the case of 1/2" and 3/4" pumping pipes, which account for 50% of all pumps. On the other hand, savings are obtained due to the standardization itself. The main reason not to standardize to one single diameter of 2" for exit pipes is social acceptance. With a 2" exit pipe on a pump with 1/2" pumping pipes, the stream of water is very small compared to the diameter of the pipe. This causes rejection on the part of the user and is therefore a very sensitive topic in the relationship between the user and the installation technician who receives the first signals of acceptance or rejection. The pump producer or, on occasion, the water and sewage project leader also must take into consideration the perceptions of users.

MEASURES TO BE USED FOR INSTALLATION

		Depth (meter)				
Mechanism	Unit	0 – 11	11 - 19	19 - 29	29 – 37	37 - 50
Nominal diameter of piston	Inch	1	3/4	1/2	1/2	1/2
Diameter of rope	Inch	1/8	1/8	1/8	1/4	1/4
Rim no.	Inch	20	20	20	16	16
Type of installation	Normal	Normal	Normal	Normal	Normal	Drilled well
Number of cranks	1	1	1	1	1	2
Wooden bearings	No	No	No	No	No	Yes

INSTALLATION ACCESSORIES (0 - 11 Meters in depth)

No.	Accessories	Unit	DEPTH
			0 - 11 Meters
1	Nipple	Inch	2
2	Tee	Inch	2
3	Discharge elbow	Inch	2
4	Discharge pipe	Inch	2
5	Reduction	Inch	2 - 1
6	Primary wedge	Inch	1
7	Secondary wedge	Inch	1
8	Supporting wedge	Inch	1 1/4
9	Pumping pipes	Inch	1

- It is recommended that the well, on which the pump is being installed, have a platform and concrete slab. It is also necessary that there be drainage infrastructure at the foot of the well.

INSTALLATION ACCESSORIES (19 - 50 Meters in depth)

No.	Accessories	Unit	DEPTH	
			11 - 19 meters	19 – 50 meters
1	Nipple	Inch	1 ½	1
2	Tee	Inch	1 ½	1
3	Discharge elbow	Inch	1 ½	1
4	Discharge pipe	Inch	1 ½	1
5	Reduction	Inch	1 ½ - 3/4	1 – 1/2
6	Primary wedge	Inch	3/4	1/2
7	Secondary wedge	Inch	3/4	1/2
8	Reduction	Inch	1 ¼ - 1	1 ¼ - ¾
9	Pumping pipe	Inch	3/4	1/2

D.b. INSTALLATION ON THE WELL COVER.

The family pump is usually installed on a wooden frame or cover as indicated in the installation manual. It is fastened with screws. It is not recommended that nails be used, as they tend to loosen over time due to movement and water.

The extra-strong and community pumps are often installed on concrete slabs using plugs and screws. In cases where making the concrete slab is included, a grill with six bolts embedded into the concrete can be used, on which the rope pump is subsequently installed fastening it with nuts.

There are also cases wherein the leg supports are completely embedded in the concrete of the slab. It is a permanent installation, which requires partial destruction of the well cover. This type of installation has the advantage of ensuring that the pump is firmly fastened to the cover. This method may be used in the context of water and sewage projects, but is not recommended.

APPENDICES

◘ ASPECTS OF DIVERSIFICATION OF THE ROPE PUMP

The rope pump is a simple technology that has been widely applied in the Nicaraguan rural area, especially in water and sanitation projects. But it has also become an alternative to support small farm production through other models that constitute the diversification illustrated for future producers or persons interested in this technology.

The following models exist:
- Pumps for drilled wells.
- Double-crank pumps.
- Arial pumps. (to fill tanks.)
- Bici-bombas. (bicycle type pumps.)
- Air pumps. (activated by the wind)
- Animal traction pumps. (activated by a horse or ox)
- Motor pumps. (activated by a gasoline motor.)
- Tractor-adapted pumps. (Activated by the power of a tractor)

◘ THE DOUBLE-CRANK PUMP

The double-crank pump is similar to the extra-strong pump, with certain adaptations in order to be able to extract water from relatively deep (37 to 50 meters), dug or drilled wells. When two people work to turn the wheel, the power applied is duplicated (75 watts x 2) and therefore, there is a capacity to raise the water column from this depth. This is the reason for the double crank on this type of pump.

The structure of this pump is the same as the extra-strong pump. The pieces of tire that are used to make the wheel are from a # 16" hubcap, which are more flexible. This is why they have 12 clambs made of iron strips of 1/8" x 1" with their respective spokes and supports. It is important to mention that even though this pump is being installed on a dug well, it should be installed as if it were a drilled well in order to increase contact between the wheel and rope and avoid sliding.

The two handles are attached together by soldering down the center of the two bushings of the wheel, so that it does not suffer added weight since tension is placed on the bushings. The bearings are wooden blocks with an inside nominal diameter of ¾", and therefore the handles and wheel are removable. The piston and pumping pipes have nominal measurements of ½", and the discharge pipe is 1".
The rope to be used is a relatively thick nominal measurement of 1/4", so as to ensure that it has sufficient strength to support the weight of the water column. Furthermore, when the rope takes up more of the space in the pipe, the volume of water to be extracted is less, thus making the crank easier to turn and the human energy expended

less. On the other hand, at this depth knots are not used to fasten the pistons. Instead braids or injected polyethylene knots are used.

In these pumps which are installed for depths of less than 37 meters, pipes with larger diameters and 20” hubcaps can be used, resulting in greater amounts of water for special applications such as draining wells.

THE PUMP FOR DRILLED WELLS.

The double-crank pump, which has a proven limit of 50 meters in depth, is recommended for drilled wells, as they are usually deep. Drilled wells originated in water and sewage projects in rural areas, and their diameter is in the range of 4" to 12". When the well is drilled, a PVC pipe is inserted becoming the walls of the well. A PVC plug is placed on the terminal of the pipe. Installing a rope pump on a drilled well is simple, but certain technical parameters must be considered. A 32" (long) x 23.5" (wide) x 14" (high) pedestal must be built so that the exit pipe is located at the height of a bucket.

An enamel ceramic piece with fastening support is installed in the pump structure, which must be aligned with the return pipe so as to ensure that the rope enters vertically without touching the pipe. Another method for inserting the rope into the pipe is by using a curved pipe which starts in a horizontal direction below the wheel and almost makes a 90^{o} turn to enter the return pipe which projects from the plug of the casing. This curved pipe can be made of PVC, filled with sand and heated slowly. However, the rope tends to wear a groove in the curved pipe made of PVC. A good alternative to replace the PVC curved pipe is bent thin-walled galvanized pipe.

Since these wells are deep and of a small diameter, on installation the guide tends to twist and get tangles up with the rope. This is the reason for double pipes, the pumping pipe and the return pipe, which lead to the sealed plug which has two holes, and which should be aligned with the ceramic piece. The installation accessories should be placed past the sealed PVC plug and should remain firm so as to ensure that the pipes do not sink to the bottom.
The guides used are cylinder-shaped and must measure 1" less than the diameter of the well. The ceramic piece for 4" wells is smaller than that normally used on drilled wells.

OTHER TYPES OF PUMPS

The other types of pumps previously mentioned, such as the aerial pump (to fill tanks), the Bici-bomba (bicycle type pump), the Air-pump (activated by the wind), the animal traction pump (activated by a horse or ox), the motor pump (activated by a gasoline motor) and the Tractor adapted pump (Activated by the force of a tractor), are not discussed in this document.