DESIGN AND FABRICATION OF A MANUALLY OPERATED PUMP FOR LIFTING OF FLUIDS FROM AN UNDER GROUND TANK.

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PGD/MECH/99/2000/203

A PROJECT REPORT SUBMITTED IN PARTIAL
FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF
POSTGRADUATE DIPLOMA CERTIFICATE IN THE MECHANICAL
ENGINEERING DEPARTMENT,
FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA
NIGER STATE

SEPTEMBER 2001

APPROVAL PAGE

This is to certify that this project work has been read and have met the standard for the award of Postgraduate Diploma Certificate in Mechanical Engineering.

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DEDICATION

This project is dedicated to my parents Mallam Musa Adamu and Mallama Rahmatu Musa Ewugi.

Lastly, my profound gratitude also goes to almighty Allah for sparing my life and guiding me throughout the period of the programme, and to all who contributed to the successful completion of this research work and cause, I say thank you and Allah bless you all.

ACKNOWLEDGEMENT

I wish to express my profound gratitude and appreciation to all those people who helped and contributed in making this course and particularly this project a success.

I am particularly grateful to Mallam Nasir Abdulkarim my project supervisor for his help and guidance throughout the course of this project.

My gratitude also extend to my Head of Department Professor R.H Khan and other members of staff Mr S.A Ayo, Mr O.A. Olugboji, Mallam S.A Mohammed, Dr M.S Abifarin, Mallam M.B. Ndaliman, Mallam O.K Abubakar, Mr O.J Okegbile and Dr S.O Ubokwe, Dr A.B Hassan for their guidance and support throughout the programme.

My special thanks goes to Engr. E.V. Oyedeji for using his workshop in carrying out the construction work and other organisation such as Niger State Water Board for their support and use of their facilities.

My special thanks also goes to Mallam Ndanusa Malik for his fatherly advice.

ABSTRACT

The problem of adequate supply of freeborn disease water and storage of liquid in a level surface has brought about this study and fabrication of manually operated pump.

The pump is designed for lifting of fluid (e.g. water) from under ground tank or any waterways below the ground surface. Rural areas or where electrically operated pumps are not available and clean water is required, manually operated pump becomes in evitable. This project is simple in design, less expensive, low technical know how and durable.

The pump is required to be powered by one operator at a time, depending on the depth of suction lift. The overage discharge of the pump at 4 meter suction lift is about 1000 litre/minutes for lifting under ground surface water.

TABLE OF CONTENT

CONTENT **PAGE**

CHAPTER ONE

CHAPTER TWO

CHAPTER THREE

CHAPTER FOUR

CHAPTER FIVE

CHAPTER SIX

CHAPTER SEVEN

CHAPTER ONE

1.0 INTRODUCTION

Water is one of the primary resources necessary to support life, as has been so tragically demonstrated in the recent years by several drought in the arid and semi arid regions of the world especially Africa. In many of these areas water exist below the ground. And with the lack of adequate rainfall agricultural production has suffered a great set back. For this problem to be solved a means of pumping water from the underground level for i.e. irrigation purpose has to be designed.

Over the years, many method have been designed to help solve the problem of pumping water to irrigate farm land, but these has often gone beyond the means or technical capability of the small communities or farmers.

Although the number of the units in the field is still small, the design of the hand pumping system (manually operated) offers many advantages over the traditional technologies available, because there are few moving parts, maintenance and its cost is reduced to a minimum. Also the reliability of the pumping system is high.

The hand pump is a very remarkable human powered pump especially design for small scaler irrigation. The pump user leg museles in a comfortable walking motion, and can be operated by one person at a time.

The pump is designed to lift water by suction from under ground tank or wells of up to 7.5 metre. (24.5 feet) deep or from surface sources.

Because of its efficient and effective of the body's strongest muscles, the pump can lift up to seven thousand litres of water per hour, which is enough to irrigate about half a hectare of land. Apart from lifting water from a underground tank or well, the pump is designed to deliver the water under pressure either to additional height above, or up to 100 metres horizontally. The pump has connections for both suction and discharge piping.

The concept of suction pressure or universal pump was first presented in practical design by a mechanical engineer Dan Jenkins in 1958. The pump is simple to build, as it is made from standard PVC pipes and fittings. However the design has its disadvantage, because the fittings are costly, comparatively fragile and may not be available in many countries to Local farmers and artisans.

The design presented here is made primarily from mild or galvanized steel sheet, and is assemble by electric welding. It is very durable it reasonably well maintained, yet is light enough to be carried by a single person. The design represents a trade of between production cost and complexity on one hand and durability on the other.

The early chapter act as a guide to those unfamiliar with the pump, illustrating typical application and reviewing current technologies available. The final sections cover practical manufacturing, maintenance instructions and detailed drawings of the manually operated pump (Hand pump).

CHAPTER TWO

2.0 LITERATURE REVIEW.

Irrigation is the science of supplying water to plants for its growth and maturing. It is the artificial means of applying water to soil with a view of fulfilling the following objectives:

- Ensure enough moisture essential for plant life
- Provide crop insurance against short duration drought
- Cool the soil and atmosphere to provide a congenial environment for plant.
- Wash out or dilute harmful salt in the soil
- Reduce hazards of soil piping
- Softens the tillage pans (Michael 1978).

For the above objectives to be achieved in irrigation, water must be pumped from below the ground level to irrigate farm land. And throughout the developing world the most widespread of raising it to the surface is still by hand pumps or with the assistance of animals. The principal mechanized power source is the diesel engine is often beyond the technical capability of small communities or local farmers.

2.1 WHAT IS SO SPECIAL ABOUT MANUALLY OPERATED PUMPS (HAND PUMP)?

The pump has a number of features that distinguishes it from most human powered pumps. First it is a high capacity pumps designed lift water from shallow wells or surface sources. Most hand pumps ate designed to lift relatively small quantities of water from underground tanks (wells) and bore holes.

Irrigation, even on a small scale, the pump, with a capacity of 5000 – 7000 litres per hour, can irrigate ¼ hectare with a family's own labour. Most hand pumps which deliver about 1000 litres per hour can irrigate no more than 1/10 hectare under average conditions.

Secondly the pump lifts water from the well by suction. The pump cylinders that develop this suction forms part of a self contained unit that sits at the ground level. Most hand pumps have their delivery mechanism and discharge spots above the ground, but their pumps and cylinders are located under water inside the well. This configuration enables the pump to deliver water from great depths, but require that they may be per mannerly installed on a single well. (Robert and Rosaler 1983)

Portability is an important characteristic of pumps used for small scale irrigation for the following reasons. (Adewole 1992)

It enables a single pumps to be used on a number of wells, each of which(because of low recharge rates) may have the capacity to irrigate only a small area. Many farmers in Africa who irrigate with hand dug wells have a number of wells on their farms. Multiple wells increase the aggregate quantity of water available, assure a reliable supply and reduce the distance that must be physically carried (usually by sprinkler can) to the crop. (Christiansen J.E 1948).

By moving the pump from one location to another, the can minimize the amount of piping net work or channel that must be available to irrigate the entire farm. This is important because of the light cost of pipes, and on sandy soil unlined channels lose a large proportion of water being delivered by the pump. Keeping the distance from the pumps to the crop will minimize those loses.

The pumps is easily dismounted and store at the end of the day's work, thus reducing the risk of theft or accidental damage.

The pump (Hand) like all pumps that lift water by suction cannot draw from wells that are deeper than 7.5 metre. This is because when a perfect vacuum is created by the pump in its suction pipe, the pressure of the atmosphere pressuring down on the water in the well is only sufficient to lift the column in the suction pipe 9.8 metres. If the pump is imperfect and leak a little air or there is a small leak where the suction pipe is attached to the pump, the maximum life will be less (in addition, even where there is a perfect vacuum water cannot be drawn at high volume from a well of more than nine metres depth (9). Since the was of the water in the suction pipe has considerable inertia, it will allow the development of a vacuum on top of the water column if the pistons are circled at normal rate, leading to a very much more reduced rate of delivery). (Doorenbas and Pruit, 1977)

Motorized centrifugal pumps, which are the kind most commonly used by the affluent farmer in African, usually lifts water no more than 6 metres due to cavitations or bubble formation around their fast turning impellers. A well made Hand pump (manually operated pump) can do some what better, lifting water by suction approximately 7.5 metres at sea level and 6 metres at 2000 metres above sea level. (Rohwer 1943).

Although, the limited lift of the pump makes it is applicable to areas where the water table lies more than 7.5 metres below the surface. This is an important limitation for a human powered pump. This is because the human body has a small and finite amount of power, thus as water depth increase, the amount that can be lifted in a given period of time decreases proportionality. A simple healthy adult male working on a hand pump can lift about 6000 litres of water an hour from a depth of 4 metres, and approximately 300 metres from a depth of 7.5 metres. Nevertheless, the labour cost of lifting one cubic metre of water from 7.5 metres depth is twice as much as when the water is at four metres. When the water is deeper than eight metres and can be reached with an alternative technology, the cost becomes excessive, and irrigated agriculture unprofitable. Seen from another perspective, workers will not be willing to accept the sort wages that a farmer can than afford to pay.

There are few human powered pumps on the market in less developed countries that are large capacity shallow lift pumps. Furthermore, (and this is a critical difference) there are more that are operated by the legs in the natural stepping motion used on the treadle pump. There are important characteristics of the pump, because they allow the operator to work for long period of time without excessive fatigue. Leg muscles are by far the strongest in the human body, and they are harnessed to the pump in the same manner as the legs are accessioned to work, that is when walking with a load or when climbing a gradual slope. The ability of two adults working together, facing one another makes long pumping a tolerable even sociable experience. With the hands free one can read or dandle an infant while working the pump. (Schwab *etal*, 1996)

2.2 ALTERNATIVE IRRIGATION PUMPS TO THE MAUNALLY OPERATED PUMP. (Frangmeier D.D. 1977)

THE JAPPY PUMP

One shallow lift hand pump that is widely available in Africa is the jappy pump. The Jappy is a cast iron pump that uses a hand operated lever to rotate a vane in its cylindrical housing. The construction of the Jappy is very simple and rugged. And like the manually operated pump, it delivers a continuous stream of water by suction and pressure. The jappy cannot however, be used for a long period of time. Because it is operated by the arm and not the legs. Conversions of a Jappy to foot operation might be possible, although its cost would be substantially greater than that of the treadle pump.

Since the Jappy in produced by casting and machining, it cannot be produced (or easily repaired) by artisans (as in the case of the treadle pump), and would tend to be expensive of made in small quantities by formal sector manufactures who are not suitable equipped to achieve economics of scale.

THE ROWER PUMP (Maff 1982).

In addition to the treadle pump there are at least two other pumps that are not in wide spread use in Africa, but which may have considerable potential for small scale irrigation. One of these is the rower pump, a very small single acting shallow lift pump. The rower pump is some what less expensive and simpler to produce than the hand pump, because it has fewer parts, and these are primarily made from PVC. It is an efficient pump, and it use the arm and back muscle of the human body and can therefore attain moderately high rate of delivery. (John E.E. 1966)

Thus, the rower pump has mainly being installed in a semi permanent configuration on shallow tube wells and hand dug wells. This is partly because its PVC construction makes it susceptible to breakage and damage due to long term exposure to sunlight. For this reason it is usually buried, to protection and mechanical support. Its intrinsic disadvantages when compared to the treadle pump are that:

- it does not provide a variable mechanical advantage in the way the treadle of the pump do.
- It cannot be used as a pressure pump.
- For the same volume of water pumped it is more tiring to use than the treadle pump. (Church A.H. 1944).

Because the rower pump cannot be used as a pressure pump, it cannot move water through long length of pipe and cannot deliver water to a reservoir located above the pump.

THE ROPE AND THE WASHER PUMP.

The second type of the human powered pump that may be applicable to small scale irrigation in the rope and washer pump. The rope and washer pump is not really a pump at all, but lift water by carrying it between successive washer that more through a pipe, spaced equally apart our a loop of rope. The rope and washer pump is also some what easier to produce than the hand pump, but share same disadvantages as the rower pump. While the rope and washer pump can be set up to use power from the legs by attaching pedals to the drive wheel and installing a seat for the operator, it has being generally installed using a hand powered crank. The hand cranked version quickly tires the operator, and it is not well suited for providing large amount of water required for irrigation. Usually made of PVC, its construction is inherently vulnerable to breakage caused by the thrashing motion of the rope on entering the lift tube, and the backward meshing of the washers with the drive pulley. (Wood I.D. 1950).

The rope and washer pump has several limitations these are that;

- it cannot be used to develop pressure, or lift water above the pump itself.
- It is at its most efficient when the pipe in which the rope travels is vertical or nearly so.
- It cannot be installed on a tube well, unless the casing is large enough to accommodate the riser pipe and the return rim of chain.
- The friction of numerous washers traveling in the rise pipe adds significantly to energy losses. (Larson C.L and D.M manbeck 1961).

There factors effectively limits its use to the hand dug wells of fairly wide diameter, and preclude pumping from some surface sources such as rivers and small streams with gradually slopping banks. (Richey, C.B 1961).

A third type of human powered pump that may have limited applicability for small scale irrigation is the Diaphragm pump. This type of pump uses a flexible bellow like diaphragm usually made of rubber, which is mounted between two steel plates. By changing the position of these plates up and down, the volume of the water contained in the bellow is attend thereby creating a pumping action. The Diaphragm is suited for extremely low lifts, where the head is less than two metres as may be encountered in the irrigation of low land agricultural cultivation. It does not suit majority of circumstances encountered in small irrigation, and for which the treadle pump is well suited.

THE SHADOOF PUMP (Doorenbas and pruit 1977).

This pump which is common in Egypt and many sahelian countries, is probably the most cost effective and efficient traditional water lifting system used for irrigation.

Depending on the power of the human arms and the upper trunk to operate, it lifts up to 2,500 litres of water per hour from four metres depth. The treadle pump gains its distinct advantage, because it uses a different muscle group (the legs) which are far more powerful than the human arms. It reduces wasted motion, because it is double – cylindered and double acting, both up and down strokes deliver water.

Different alternatives to the treadle pump has been mentioned because each of these pumps are well designed, and may under any particular circumstance be more appropriate than the treadle pump. The manually operated lift pump (hand pump) is slightly more expensive than the rower, rope and washer, the diaphragm and shadoof pumps, but it is more versatile and can deliver water through a broader range of heads for a longer time at higher volume without user fatigue. (Michael, 1977).

The pump is made from mild steel, and is assembled by arc welding. It can therefore be produced by a large number of metal working artisans who are usually engaged in making steel gates and window grills, as well as by small and medium scale manufacturers of metal products. Although the inside is unpainted, they resist rust because of the lubricating and polishing action of the nylon rubber leather pump cups. The use of steel sheets results in a fairly lightweight pump that is in expensive, yet able to stand the stresses and wear of long use.

Unique features of the hand pump include:

- Its versatility, and the ability to deliver water by suction as well as by pressure. (Code, W.E, 1936).
- Its low clearance, or the volume that exist between the piston and the valves when at the bottom of the stoke. Low clearance helps the pump to prime its self as the suction lift approaches the theoretical limit of 9.8 metres.
- Attachment of the operating lever via the support tube and intake pipe to the pump body. This last feature facilitates setting up the pump, carrying the pump, and improves its stability when in use.

These unique features mentioned above gives the lever irrigation pumping system an edge over the most widely known irrigation pumping system.

CHAPTER THREE

3.0 DESIGN ANALYSIS AND MANUFACTURING TECHNIQUES

3.1 DESIGN ANALYSIS

Reciprocating pumps also called piston or displacement pumps function by means of a piston movement, which displaces water in a cylinder. The flow is controlled by valves. The piston Nylon is a cylindrical piece, which moves up and down inside a hollow cylinder. The capacity of the reciprocating pumps depends on the size of the cylinder chamber, the length and the speed of the stroke.

While the basic principles of operation apply to all piston pumps, there are many modifications in design, which adapt these pumps to specific uses. Piston pumps may be either single or double acting. Single acting pumps have one discharge stroke for every two strokes of the piston. Thus the water is delivered during stroke alternate strokes of the piston, while double acting pumps are constructed with piston and valve so arranged that water can be pumped on both inward and outward movements of the piston. In this work however, a single acting pump but with duplex cylinders, so arranged to pump a continuous stream of water during each downward stroke, will be used.

3.1.2. **DISCHARGE CAPACITY OF THE PUMP.**

The main factors influencing the selection of pumping sets are:

i. the requirement of irrigation water by the crops to be irrigated,
ii. yield of the sources of water (open wells, tube wells, streams, rivers, ponds, etc)
iii. the availability and cost of the type of pump and kind of energy.

In this design, consideration will be made of the maximum water requirement of the crops per day in peak periods in calculating the size of the pump required. And consequently, efforts would be made to adjust the other factors within possible limits so as to have efficient utilization of the resource potential.

Discharge capacity of pump based on requirement of irrigation water by the crops should meet the peak demand of water for selected cropping pattern. The rate of the pumping depends on the following:-

a. area under utilization (i.e. under the crops)
b. water requirement of the crops
c. rotation period (interval between two successive irrigation of a crop)
d. duration of operation each day.

According to Michael (1978), the following relationship is used for the computation of the rate of pump discharge.

$$Q = \frac{AY}{RT} \times \frac{1000}{36}$$

$$Q = 27.78 \frac{AY}{RT} \qquad 3.1$$

Where Q = rate of discharge of pump (litres/sec)

A = area of land under the crop (hectares)

Y = depth of irrigation (cm)

R = rotation period (days)

T = duration of pump (hours/day)

The depth of irrigation application including application loses is given as

$$Y = \frac{P \times S_a \times D}{E_a} \text{ mm} \qquad 3.2$$

And frequency of irrigation expressed as irrigation interval of the individual field is given as:

$$R = \frac{P \times S_a \times D}{ET_{\cdot crop}} \text{ days} \qquad 3.3$$

Where P = fraction of available soil water permitting unrestricted evapotranspiration,

S_a = total available soil water. Mm/m soil depth

D = rooting depth. M

E_a = application efficiency

Since P,D and $E_{T\ crop}$ will over the growing season, the depth in millimeters (mm) and irrigation interval (days) will also vary hence

$$S_a = S_{fe} - S_w \qquad 3.4$$

Where S_{fe} = soil water content at field capacity. Mm/m

S_w = soil water content at wilting point, mm/m

CHAPTER FOUR

4.0 DESIGN CALCULATIONS

The predominant soil considered in this project is sandy clay loam and from table 3.1 S_a = 140 at 0.2 bar. Hwen the land is fully irrigated, the soil water tension is smallest, i.e. 0.2 bar. At 15 bar, the soil has completely lost all water.

Similarly, from table 3.2 rooting depth of vegetable (D) is 0.5m

Fraction of available soil water (P) = 0.2

Therefore from above,

$P = 0.2$

$D = 0.5$

$S_a = 140 \text{mm/m}$

Average $ET_c = 4.8$ mm/day (see table 2.1)

Let $E_a = 65\%$ for the purpose of this computation.

From equation 3.2 depth of irrigation application

$$Y = \frac{P \times S_a \times D}{E_a} \qquad 4.1$$

$$\therefore Y = \frac{0.2 \times 140 \times 0.5}{0.65} = 21.5 \text{ mm}$$

$$= 2.15 \text{cm}$$

TABLE 4.1 Relation between soil water tension in bars (Atmospheres) and available soil water in mm/m soil DEPTH.

Soil Water Tension (atmospheres)	0.2	0.5	2.5	15
	Available soil water in mm/m			
	(S_a)			
Heavy clay	180	150	80	0
Silty clay	190	170	100	0
Loam	200	150	70	0
Silt loam	250	190	50	0
Silty clay loam	160	120	70	0
Fine texture soils	200	150	70	0
Sandy clay loam	140	110	60	0
Sandy loam	130	80	30	0
Loamy fine sand	140	110	50	0
Medium texture soils	140	100	50	0
Medium fine sand	60	30	20	0
Coarse texture soils	60	30	20	0

Source:- Doorebas and Pruitt, 1977

TABLE 4.2 Generalized data on rooting depth of full-grown crops, fractions of available soil. Water (p.sa) for different soil types (in mm/m soil depth) when E_t crop IS 5-6 mm/day

Crop	Rooting depth (D) m	Fraction (P) of available soil water	Readily available soil water (p.Sa) Mm/m		
			Fine	medium	coarse
Alfalfa	1.0......2.0	0.55	110	75	35
Banana	0.5......0.9	0.35	70	50	20
Barley 2/	1.0......1.5	0.55	110	75	35
Beans 2/	0.5.......0.7	0.45	90	65	30
Beets	0.6......1.0	0.5	100	70	35
Cabbage	0.4.......0.5	0.45	90	65	30
Carrots	0.5...... 1.0	0.35	70	50	20
Celery	0.3.......0.5	0.2	40	25	10
Citrus	1.2.......1.5	0.5	100	70	30
Clover	0.6.......0.9	0.35	70	50	20
Cacao		0.2	40	30	15
Cotton	1.0........1.7	0.65[8]	130	90[*]	40
Cucumber	0.7.......1.2	0.5	100	70	30
Dates	1.5........2.5	0.5	100	70	30
Dec. orchards	1.0......2.0	0.5	100	70	30
Flax 2/	1.0......1.5	0.5	100	70	30
Grains small 2/	0.9....1.5	0.6	120	80	40
Winter 2/	1.5......2.0	0.6	120	80	40
Grapes	1.0.....2.0	0.35	70	50	20
Grass	0.5.....1.5	0.5	100	70	30
Groundnuts	0.5....1.0	0.4	80	55	25

Crop	Rooting depth (D) m	Fraction (P) of available soil water	Readily available soil water (p.Sa) Mm/m		
			Fine	medium	coarse
Letture	0.3....0.5	0.3	60	40	20
Maize 2/	0.1...1.7	0.6	120	80	40
Silage		0.5	100	70	30
Melons	1.0.....1.5	0.35	70	50	25
Olives	1.2.....1.7	0.65	130	95	45
Onions	0.3....0.5	0.25	50	35	15
Palm trees	0.7....1.1	0.65	130	90	40
Peas	0.6....1.0	0.35	70	50	25
Peppers	0.5... 1.0	0.25	50	35	15
Pineapple	0.3...0.6	0.5	100	65	30
Potatoes	0.4....0.6	0.25	50	30	15
Safflower 2/	1.0...2.0	0.6	120	80	40
Sisal	0.5....1.0	0.8	155	110	50
Sorghum 2/	1.0....2.0	0.55	110	75	35
Soybeans	0.6...1.3	0.5	100	75	35
Spinach	0.3....0.5	0.2	40	30	15
Strawberries	02.....0.3	0.15	30	20	10
Sugar beet	0.7...1.2	0.5	100	70	30
Sugar Cane 2/	1.2....2.0	0.65	130	90	40
Sunflower 2/	0.8....1.5	0.45	90	60	30
Sweet Potatoes	1.0....1.5	0.65	130	90	40
Tobacco early	0.5.....1.0	0.35	70	50	25
Late		0.65	130	90	40
Tomatoes	0.7....1.5	0.4	180	60	25
Vegetables	0.3....0.6	0.2	40	30	15
Wheat	1.0....1.5	0.55	105	70	35
Ripening		0.9	180	130	55
Total available soil water (Sa)			200	140	60

1/ When $E_{t\ crop}$ is 3mm/day or smaller increase values by some 30% when E_t crop is 8 mm/day or more reduce values by 30% assuming non-saline conditions (Ecc < 2 mmnos/cm).

2/ Higher values than those shown apply during ripening.

Source:- Doorenbas and Pruitt, 1977.

Similarly, from equation 3.3 Rotation period (Irrigation Interval)

$$\therefore \quad R = \frac{(P \times S_a)D}{ET_e} \qquad 4.2$$

$$\therefore \quad R = \frac{0.2 \times 140 \times 0.5}{4.8}$$

$$= 2.9 \text{ days}$$

$$= 3.0 \text{ days approx}$$

REQUIRED RATE OF DISCHARGE OF PUMP

1.1.2 To compute the rate of discharge of the pump, we use equation 3.1, that is,

1.1.3 $Q = \frac{27.78\, Ay}{RT}$

Where area to be cultivated (A) = 0.5 ha

Depth of irrigation application (y) = 2.15c

Irrigation interval ® = 3.0 days

Duration of pumping (T) = 4 hrs/days (assumed)

$$\therefore Q = \frac{27.78 \times 0.5 \times 2.15}{2 \times 4} \qquad 4.3$$

$$= 2.49 \text{ litres/sec}$$

$$= 3 \times 10^{-3} m^3/s$$

4.1.2 **DETERMINATION OF PUMP BORE AND STROKE**

The capacity of a reciprocating pump could be determined by the size of the cylinder (working barrel), the number of piston strokes or the rotative speed of the pump shaft, and the number of cylinders. For a single acting pump. Cherkasky (1985) expressed that the amount of liquid (water) drawn in and delivered is

$$Q = \frac{\text{⑥}\, d^2}{4} \cdot \frac{S.\ N}{60}\, \eta_{vol} \qquad 4.4$$

Where

Q = Capacity m^3/s

D = Inner diameter of cylinder

S = Piston Stroke

η_{vol} = Volumetric efficiency

N = number of piston double strokes/min

Volumetric efficiency is determined in the course of pump test, by measuring the actual volume of liquid delivered by the pump and dividing by the theoretical displacement.

According to Kurt, (1966), volumetric efficiency η_{vol} is normally between 0.7 to 0.97, while stroke – bore ratio S/d and the average piston speed Cp.av which are part of the characteristics of reciprocating pumps ranges from; 0.8 – 2; and 0.9m/s respectively. The following are therefore adopted for this design.

Volumetric efficiency $\eta_{vol} = 0.7$

Stroke – bore ratio s/d 2; ∴ S = 2d

Number of piston double strokes/min = 20 strokes

Substituting the value of 'S' into the equation (3.*), we obtain

$$Q = \frac{⑥\, d^2}{4} . 2d. \frac{N}{60} \quad \eta_{vol}$$

$$= \frac{2⑥\ d^3 . N}{240} \ \eta_{vol}$$

$$= \frac{⑥\ .d^3 . N \ \eta_{vol}}{120}$$

$$:. \ d = 3\sqrt{\frac{120.0}{⑥ . N. \eta_{vol}}} \qquad 4.5$$

but $Q = 3 \times 10^{-3} m^3/s$ (from equation 3.7)

$N = 20$

$\eta_{vo} = 0.7$

substituting in equation (3.9) gives

$$:. \ d = 3\sqrt{\frac{120 \times 3 \times 10^3}{⑥ \times 20 \times 0.7}}$$

$$= 2.201530847m$$

$$= \underline{2.1.53mm}$$

For convenience, since the pump is to be operated using legs, the bore is divided into two to provide a cylinder each for human leg.

Therefore the diameter of each cylinder is taken to be 100mm, from which, the required stroke is 200mm.

4.1.3 DETERMINATION OF FLOW VELOCITY

Using the relation $Q = V A$ 4.6

Where Q = Volumetric flow rate of water flowing per second (m^3/s

V = Velocity of flow (m/s)

A = Area of the pump cylinder (m^2)

But area of a cylinder is given by

$$A = \frac{\text{⑥}\, d^2}{4}$$

Therefore from equation 3.10, we obtain

$$V = Q/A = \frac{4Q}{\text{⑥}\, d^2} \qquad 4.7$$

Substituting the value of the diameter of the cylinder to be 100mm = 0.1m and $Q = 3 \times 10^{-3} m^3/sec$. We obtain

$$V = \frac{4 \times 3 \times 10^{3+}}{\text{⑥} \times (0.1)^2}$$

$$= 0.381971863 m/s$$

$$= 0.38 m/s \text{ approx}$$

4.1.4 PRESSURE HEAD

If a tube is placed with one end in a bowl of water and air is draw out of the top end of the tube, the pressure in the tube falls below that of atmosphere: leading to the formation of 'partial vacuum'.

But the water in the bowl has exerted upon it the pressure of the atmosphere, which rest on the surface. This pressure, being now greater than that in the upper part of the tube drives the water up the tube. This balances the difference between the upward atmospheric pressure of the water at the bottom of the tube and the reduced air pressure in the upper part of the tube. The operation of the suction pump is of this nature. By the principle of transmissibility of pressure, the upward pressure exerted by the water in the tube, is equal to the downward pressure exerted by the atmosphere on the free surface. This is expressed mathematically as:-

$$h = \frac{P_a}{w} \qquad 4.8$$

in which h = pressure head, (m)

where; P_a = pressure inside the tube (KN/m^2)

W = specific weight of water (kg/M^2)

But atmospheric pressure (P_a) = 101.3 KN/m^2

specific weight of water (w) = 9800N/m^2

(Note w = ρg = 1000 x 9.8)

$$\therefore \text{ Pressure head of water } h = \frac{101.3 \times 10^3}{9800}$$

$$= 10.33673469m$$

$$= 10.34m \text{ approx.}$$

Theoretically, the pump can lift water from a height of up to one atmosphere or 10.34m.

The friction, leakages and the mass of water in the suction pipe have considerable inertia. This will allow the development of vauum on top of the water column if the piston are cycled at a normal rate of delivery, a height of 7m is considered as a maximum height for this work. This is the piezometric surface (Static suction lift). Hence pressure head of water h = 7m (maximium).

4.1.5 **STATIC DISCHARGE HEAD**

The pump is designed to be used by one or two operators and since the force applied for the pumping is directly proportional to the weight of the operator(s), the total vertical distance that water can be pumped is limited by the total weight of the operator(s)

Considering the operation of the pump by two adults with an average effective weight of 50kg each, then, force applied on the piston

F = mass (m) a acceleration due to gravity (a)

$$\therefore F = m \times a \qquad 4.9$$

Take (acceleration due to gravity) $a = 10.0\text{m/s}^2$

$m = 100\text{kg}$

From equation 3.13 $F = 100 \times 10$

$= 1000\text{N}$

but pump cylinder diameter = 100mm

$= 0.1\text{m}$

and pressure (P) developed $= \frac{\text{Force}}{\text{Unit Area}}$ 4.10

$$= \frac{F}{⑥\, d^2/4}$$

$$= \frac{4F}{⑥\, d^2}$$

$$= \frac{4 \times 1000}{⑥ \times 0.1^2}$$

$$= 127323.955\text{N/m}^2$$

For a reciprocating pump supplied with water exposed to atmospheric pressure (P_1) and $V_1 = 0$, with a water level (H_1) at 10.0m (neglecting losses) above static water level being pumped at $V_2 = 0.32$m/s: the static discharge head could be computed using Bernoulli's equation. Applying Bernoulli's theorem between the static water level and the static discharged head of the pump (neglecting leakages and frictional loses).

$$\frac{P_1}{Pg} + \frac{V_1^2}{2g} + H_1 = \frac{P_2}{pg} + \frac{V_2^2}{2g} + H_2 = \text{Constant} \qquad 4.11$$

Where $P_1 = 101.3\text{KN/m}^2$ (Atmospheric pressure)

$P_2 = 127.3\ \text{KN/m}^2$

$V_1 = 0$

$V_2 = 0.38$m/s

$H_1 = 10.0$m

$H_2 = ?$

From the above relation, $\frac{103.3}{1000 \times 10} + \frac{0}{2 \times 10} + 10 = \frac{127.3}{1000 \times 10} + \frac{0.38}{2 \times 10} + H_2$

$0.1013 \quad + 0 + \ 10 = 0.01273 + 0.019 + H_2$

$10.1013 \ = \ 0.03173 + H_2$

:. $H_2 = 10.01013 - 0.03173$

$= \ 9.9784m$

A static water head $H_2 = 9.8m$ will be used

4.1.6 **DETERMINIATION OF THE PUMP CYLINDER THICKNESS**

A thin walled cylinder containing fluid under pressure is subjected by symmetry, to three principal stresses, thus;

i. a uniform radial pressure normal to the walls and since the cylinder tends to expand radially, there will be a tensile or hoop stress (circumferential stress) ⑨$_1$

ii. in addition to hoop stress, a longitudinal or axial stress ⑨$_2$ arising from the force due to pressures on the closed ends is developed.

iii. the radial stress which have a value equal to the internal pressure at the inside surface and zero at the outside surface is very small and can be neglected.

An open ended cylinder is been considered and only the hoop stress ⑨$_1$ is therefore relevant.

According to Ryder

⑨$_1$ = $Pd/2t$ 4.12

Where

⑨$_1$ = hoop stress

p = pressure force

t = thickness

And it could be assumed with reasonable accuracy that, if the ratio of thickness to internal diameter is less than about 1/20; the hoop stress is constant over the thickness of the cylinder; but the diameter to be utilized should be the mean diameter. To eliminate the error that might be made for not using the mean diameter, the following relation is used to determine the thickness of the pump cylinder;

$$\text{Hoop stress } ⑨_1 \quad \left[\frac{d_2^2 + d_1^2}{d_2^2 + d_1^2} \right] P_1 \times F_s \qquad 4.13$$

Where: ⑨$_1$ = hoop stress

d_2 = external diameter of the cylinder

d_1 = internal diameter of the cylinder

P_1 = internal pressure

F_s = factor of safety

According to Oberg (1988), the allowable stress for the pressure cylinder is within the range of 41 N/mm^2

Because the type of load involve is a 'fluctuating' type, and the magnitude of the load is frequently subject to uncertainty, there is need for a factor of safety (F_s). Values used in Engineering design according to Ryder, vary from about 3 (for dead loads accurately known) to 12 for shock loads of indefinite magnitude). For this design let F_s = 5 and ⑨$_1$ = 48N/mm^2

Hence, from equation (3.17).

$$\left[\frac{d_2^2 + d_1^2}{d_2^2 + d_1^2} \right] P_1 \times F_s$$

Where ⑨ = $48N/mm^2$

$d_2 = ?$

$d_1 = 100mm$

$p_1 = 0.127N/mm^2$

$F_s = 5$

Thickness $t = \frac{d_2 - d_1}{2}$

Hence, we have

$$48 = \frac{[\,d_2^2 + 100^2\,]}{d_2^2 + 100^2}\ 0.127 \times 5$$

$$\frac{48}{0.635} = \frac{d_2^2 + 100^2}{d_2^2 + 100^2}$$

$48d_2^{2\,-}\ 480000 = 0.635d_2^2 + 6350$

$48d_2^2 - 0.635d_2^2 = 6350 + 480000$

$47.365d_2^2 = 486350$

$$d_2 = \sqrt{\frac{(486350)}{(47.365)}}$$

$= 101.33mm$

hence $d_2 - d_1 = 101.33 - 100$

therefore, $t = 1.33 \times 2$

$= 2.66mm$

for the purpose of vibration and welding, a thickness of 3mm will be used for the pressure cylinder.

4.1.7 DIAMETER OF CONNECTING (PISTON) ROD

The piston rod connects the pump piston to the pedal and therefore transmits forces from the operator(s) to the piston during the pumping stroke. For the rod to with stand vibration and bending, mild steel is preferred.

According to Sports. (1988), the ASME code B17c. recommends that, for commercial shafting without any definite specifications for physical and chemical properties of the material, the yield strength $⑨_1$ of such steels range from 45N/mm^2 to 70 N/mm^2

But Yield strength $⑨ = +\underline{F} \times F_s$ 4.14

Where F = force

F_s = factor of safety

$A = \text{Area} = \frac{⑥ d^2}{4}$

d = diameter of rod

$$\therefore ⑨_y = \frac{F \times F_s \times 4}{⑥ d^2}$$

let $⑨_y = 45$ N/mm^2

$F = 100 \times 10$N

$F_s = 5$

Hence $$45 = \frac{100 \times 10 \times 5 \times 4}{⑥ d^2}$$

$$\sqrt{}\frac{100 \times 10 \times 5 \times 4}{45 \text{ ⑥}} = 11.89\text{mm diameter}$$

For the purpose of this design, a pump rod diameter of 12mm will be used.

4.1.8 DESIGN OF THE VALVE BOX

Mechanical valve are devices for the control of flow or pressure in a pipe or between component of machines. There are an enormous number of different types of valves in use, and almost as many designations, according to functions. Flow medium and mechanical design. Broadly speaking, valves can be divided into three groups according to functions; pressure control, flow control, and fluidic logic.

4.1.9 **PRESSURE CONTROL VALVES:-** are two way valves which are normally either close or open, and which are usually infinitely variable between these two extreme positions, according to flow rate and pressure differentials. For instance, safety valves held close by a spring or weight but will open if pressure exceeds a specified maximum.

4.1.10 **FLOW CONTROL VALVES:-** are single input alternative output devices which either divert or divide the flow, such as a hinged plate in a pipe junction which can allow flow from one input pipe to one several output.

4.1.11 **A FLUIDIC LOGIC VALVE**:-is so called by analogue with mathematical and philosophical discipline of logic. In its simplest form, it is a multiple-input single output valve which can invert a state of operation from flow to non-flow, or vie versa, as in a logical 'negation' or combine several states of input to one output as in a logical 'conjunction' or 'disjunction'.

The valves employed in this design are simple check valves, opening and closing in response to the water pressure acting upon them. The outlet valve opens away from the cylinder and let water out of the cylinder when the piston is moving downwards. The inlet valve opens into the cylinder and lets water into the cylinder when the piston moves upward. Each cylinder has an inlet outlet valve. The inlet valves are so arranged to draw water from the inlet chamber of the valve box that connects with the intake pipe. Similarly, the two outlet valves discharge water into the outlet chamber, connected to the outlet pipe of the pump.

The rubber valve flaps are fabricated from a 2.0mm thick rubber to make a tight seal with seat. The selection of rubber is in accordance to the nature of service, as appropriate stiffness necessary to ensure that the outlet valve is closed easily.

According to Ganic and Hicks (1991), the net valve required ranges from 45% to 60% of the piston area. Because this pump is human powered and to create easily, 35% of the piston area is to be considered.

Diameter D_p of piston = 100mm

Area of piston $A_p = \frac{\pi \times D_p^2}{4}$

$$= \frac{\pi \times 100^2}{4} = 785381634\text{mm}^2$$

$$\therefore A_p = 785\text{mm}^2$$

Inlet and outlet valve area = $\frac{35}{1000} \times 7854$

$$= 2748.9\text{mm}^2$$

Diameter of each valve port, can be computed thus;

$$2 \times \frac{\pi \times d^2}{4} = 2748.9$$

$$d_v = \sqrt{\frac{2748.9 \times 4}{2 \times \pi}}$$

$$= 41.83305024\text{mm}$$

For the purpose of this design, d_v = 42mm will be used.

Since rubber flaps are to be used as valves, a 42mm diameter valve port might cupped in the flap during suction stroke, therefore, the drilling of some holes, say, 12mm holes that will sum up to 42mm diameter will be of advantage.

Form the formula of the area of a circle, the area of a 12mm diameter hole = $\frac{\pi \times 12^2}{4}$

$$= 113.0973355\text{mm}^2$$

$$= 113\text{mm}^2 \text{ approx.}$$

But the total valve area = 2748.9mm^2

$\therefore$ The number of 12 mm holes required = $\frac{2748.9}{113}$ = 24.3266holes

In this design work, 24 holes, that is, 12 holes each for both inlet and outlet valve per cylinder.

4.2 **EVALUATION OF FORCES**

According to Sportts (1988), the effects of forces and moments that act upon the different parts of a machine are of primary importance to the machine designer, this to guide against failures. Below, Fig. 2.1 is the force loading diagram and its reactions on the pump pedal. Frictional forces are assumed to be negligible. One end of the pedal arehinged while the others ends are free.

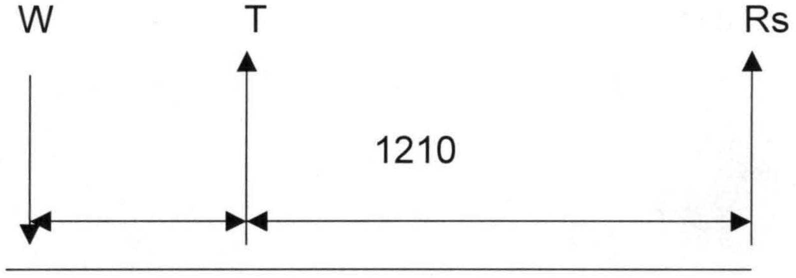

FIG. 2.1a Forces on the Pedal

Where

Mass of operator (w) = 100kg = 1000N

Tension force in rope (T) = ?

Reaction force at the fixed end (Rs)= ?

$\sum fy$ $\quad T + Rs = w$ $\quad$ 4.15

Similarly

$\sum Ms \qquad 1.21T = 1.51W \qquad\qquad 4.16$

$$\therefore T = \frac{1.51 \times w}{1.21} = \frac{1.51 \times 1000}{1.21}$$

$= 1247.93$ N

from equation 3.19,

$T + Rs = w$

$1247.93 + Rs = 1000$ N

$\therefore Rs = (1000 - 1247.93) = -247.93$ N (the – ve sign signifies that the force is acting in the opposite direction)

substituting the valves of the forces and taking moments,

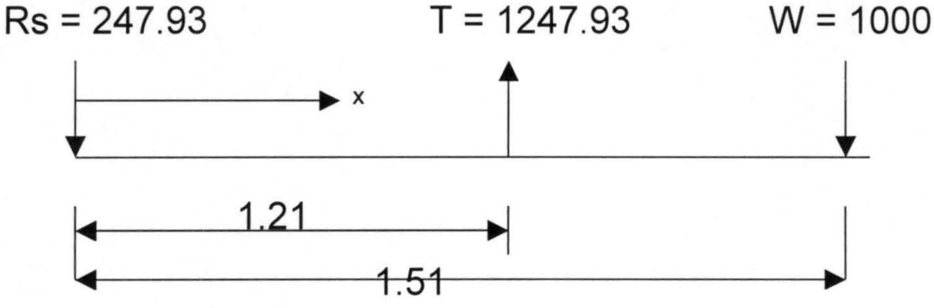

FIG.2.1b

From fig. 2.1b above, summation of bending moment gives;

$M + 247.93 X - 124.93 (X - 1.21) + 1000 (X - 1.51) = 0$

$\therefore M = - 247.93 X + 1247.93 (X - 1.21) - 1000 (X - 1.51)$

At $X = 1.21$; $M = -247.93 \times 1.21 = -300$Nm

At $X = 1.51$; $M = 247.93 \times 1.51 + 1247.93 \times 0.3 = 0$

$\therefore$ The bending moment M = 300 Nm (in the downward direction)

But $\sigma = \frac{M}{Z}$ 4.17

Where;

σ = allowable stress in the material N/m^2

M = bending moment Nm

Z = modulus of section m^3

According to Oberg & et.al, 1988, the allowable yield stress σw for wood is 16 Mpa;

Therefore σw 16 x 106 N/m^2

M = 300Nm

Z = ?

:. From equation 3.20,

$$Z = \frac{M}{\sigma w} = \frac{300}{16 \times 10^6}$$

$$= 1.87 \times 10^{-5}$$

but $Z = \frac{bh^2}{6}$ (for a rectangular cross section)

Where; b = width

H = height (thickness)

Let b = 2h;

Hence;

$$Z = \frac{2h \times h^2}{6} = \frac{2h^2}{6} = \frac{h^3}{6}$$

$$h = (3z)^{1/3}$$

$$= 3 \times 1.875 \times 10^{-5}$$

$$= 3\sqrt{0.038315471}\text{m}$$

$$= 38.32\text{mm}$$

Hence h = 38.32mm, and b=2h =76.64mm

A thickness of 40mm and width of 80mm are used for the planks.

4.2.1 **FORCE REACTION ON THE LEVER SUPPORTS**

The force acting on the support is the reactive force which now acts as a compressive force at an angle.

Rs = 247.93

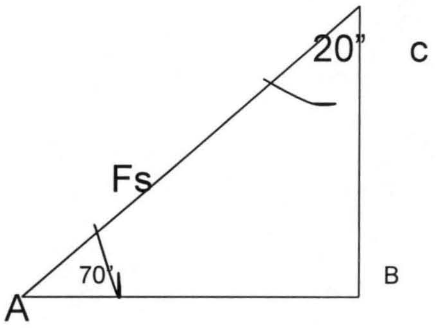

FIG. 2.2 forces on pedal support

Resolving the reactive force R_s in the above diagram along the support to get the values of F_s, which is the actual active force on the support.

Resolving R_s along AC;

$$R_s = \frac{2478.93}{\text{Cos } 20} \qquad = 263.84 \text{ N}$$

From equation 3.18,

$$\sigma = \frac{F}{A} \times Fs$$

And $\sigma y = 45$ N/mm

$Fs = 263.84$ N
$A = ?$ (cross sectional Area)

$$:.\ A \quad \frac{F}{\sigma y} = \frac{263.84}{45} = 5.863mm2$$

With the cross sectional Area, the diameter of the steel material that with stand the force is calculated thus:

$$A \qquad \frac{\pi \times d^2}{4}$$

$$\text{Where } d = \sqrt{\frac{4 \times A}{\pi}} = \sqrt{\frac{4 \times 5.863}{\pi}}$$

$$= 2.73mm$$

The equivalent outer and inner diameters of a hollow steel pipe are deduced from table and according to maltra and parsed. 1985 equivalent Outer and nominal diameter are 21.3mm and 15mm respectively. However a pipe of 27mm and 21mm will be used to account for any unrecognised forces.

4.2.2 **MANUFACTURING TECHNIQUES**.

The manufacturing methods and materials used for the production of each component are hereby highlighted. Considering the hard conditions under which the pump might be used, the fact that it is aimed for used by low-income farmers and to be produce by metal working, artisan, most part of the pump are made from mild steel and assembled by are welding process.

4.2.3 **PUMP CYLINDERS:**

The two cylinder of the irrigation pump are made from commercial steel though this could be made by rolling mild steel sheet around a steel pipe mandrel and the seam Galvanised pipe can also be used but the Zinc coating should be ground off where the pipe will be welded. This is to facilitate the welding, and to prevent the welder breathing noxious Zinc oxide fumes.

A rounded edge was made on one end of these pipes that will not be welded to the pump body. This is done to facilitate the attachment of PVC couplings when installing the pump in the field.

Finally, the box divider also made from a 3mm thick mild steel sheet measuring 240mm by 60mm was inserted into the box dividing the inlet ports from the outlet port and welded into position. Care was taken to ensure that the divider was made vertical, straight and of the same height with the side band at both of the valve box.

CHAPTER FIVE

5.0 MANUFACTURING PROCESS OF PUMP COMPONENTS

5.1 MANUFACTURING PROCESS

The aim of this project is to design and fabricate a manually operated lift pump to be able to draw water from a depth of about 7.5 metres (depth of an average well) for irrigation work. It is therefore necessary to state clearly the manufacturing process involved in the constructing every component of the pump. Manufacturing process deals with use of production technology (tie turning welding, soldering etc) to construct a component.

The parts of the pump listed below are manufacturing, except for standardized components like bolts and nuts.

	PARTS OF THE PUMP	MATERIALS
i.	Pump Cylinders	Mild Steel
ii.	Valve Box	Mild Steel
iii.	Inlet and Discharge Pipe	Galvanised Pipe
iv.	Level Handle	Hard Wood
v.	Lever Supports	Mild Steel Pipe
vi.	Lever	Hard Wood
vii.	Piston Washers	Mild Steel
viii.	Piston Rods	Mild Steel
ix.	Base Board	Hard Wood
x.	Pistons	Hard Rubber (Nylon)

5.2 MAKING THE PUMP CYLINDER (TWO PIECES)

The cylinders of the hand pump were made from mild steel sheet dimension which was rolled around a steel pipe mandrel to form a cylinder. The seam is subsequently welded to make the rolled steel sheet form a perfect cylindrical shape.

Each cylinder is made from a piece of 1.5mm (1/16") or 2.0mm thick steel sheet, measuring 330* 330mm. The 1.5mm thickness is best, because the sheet can easily bend around the mandrel, yet thick enough to be arc welded without great difficulty and without causing distortion see figure. 9A

Another alternative to rolling the mild steel sheet was to use a mild steel pipe of 102mm inside diameter, 106mm outside and length of 330mm.

5.3: **VALVE BOX**

The value box consist of the following components:

1 – VALVE PLATE:

The first part of the valve box is the valve plate, it is the to of the valve box to which the cylinders are welded. The plank was cut from a 3mm mild steel sheet as a rectangle measuring 130mm by 240mm. The valve plate consists of holes, which were drilled to form the ports (inlet and outlet ports). Each valve port has or carries twelve holes of 12mm diameter see figure. 7, the valve plate has four sets of marks, which were drilled to form the inlet and outlet valve in the two cylinders. These holes were drilled with a 6.5 drill bit.

2 – VALVE SIDE BAND:

The side band was cut from a 3mm thick mild steel sheet, and measuring 63mm wide and 670mm long. The side band was cut accurately, so that its edge is paralled and straight. It was welded to the value plate by bending round the plate, the end of the side band came closely together when the bending was completed. (see fig. 9B

3 – VALVE BOX HOLD DOWN POCKETS (SIX PIECES)

The pockets or bushing are made from 30mm square blank from a 3mm thick mild steel sheet. These blanks were their bent in the vice to a semi – circular section (see figure 8c).

After the above processes, the cylinders were welded on the valve box by positioning on the plate to the holes drilled on the plates. The disc has the same diameter as the inside of the cylinder.

5.4 INLET AND OUTLET PIPES

The inlet and outlet pipes were cut from a length of 42* 49mm bland galvanized water pipe. The inlet pipe was cut to a length of 900mm, while the outlet pipe was cut to a length of 100mm. It was vital to ensure that the inlet pipe, which is longer of the two, and the outlet pipe were put on the correct side of the valve box.

The shorter (outlet) pipe is welded on the side of the pump, which has the largest space between the cylinder and the side band.

The final and major step in making the pump body was to weld the valve box divider in place.

The value box divider was made from 60mm* 240mm steel strip of 3mm thickness. The value box divider was welded at the middle of the valve plate to divided the suction and delivery port of the valve box.

5.5 LEVER SUPPORT(S)

The lever supports were made from 27mm* 32mm was cut to 630.6mm length black water pipe welded to a 3mm thick steel sheet and bolted with the M8 x 100mm to the base wood. (see fig. 10c)

5.6 **MAKING THE PISTON ASSEMBLY.**

The piston of the pump consist of one rubber piston attached to the piston rod with a pair of steel washers, all of which were held together by a bolt M17 to the end of the piston rod. The upper and lower was hers serve to stiffen the pump cup and made to a size of only 2mm smaller than the pump cylinder to help to centralize the piston in the cylinder.

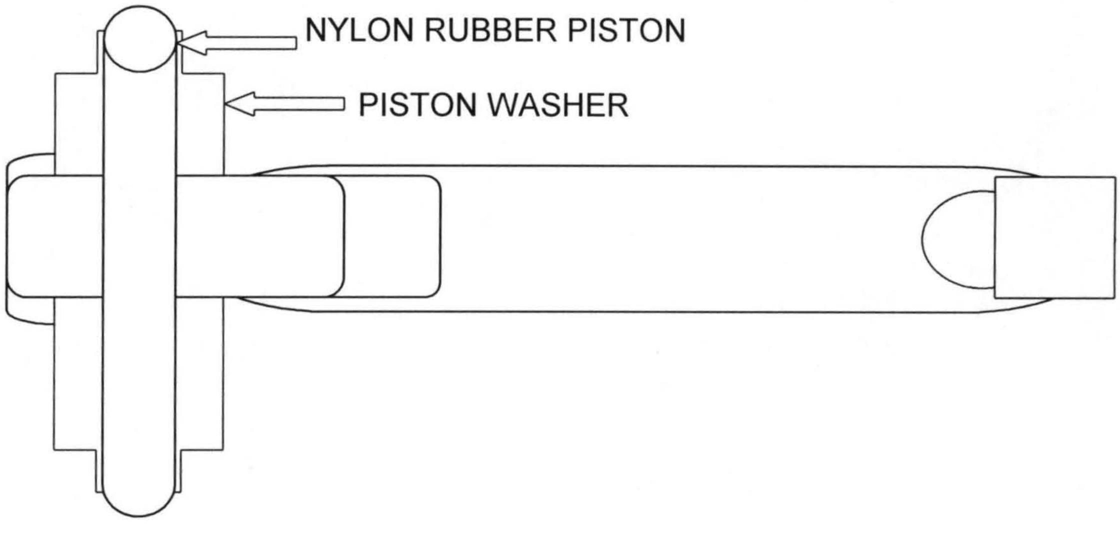

Fig. 5.1 Complete piston, piston rod assembly.

The pump support washers were made from a 3 mm thick mild steel sheet. The upper and lower washers are 90mm in diameter and the washers have 12.5mm centre holes (see figure ...8A.).

The piston rods were made from steel cut to a length of 440mm and 17mm diameter round rod drilled at one end to be guided together operating lever and taped at the other end to accommodate M17 bolt to hold the piston in position. (see figure...5).

5.7 MAKING THE WOODEN PART(S) OF THE PUMP.

Three parts of the pump were made from wood one the operating lever, base board and lever support base. A wood of medium hardness such as mahogany, may be used for the operating lever (handle) and the base board, but the lever support base must be made from the hardest wood available.

5.7.1 OPERATING LEVER.

The operating lever can be cut by sawing a 30mm thick hard wood plank in to pieces of 45mm wide, or by sawing an 80mm square hard wood post in to two halves, roughly measuring 30mm by 60mm. The levers should be 712mm long. The lever(s) were drilled with a

10mm drill bit at a distance of 10mm from one end. It was then fixed to the lever support and positioned almost horizontally or paralled to the ground level, resting above the cylinder. (see figure below).

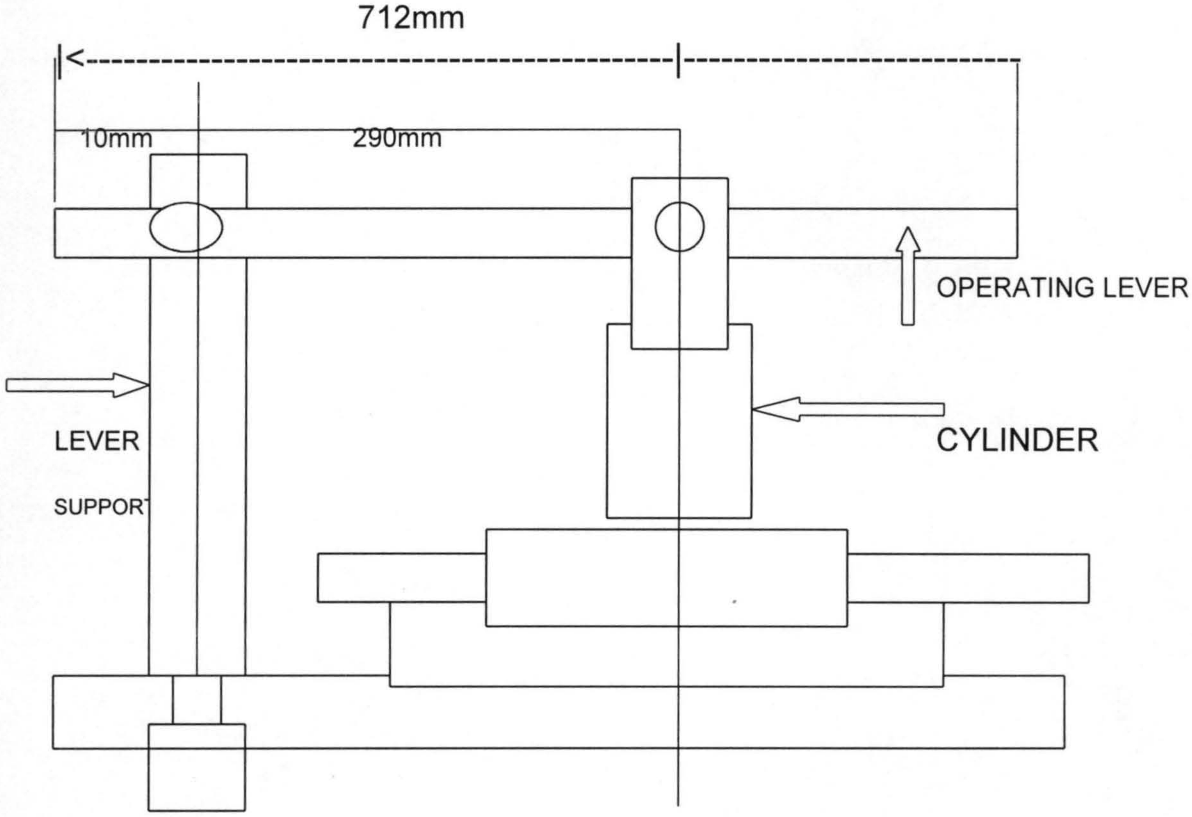

Fig. 5.2

5.7.2 BASE BOARD

The last wooden part to be made is the baseboard on to which the pump is mounted, and which forms the bottom of the value box. In making the baseboard a plank of 200mm wide and 30mm thick that is seasoned and flat is used. Two cleats or made from 40mm square hard wood were then bolted to the baseboard. The cleats reinforces the baseboard, increase the stability of the pump, and help to keep the baseboard and the value box studs clean and dry when the pump is in use.

5.8 **ASSEMBLY OF THE PUMP.**

When the baseboard was complete, ten bolts measuring M8 by 70mm (six pieces) M8 by 100mm (4 pieces) 6pcs were inserted in to the six pockets or bushings on the wall of the valve box and 4 pieces were used to bolt baseboard with lever support base. A rubber gasket was fitted over the bolts through holes drilled in the previous processes. Sheet metal washers were placed over the bolts and nuts threaded on, and tightened down.

Once the pump was mounted on the base board, the pump is set in its up right position and the operating handles (lever) were inserted the two moveable joints was lubricated with light grease to allow for the easy operation of the pump.

Next the piston assembly was assembled, and inserted in to the cylinders. Care should to take to ensure that the piston is gently manipulated in to the cylinder to avoid damage to the piston.

The final step in assembling the pump was to install operating levers that connect the two piston and the levers. Firstly, one of the pistons was lowered until it touched the bottom of the cylinder, and other raised until it reached the top of its cylinder.

CHAPTER SIX

6.0 COST ANALYSIS

The cost of producing a manually operated pump mainly depends upon the local cost of its raw material and of the labour required for its manufacture, as well as the efficiency and scale of production. The cost of production is based mainly on two factors, these are material cost and labour cost.

6.1 MATERIAL COST

This is the cost of raw materials and cost of standard bought in parts that are assembled make up the finished product. It is based on current market prices. The materials used for the manufacture of this pump are readily available in the market and are comparatively cheap.

Details of breakdown of material cost is given in the table below:

TABLE 6.1 DETAIL MATERIAL COST

S/N	MATERIAL DESCRIPTION	Qty	UNIT COST =N=	TOTAL COST
1.	Cylinder (102mm * 330mm Length	2	600.00	1200.00
2.	Hard Wood Plank	1	300.00	300.00
3.	Black Ungalvanised Pipe	1	200.00	200.00
4.	Mild Steel Rod (....mm, ..mm,..mm	1	150.00	150.00
5.	Bolts and Nuts/Washer	18	20.00	360.00
6.	Mild Steel Sheet 3mm Thick	1	600.00	600.00
7.	Carbide Tool	2	200.00	400.00
8.	Emery Cloth	1	150.00	150.00
9.	Flexible Hose	1	300.00	300.00
10.	Nylon Rubber	1	200.00	200.00
	Total			3,860.00

6.1.1 LABOUR COST

This is the cost of during the production of the pump, taking in to account the standard amount in relation to the skill of the technician involved in the operational sequence. It is computed on hourly basis and charges per hour. The total number of working hours for the completion of the pump construction is computed below:

- Number of working hours per day = 8 hours
- Number of working days per week = 5 days
- Number of working weeks for job completion = 7 weeks
- Labour charge per hour = N20.00

Total cost of labour = 8 x 5 x 7 x 20

= N5,600.00

6.1.2 MISCELLANEOUS COST

Miscellaneous cost are other expenses incurred during the manufacturing process of the pump. These include the cost of scouting for materials as well as accounting for waste and damages during production, and also transportation cost.

Therefore miscellaneous cost = N1,000.00.

The overall cost of production is, cost of materials, cost of production and running cost.

That is:

Material cost	=N=3,860.00
Labour cost	=N=5,600.00
Miscellaneous cost	=N=1,000.00
	=N=10,460.00

The total cost of the pump is thus put at ten thousand four hundred and sixty Naira only.

When compared with motorized pumps the manually operated pump (Hand pump) is cheaper, which gives it an added advantage for rural farmers.

6.2 STARTING THE PUMP

6.21 PRIMING AND SUCTION ARRANGEMENT

Priming the pump, the operator must work the operating levers quickly to evacuate the air and pull water up. To facilitate the sealing of the pistons against the entering of air, a water gallon can be used to fill the cylinders with water from the top, above the piston. This is necessary at the time of start up (Priming): When cylinders are full of water, they tend to create their own seal of the pump to the piston wall is not good enough, it should be removed and worked upon.

If the pump does start at all or does not work well, check that there are no leaks in the suction pipe and that there is a good seal between the pump and the base board, the Nylon pistons and the cylinders (leaks around the pistons can be eliminated by removing the piston and expending the piston by tightening the piston bolts move).

If water or fluid reaches the pump, but the pumping seems difficult and the levers move slowly, check the intake to the suction pipe. If the suction intake does not sit at the bottom of the well or surface water or under ground tank or river and the intake screen is not clogged, the piston may require. Lubrication i.e. by applying film of lubricating oil or replacement of new Nylon pistons.

6.3 MAINTENANCE AND REPAIR REQUIREMENTS

The parts of the pump that requires maintenance are easily accessible these are:-

- Operating Lever
- Nylon Rubber Piston
- Lever Joints
- Value Flaps

6.3.1 OPERATING LEVER.

The operating lever should be checked and lubricated every day that pump will be used.

6.3.2 NYLON RUBBER PISTONS

The part that is most likely to cause malfunction is the Nylon Rubber Pistons. If the pump is not used frequently, the pistons will dry out quickly. To prevent piston stiffness and wearing of the piston, remove the piston from the cylinders and apply light lubricating oil.

6.3.3 LEVER JOINTS

The lever joint should also be checked and lubricated every day to avoid local noise and stiffness of the operating levers.

6.3.4 SUCTION PIPE.

If the pumping becomes difficult, check that the intake (suction) pipe and fitter or strainers are not blocked. If a flexible hose is used, check that it is not sharply bent along its length. The strainer at the intake pipe should be properly attached to it, so as to prevent particles both small and big stones, sand that may enter the pump during suction. These will prevent the values from closing properly. The sand, gravel and stones can be removed easily by dismountling the pump and cleaning it.

6.3.5 VALVE FLAPS

The regular inspection of the value is very important, the value should be inspected for any sign of wear especially around the clamps, or if the rubber has developed a distorted and tired appearance (especially if the valve port holes has started to cut in the valve rubber), they should be replaced.

Periodic inspection and preventive maintenance (PM) for the hand pump will increase the service life span of the pump. This approach (maintenance) will save money and time.

CHAPTER SEVEN

7.0 DISCUSSIONS, RECOMMENDATION AND CONCLUSION

Design and production research project is a system of analysis involving load and stress calculations, material selection, manufacturing process and cost analysis. A research project design and production of a manually operated (hand) pump cannot be exhaustive but it aims to show that with all seriousness, in country production of pumps is possible.

The entire project work was carried out using locally sourced, cheap and qualitative materials. Since it is produced locally, it could be affordable to peasants and small-scale farmers.

7.1 RECOMMENDATIONS

During the production and testing of the pump, new discoveries were made which lead to better performance and ease of operation of the pump. These discoveries lead to the following recommendations:

1. If the pump is to be used from domestic application (Under ground water wells or surface water) or small-scale irrigation, a foot valve or non-return valve should be fixed at the end of the intake hose which is attached to the inlet pipe, this is to allow the pump to remain primed always.
2. Since the flow is pulsating in nature it will be necessary to use vessel just before and after the cylinder. This will give uniform flow of the liquid in both suction and delivery pipes.
3. The maintenance of the pump must be give due consideration so that it can function properly. Correct operation and repair procedures are important factors in successful long term operation of the hand pump.

7.1.1 **CONCLUSION**

The need for pumping system in irrigation farming or domestic purposes cannot be over emphasized in country like Nigeria that is desiring to go in to green revolution in areas where there is no adequate rainfall or where dry season farming is applicable. The design and manufacturing process carried out in this project work will go a long way to help solve some of the problem encountered in irrigation pumping system.

With little or no modification, the hand pump can work comfortably well in pumping water for domestic application and irrigation work in rural areas, and because it is considerably cheap as compared to motorized pumping system, it is affordable to rural and peasant farmers.

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