DESIGN AND CONSTRUCTION OF HAND OPERATED WATER PUMP

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DEDICATION.

TO

My father, Alhaji Muhammed Jiya the late Kpotun of Zambufu

My mother, Hajiya Aishatu Jiya

For their love, guidance, support and encouragement.

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Finally I am grateful to God who have given me life and health to undertake this project.

NOTATION

A	=	Surface area of the pump cylinder
Ap	=	Area of Piston
Dc	=	Major diameter
Dp	=	Diameter of Piston
Cp	=	Capacity of pump
W	=	Weight
e	=	Strain
F	=	Force
Uf	=	Coefficient of Friction
L	=	Length of Materials
Ts	=	Tensile Stress
M	=	Mass
E	=	Effort
SH	=	Depth. of static water level
N	=	Number of Strokes per minute
Qt	=	Discharge rate
q	=	Discharge per stroke
S	=	Leakage
SH_2O	=	Density of water
Pbrass	=	Density of Brass
Tl	=	Tensile load
Mp	=	Mass of pump
PR	=	Pressure
Pe	=	Power Torque
S_L	=	Suction Lift
RA	=	Relative acceleration of handle
VA	=	Velocity of Handle
Ad	=	Area of delivery pipe
Dd	=	Effective Diameter of delivery pipe
Hd	=	Pump Head
Hatm	=	Atmospheric pressure
Hi	=	Delivery Lift

g	=	Acceleration due gravity
RE	=	Regnoid's number
Vk	=	Kinematic Viscosity
M.E	=	Mechanical efficiency
V.E	=	Volumetric efficiency
WA	=	Angular velocity
Ys	=	Yield strength
S.F	=	Safety factor
MmB	=	Maximum Bending moment
Kc	=	Total loss of friction
Cco	=	Co-efficient of contraction
Wp	=	Angular Acceleration.

TABLE OF CONTENT

CHAPTER THREE

CHAPTER FOUR

LIST OF TABLES

LIST OF FIGURES

ABSTRACT.

The work reported here is design of a hand operated pump that delivers water from depth of 35m at a speed of 30 strokes/minute, and has a discharge rate of 9.9 litres/min.

The pump which is cost effective was fabricated using easily available materials and techniques of fabrication. The design is suitable for the rural communities, due to its low cost and simplicity.

A test carried out on the fabricated prototype pump showed some remarkable performances.

CHAPTER ONE

1.0 INTRODUCTION

Water is a creation of nature whose existence was established long before other creatures. Major religious scripts has it that the whole of the earth was filled with water before it was seperated into land and sea masses respectively. About 80% of the total earth surface is occupied by water and the remaining 20% by land mass on which living creatures live and depend on the water mass for survival. One can say therefore, that water is a free gift of nature to all living creatures.

This nature's gift is sustained permanently through the process of water cycle. During intensive heating of the earth surface by the sun, large percentage of the water gets evaporated into the atmosphere in form of water vapour. The water vapour falls back as rain water. This is the water cycle (EJUP, PACEY 1965). This rain is evenly distributed all over the world so that the cycle is kept uniform only varying slightly from one locality to another. When the rain falls, some run-off to form rivulets and rivers which later empties into the sea. The rest either evaporates again into the atmosphere or percolates deep down to form underground fluvial system, otherwise known as water-table. This underground water table along with surface drainage system forms the hydrological system of any given geographical area with the system being self-sustaining. The water cycle is kept on permanent, thus making the water available evenly throughout the year. The even distribution of the hydrological system makes some areas to have water throughout the season, some intermittently and some not having at all.

In most cases some people have to travel some distances before they can get drinking water. The water so obtained may not be clean enough for domestic uses, thus leading to outbreak of water borne diseases as a result of using unclean water. Governments all over the world strive to solve the problem of providing drinking water at the safest level within a minimum cost to her populace and as such had to embark on water related projects in cities, semi-urban set-ups and other rural localities. These projects involve huge capital investment which in many cases may not be readily available.

The problem is further aggrevated, if the Human population that is to benefit from giant water projects are not concentrated in a location, because of large distribution network that will require high financial investment.

In the cities where population is concentrated, and it is possible to execute giant water schemes; the problems like umprecedented population explosion renders whatever projection of water capacity and distribution ineffective within a short time. Unplanned urban development like construction of buildings, highways construction etc. sometimes result in the damage to water pipes thereby affecting the distribution of water.

Bad water can be harmful, because it can result in deadly diseases. Majority of the infectious diseases are water borne and can be eradicated quickly and effectively through the provision of clean water for domestic use.

1.1. NATURE OF THE PROBLEMS

Having considered the numerous problems associated with conterminated water and the question of supplying citizens with clean water within an affordable cost at the rural level, there is the need to look for other cheap durable and easy to operate alternative source of making clean water available using local materials and technology in place of costly ones.

The closest to satisfying the above requirements are the use of simple pumping machines that are normally designed and perfected for use in a given locality. The sophistication of the pump machine will depend on;

(1) The target population the system is going to cater for.

(2) The simplicity of the technology and maintenance of the system.

(3) The availability of spare parts in view of parts replacement when the need arises.

(4) Personnel needed to maintain and manage the system in line with village level operation, maintenance and management(VLOM) Concepts.

Getting water from the underground water table will reduce the cost of making water available through a network of pipe-borne water system which is capital intensive. It also reduces the susceptability of the populace to many water borne diseases (EJUP, PACEY, 1965). The quality of the life of the rural populace who use such manually operated water pumps are thereby improved (Wagner, 1959).

1.2 AIMS AND OBJECTIVES

With the above in mind the aim of this project was to design and fabricate a hand operated water pump from easily available materials using the local technologies that will minimise the cost.

1.3 LIMITATION OF THIS STUDY

This author would have wanted to practically test the pump in an ideal well whose depth is known, but because of the time constraint these was not possible. A small water reservoir in front of the mechanical workshop of (thermal fluid, Applied mechanic and automobile workshop) Federal University of Technology, Minna was used to test the designed and fabricated water pump.

CHAPTER TWO.

2.0 LITERATURE REVIEW

2.1 SOURCE OF WATER

What is seen as water exists in cycle. When the rain falls, some run-off to form streams, and rivers which enventually empties into the sea, while the rest evaporates to the clouds or percolate into the soil to form underground water table (Strahler 1980). Thus the sources of water to man are;

a. Rain-water which are collected in basins, drums and other clean containers.

b. Brokes, Streams, and rivers.

c. Underground-water (aquifer water)

d. Sea-water

e. Industrial manufacturing of water.

2.1.1. RAIN WATER

Rain water is got from coalesced water vapour that had long evaporated from the earth surface (Wagner 1989, Tyler 1960). When it falls back as rain, it can be harvested through its collection in tanks, basins, underground tanks e.t.c. At the instance of its falling and when it gets into storage impurities get into it via air, animals, dirty containers e.t.c. In some cases it becomes the breeding ground for insects; for example mosquitoes. When this happens the rain water is rendered unsafe for drinking and other domestic uses. If not for the above fact it could have been the cheapest source of clean water. Other militating problem are that rain fall is not regular and secondly provision has to be made for its long time storage.

The result of some rain fall that escaped collection is the run-off which are in small channels that when linked together they form tributary to one another. These tributaries at the end manifest into streams and rivers. The streams and rivers can be harnessed to get safe and clean water for drinking and other domestic uses.

The major militating factor against its adaptation in rural setting is due to its capital intensive nature. The expenditure are encountered through;

i. Provision of water-work away from the locality.

ii. Provision of water treating equipment.

iii. Provision of pipes and kits for the distribution of the water to areas of need.

iv. Provision of personnel and logistics to over see the functioning of the entire set-up.

The combination of several rivers draining into a basin coupled with rain fall form the sea (EJUP, PACEY 1965). Due to its exposure to great sun heating, evaporation takes place along with the concentration of mineral rocks that had dissolved in the tributaries thus making it salty (Tyler 1960). It is this salty nature of the sea-water that makes it impossible for it to be used for drinking and other domestic uses.

2.1.2 INDUSTRIAL WATER SOURCE

Science as is always the case wants to find solution to all human problems. Hence, the possibility of manufacturing water in the laboratory. This possibility can be extended to a large scale situation of manufacturing water for drinking and domestic uses (Rogar 1982). But the major problem would be whether the water so manufactured can be adequate and at what cost in terms of finance and other resources expended on the venture.

2.1.3 UNDERGROUND WATER SOURCE

The last source of water is the underground source that is derived from the rain-fall that got percolated deep into the earth and some rivers/sea that actually replenish aquifer water (underground water table) when the need arises. The water table exists in almost every-where beneath the earth surface. It varies in depth from one locality to another. The quality of the underground water will depend on (Wagner 1959);

a. Human activities through;

(i) Deposition of water conterminating materials like burying of radio-active substance in a hazardous manner.

(ii) Sippage of impurities such as sippage of animal(faecal) material into the borehole.

b. Environmental activities.

(i) Crustal activities which might result in radio-active materials of the underground water.

(ii) Concentration of iron-mineral in the underground water which is due to the concentration of iron-mineral in the geological material of a given locality.

2.2, METHOD OF BRINGING WATER TO THE SURFACE

Early civilisation normally dig an open well and as such had their own method of bringing water to the surface (M/uhammed, 1980) Major methods of bring water to the surface are;

2. 2. 1. SHADOFF METHOD

This is achieved by erecting a local fulcrum (usually wood with a splitted end). On which is suspended long rod (wood) with one end tied to a rope holding the bucket for taking water from the well and the other end is tied to a heavy load which assists the operator in lifting the load of water from the well.

2. 2. 2. WINDLASS METHOD

Water lifting is achieved by tying ropes of equal length to the wheel drum so that when the wheel drum is rolled by the operators through levers one of the buckets tied to the end of one of the ropes comes out of the well with water while the bucket tied to the second rope is on its way to the well for the same purposes of bringing water to the surface (Muhammed, 1980).

2. 2. 3 BUCKET AND WHEEL METHOD

It is achieved by tying buckets to laminated wheel with its half deeply immersed in water in the open well so that when rolled each of the buckets will be dipped into the water and then filled with water which is brought to the surface (Ejup, PACEY, 1965).

2. 2. 4. DIRECT BUCKET AND ROPE METHOD

It is the most generally used type in the rural areas. Here a bucket is tied to one end of the rope and the other end is held by the user. The user lets off the bucket into the well and when the bucket is filled, he draws it out to be emptied into another bucket or basin (Wagner, 1959).

2. 2. 5 ANIMAL METHOD

With the advent of technological improvement in bucket wheel and direct bucket and rope methods, use of animals like bull to draw water from wells became feasible especially in Asian countries like India and China (Muhammed, 1980).

2.2.6 MOTORISED PUMPS.

With the exception of animals, the other methods are labour intensive because there is little or no mechanical advantage associated with these methods of bringing water to the surface. Human beings ever dynamic on thinking realised these short-comings and came about bore-holes on which pumps of various operational means can be installed to help in reducing Human effort to the barest minimum (Ejup, PACEY, 1965).

These include;

(1) Engine powered water pumps. These are classified into fuel powered pumps e.g. Diesel engine and electricity powered water pumps. They vary in size and form.

(II) Wind Powered Water pump: are pumping machines that are powered by the effort of the blowing wind. The wind strikes the surface of the wind-mill blade which makes the wheel to rotate. It is this rotation that is coverted into machanical energy used in pumping water to the surface.

(III) Solar Powered water pumps are almost the same as electrically powered water pumps. The only difference is that the required energy is supplied by the sun. The energy is then transfered into electrical energy which the pump uses to effect its work.

2. 2. 7 MANUALLY OPERATED WATER PUMPS

These are made of differents types, but all are geared towards achieving the same end.

2. 2. 8 HAND HELD LEVER OPERATED WATER PUMPS

It uses a long metal rod as its lever which the operator lifts up and down. The reciprocating movement of the lever effects movement in the cylinder of the piston through connecting rod, so that suction takes place from the water table to the surface (Bamiro 1987; Wagner, 1959).

2. 2. 9 FOOT OPERATED VERGNET PUMPS.

It uses air to transfer effort from the pedal which the operator press with leg up and down the bottom of the delivery pipe to force water upward to the surface.

Despite the motorised-pumps elimination of Human effort completely. Its cost implication makes it impossible for a cheap alternative source of the application in the rural areas. The only option is the application of manually operated pumps in view of its cheapness and high-degree of mechanical advantage. The idea of manually operated water pumps came into being in most of the African countries through the effort of UN

Agencies (N.G.A.) (MCJEUKIN 1987). The main aim of most of these organisation is to eliminate water-borne diseases. The pioneering agencies in this respect in Africa is the UNICEF which having the facts of health situation all over the world at its disposal tried its best in solving the problems Africa as a continent is facing in the health sector, among these problems are:

1. 100 Million Children have little or no access to safe clean water . Greater percentage of the population being in third world countries with Africa being in the lead.

2. 100 million people drink dirty water in third-world countries (EJUP, PACEY 1956).

3. 80 percent of the worlds disease are linked to use of dirty water and poor sanitation.

4. There are one billion reported cases of diarrhoea every year in the third-world countries causing 25 million death which includes 16000 small children dead every year.

5. People have to carry water by hand over many miles everyday (EJUP, PACEY 1965).

The first attempt of UNICEF is in the area of eliminating Guinea-worm and schistosomiasis which were the greatest of the rural scourges in the seventies and the early eighties. It is this attempt that lead to the introduction of INDIAN MARK II water pumps in Africa in view of the fact that its use in Asian countries especially in india was a success story (EJUP, PACEY, 1965).

Having discussed different types of pumps that exists in the past, their major problems are as follows:

1. Low efficiency of the discharge rate.

2. The poor quality of materials used for the construction.

3. Poor installation of the pumps.

Therefore, the project is intended to design a hand operated water pump that will have the following properties:

a. High efficiency
b. High discharge rate
c. Use of locally available materials
d. Improve quality of the pump over the previous one.

CHAPTER THREE

3.0 MATERIAL AND METHOD

3.1 INTRODUCTION.

This chapter tries to link the objective of the study listed in section 1.2 in chapter one to the source of material, calculations, fabrication and testing of the water pump.

3. 2 STATIC WATER LEVEL

The aim and objective of the design of hand water pump is to bring water from the underground level to the surface for domestic uses. Therefore, the design of the pump will depend on the depth of water to the surface for use? This depth is refered to as static water level and it is influenced by factors such as,.

i. Regularity of rain-fall

ii. Coastal nature of the land-mass

iii. Duration of dry and wet seasons

iv. Topological nature of the environment

v. Underground drainage system

The static water levels are classified into shallow static water level with a depth of 0 - 20m medium static water level with depth of 20m – 60m, and deep static water level with depth of 60m, and above (Eyangan, 1961). These classification determine the type of hand water pump to be designed and fabricated. Since the static water level in the whole of Niger State is between 30m to 35 or medium Static water level, the project was based on this data. The hand water pump can be adapted in any part of the state, while other states with similar static water level can also use the pump systems.

3. 3. DESIGN CONSIDERATION

After taking a good survey of the functional manual pumps operating across the country, it is more than obvious that a lot of work still needs to be done in the area of the followings;

(a) Local fabrication of a simple model that would not be beyond. the purchasing power of the local people since the high cost of these devices are attributable to the following:

i. Importation of raw materials in these times of economic recession where scarce foreign exchange should be channelled towards importing only those item for which no close substitute could be found locally.

ii. Complex or sophisticated fabrication technology employed during the construction requires heavy machines for machining, another costly effects which contributes heavily to the cost of production and hence the price of the output product.

(b) Sourcing of raw materials locally i.e a 90% made in Nigeria manually powered pump and at the sametime gearing effort towards minimizing the maintenance problem (e.g corrossion) associated with local and cheap materials (mild steel for example).

(c) Energy Input: The lever system of any simple machine has more machanical advantage than ordinary hand. This fact is employed to develop hand operated pump so that little Human energy/effort will be augmented by the lever system.

(d) Ruggedness of design as a consequence of high level of usage.

3. 4. MATERIAL SELECTION FOR WATER LIFTING.

This is a complex technical exercise but an insight into evaluating the material specification for the different component parts are hereby presented. Four main criteria that goes into the selection of the materials for pump devices are;

i. Strength of stressed components needed to function over a long period of time without failure due to over loading or fatigue in situations involving cyclic stress.

ii. Corrosion Resistance: This is very important to the durability of parts operating in moist environment or water. This property is also essential since the water pumped out should be pure, portable and therefore free from contermination by rust.

iii. Resistance to wear and abrassive machine parts that slide or rub over one and another wear with time, thus reducing service life drastically. Wear is considerable in components having contact with flowing water as a result of water containing suspended particulates that are abrassive in nature. The pitting (wear) takes place as a result of the grinding of particulates against the moving machine components.

iv. Cost: The cost effectiveness of any material to be selected is also a crucial factor never to be neglected. Though nature was not been kind enough to furnish us with materials that meet all the above-mentioned factors for consideration. The life of a pump, it must be noted, depends on the resistance of its materials to the above criteria but the under-listed factors contribute significantly to a longer service life;

i. Neutral water at low temperature
ii. Absence of suspended abrassive particles in water.
iii. Centinous operation at or near maximum efficiency.

3. 5 BASIC FEATURES OF HAND PUMP

The pump consist of pump head, water tank , the connecting rod, the piston assembly, the cylinder, the valves (foot and piston valves), synthetic rubber, handle, and hand support.

3. 5.1 PUMP HEAD

The pump head is provided with a centre hole of 40mm diameter, on both bottom and top flange. The pump head comprises of the handle assembly (i.e the joint, quarter joint, connecting rod that is to transmit motion and energy from user to the pump). The stroke length of 150mm is provided in the handle. Handle works on the principle of moment. The machanical advantage of the handle system is;

$$n = \frac{\text{load}}{\text{effort}} \quad \text{-- 3.50}$$

3. 5.2 CONNECTING ROD

The main operating link between the handle and the plunger machanism is the connecting rod. A good quality steel rod was used satisfactorily as a connecting rod. It is constrained to move in a straight line and subjected to tensile load from the weight of water column above the piston. Dis-connection of connecting rod will therefore not provide any movement to the plunger or piston assembly inside the cylinder. The chosen rod has diameter of 12mm.

3. 5.3. RISER PIPE

The operation of the handle result in movement of the piston up and down thereby displacing the water upward in the riser pipe, which end in the water tank. The water then comes out through the sprout. Riser pipe support the cylinder in the well. Also the connecting rod passes through it; thus preventing it from warping. It was made from galvanized steel with a total length of 18m for shallow wells and 35m for deep wells.

3. 5.4 FOOT VALVE

Foot valves or non-return valves allows water to enter into the cylinder and prevents the water from returning into the well. This explain why it is called one-way valves or non-return valves. When the piston is in the upward stroke the valve opens to allow in water into the created space and close during the down ward strokes. It helps to maintain the pump in its primed conditon.

3. 5.5 PISTON VALVE

The piston valve is otherwise called the discharge valve. The valve is closed when the piston is ascending in the cylinder and opens during the descending of piston to allow water to rush into the riser-pipe. The piston valve used is the flapper type with the flap made of the synthetic rubber. It has most of the descernable characteristics of natural rubber and is much more resistant to the deteriorating effect of water on rubber. It is covered with disc brass.

3. 5.6 SEAL

The seal performs the same function as the ring in engine cylinder. The seal around the piston fills perfectly the gap between the disc and cylinder bore. It helps in making sure that largely incompressible water find its way out through four holes (bored through the seal) during the down-ward movement of the piston; also, it prevents water from escaping between the piston and the cylinder.

3. 5.7 PUMP CYLINDER

This is the working barrel of the pump. It is the main body where the pressure is developed. The larger the diameter the shorter the stroke which is typically 150mm to 300mm for hand pumps. With provision made for piston and foot valve assembles. The longer the stroke length the smaller the cylinder bore. Also the weight of the water to be lifted increases with cylinder bore. The cylinder in this study was made of the galvanised pipe of 63mm diameter.

3.6 DESIGN STATIC HEAD

3. 6.1 SUCTION LIFT

Suction lift is the sum of static suction lift, the suction friction head and entrance loss in the suction pipe. Note that the suction friction head includes the friction in the pipe and all fittings in the suction line.

3. 6.2 SUCTION HEAD

Though a suction lift is a negative suction head, and suction head chosen was about 35m for design, the usual practice is to use the term lift for a nagative suction head. When the pump takes it's suction from an open tank having the liquid surface exposed to atmospheric pressure.

3. 6.3 DISCHARGE HEAD

It is the sum of the static discharge head, the discharge friction head, and the discharge velocity head.

3. 6.4 TOTAL HEAD AND EQUATION FOR SUCTION LIFT

It is the sum of suction lift and the discharge head. Where there is a suction head, the total head on the pump is the difference between the discharge and suction head.

Equation for suction lift of the pump can be theoretically computed by;

$$SL = B - PV, - \frac{Vip}{2g} \quad \text{--- 3.6.4.1}$$

Where

B = Distance of pressure of the liquid

Pv = Vapour pressure of liquid

SL = Suction Lift

Vip = velocity at intake of pump

CHAPTER FOUR

4.0 DESIGN CALCULATION AND ANALYSIS

This is a low speed pump with a high **degree** of efficiency. It is meant to serve the Northern part of the country especially those regions that has been marked Guinea-worm infested area. However Niger State was taken as the focal state.

In Niger State, the static water level of some local government areas are as follows.

TABLE 1

No.	Local Government Areas	Static Water Level
1.	Lavun	33.4m
2.	Agaie	30.0m
3.	Mariga	34.7m
4.	Shiroro	35.0m
5.	Lapai	30.6m
6.	Rafi	32.7m
7.	Suleja	30.0m
8.	Magama	35.0m

(Niger State water board 1992).

Based on the figures above the design Head of 35m was chosen because this would conveniently serve villages or communities in Niger State as a whole.

As earlier stated this pump is hand operated. From ergonomic point of view an average Human being can apply an effort of 15 kg which is equivalent to 150N (Rogar, 1982). This makes it possible for just one man to supply the whole community of about 50 people.

In line with effortless operation, the maximum speed was taken to be 60strokes per minute, but recommended design speed is 30 strokes per minute. This will improve the mean service time of the pump.

4.1 PUMP PARAMETER DESIGN.

The choice of the dimensions of the pump parameters was such that every part contributed to the main objective of the design. The design of the pump cylinder diameter and stroke length, delivery pipe and pumping area of the piston has been discussed before.

4.1.1 PUMP CYLINDER DIAMETER AND STROKE LENGTH.

In selecting the pump cylinder diameter, cost and convenience of operation are the major considerations. The diameter of the cylinder was linked to the effort applied because the piston will have the same diameter. This means more water would be pumped using large pistons, therefore, more effort will be applied. Force needed to pump the water may be derived from pressure equation below.

$F = P \times A$ ------- 4.2

$F = \rho gh \times \frac{\pi}{4} D^2c$ ---- 4.2

Where

F = Force

P = Pressure

A = Area

ρ = density

g = acceleration due to gravity

Dc = pump cylinder diameter

π = 3.143

h = Static head

Using a diameter of 0.063m, force needed is 780N. According to ergonomic point of view, the maximum load that man should lift must not exceed 200N. The force above is far more than 200N, therefore, a simple machine was applied with a machanical advantage of ratio 1:5. A lever is best suited for the problem.

With the application of the lever, the force was divided by five given us 136N, the effort required then is 136N, which is well below the ergonomic maximum (200N). Therefore 0.063m was taken.

However, when a cylinder diameter of 0.063 and 0.076m was considered with the same mechanical advantage ratio, the effort needed will be 190N and 250N, respectively. These two are quite close and more than the maximum of 200N for the smaller diameter. The smaller diameter pipe is cheaper and it is more suitable for pumping deep wells using the same effort. Lastly the largest diameter of bore-hole is about 160mm. Anything more will be too expensive to drill. The maximum stroke length was chosen to be 210mm. This was due to the fact that sharter strokes gave rise to short angle of travel of the lever.

4. 1.2 DELIVERY PIPE DIAMETER

Just as it is common to other engineering designs, compromise had to be made. Here, a choice had to be made between efficiency and cost. Head losses are reduced for large bore-hole pipes, thereby increasing their efficiency but they cost more than small bore-hole pipes. Since the cylinder was 0.063m in diameter, delivery pipe was taken to be 38.2mm diameter. Hence, effective area of delivery.

$ad = Ad - Acr$ ----- 4.3

Where

Ad = Area of delivery pipe

Acr = Area of connecting rod

Therefore, $ad = \frac{\pi}{4}(d^2d - d^2cr)$ - - - 4.4

$$ad = \frac{\pi}{4}(38.2^2 - 1.2^2) \times 10\text{-}4$$

$$ad = 7.15 \times 10^{-4}\ m^2$$

Effective diameter of delivery pipe

$$ad = \sqrt{\frac{4Ad}{\pi}}$$

$$ad = 3.16 \times 10^{-2} m$$

The pump cylinder is submerged in the water, this eliminates the need for a suction pipe. Throughout this analysis the effect due to suction was neglected.

4. 1.3 PISTON PARAMETER

Pumping area of piston

$$A = Acr \text{ - - - } 4\text{-}6$$

$$A = \frac{\pi}{4}(D^2c - d^2cr) \text{ - - - } 4.7$$

$$A = \frac{\pi}{4}[(0.063)^2 - (0.012)^2]$$

Area = $26.483 X 10^{-4}$ m^2

Effective piston diameter=D

$$D = \sqrt{\frac{4\pi}{\pi}}$$

$D = 4.687 \times 10^{-2}$ m

4.2 DETERMINATION OF HEAD AND HEAD LOSS

Head as earlier defined in chapter 3 is the pressure exerted by column of water on a horizontal surface at the bottom of the pipe. The pump head or cylinder head is given by the equation below.

$$Hd = Hatm + Hi + Hdi + Hfd \text{ - - - - - } 4\text{-}9$$

Where

Hd = Pump head - delivery

Hatm= Atmospheric pressure

Hi = Delivery lift

Hdi = Delivery acceleration

Hfd = Delivery pipe friction

Before proceeding, the phase velocity had to be calculated.

Since N = 60 strokes per minute that is one pumping stroke per second and the stroke length of pump cylinder is 0.280m, then, velocity V = 0.30 m/s(i.e Standard BY Wagner 1959).

Then phase velocity $W = \frac{2\pi N}{60}$ - - - - 4.10

$$W = \frac{2\pi N \text{ rad/s}}{3600}$$

By Continuity equation

$VA = ad.Vd$

$Vd = \frac{VA}{ad}$ - - - - - 4.12

Where;

VA = Velocity of handle

ad = Area of delivery pipe

Vd = Average delivery velocity

$$Vd = \frac{(22.5\ X10\ -4)m^2\ x\ 0.31m/s}{3.16\ x\ 10^{-2}m} \quad \text{— — — — — —} \quad 4.13$$

$= 0.37\ m/s$

$$Hdi = \frac{fid.\ V^2d}{2gad} \quad \text{— — —} 4.14$$

where

fld = force loss of delivery

g = Acceleration due to gravity

Using water wave length (Wagner, 1959);
Then,

$$Hfd = \frac{IALdW^2\ \ R\ COSWt}{gad} \quad \text{— — — —} 4.15$$

Where

Hfd = Delivery pipe friction
IA = Entrance loss
W = Angular velocity
t = Tangent

Ld = Length of delivery pipe

therefore, equation 4.9 becomes;

$$Hd = Hatm + Hi + \frac{FidV^2d}{2\ gad} + \frac{IAldw^2Rcoswt}{gad}$$

$$= Hatm + Hi + \frac{1}{gad}\left(\frac{FidV^2d}{2} + IAldw^2Rcoswt\right) - 4.16$$

but

$$Vd = \frac{A}{ad}\ Wrsinwt$$

As such, equation 4.16 can be written as;

$$Hd = Hatm + Hi + Sin^2wt + Ecoswt \text{— — — — —} 4.17$$

for a complete cycle

$$\int_0^{2\pi} Ecoswt = 0 \qquad 4.18$$

Thus, delivery pipe friction effect is negligible for a cycle?

therefore,

$$Hd = Hatm + Hi + \frac{FidV^2d}{2gad} \text{— — —} 4.19$$

where v^2 is the mean square value of the delivery velocity and where,

$$\frac{fid}{ad} = Ek,$$

Ek = Summation of coefficient of loss due to drag.

and

$$Hd = Hatm + Hi + \frac{V^2dEk}{2g} \quad --- 4.21$$

From Sinusidal wave formation

Vd = A pvd- - - 4.22

where,

A = Area of delivery pipe

Pvd = Average delivery velocity of pipe

$$Pvd = \frac{Vd}{A} = \frac{0.37}{0.058} = 6.38m/s$$

But mean square velocity of the delivery pipe (MSVD) = $[vd]^2$ = A pvd

ie. $[vd]^2 = A\ pvd = 0.058 \times 6.38 = MSVd = \sqrt{0.058 \times 6.38} = 0.608m/s$

4.2.1. DETERMINATION OF LOSS

(1) Form loss: There are loss associated with entrance, coupling and elbow losses.

i. Coupling loss: Drop pipes are manufactured in length of 3m; therefore, for the total length of 35m, there will be 12 coupling. From table of coefficient of loss by friction kc = 0.06 (Aderibigbe, Bayo, Ladipo, 1987). An additional 12 couplings will be needed for the connecting rod thus, a total of 24 couplings; hence, Ekc = 24 x 0.063 = 1.44.

ii. Elbow Loss: The water had to turn twice in the delivery system, hence, the coefficient of Loss for elbow is Ke = 0.8 (Aderibigbe, Bayo, Ladipo, 1987).

Eke = 0.8x2 = 1.6

iii. Entrance loss: Due to the reduction of area from the cylinder to the delivery pipe, losses are generated with losses coefficient K given by (Aderibigbe, Ladipol Bayo, 1987);

$$K = \left(\frac{L}{cc} - 1\right)^2 \quad --- 4.23$$

cc = Coefficient of contraction = 0.52

$$K = (1/0.52 - 1)^2 = 0.852$$

The summation of all this coefficient of loss KT due to form losses and drag is;

$$KT = EKC + EKe + K \quad --- 4.24$$

2. Skin friction loss: Due to the viscosity of water, there are losses due to flow at the boundaries; that is, the walls of the delivery pipe. Thus, Reynoid number Re will be the flow parameter used in evaluation.

Re = KTV ad/U– – – – 4.25

Where,

Re = Coefficient of turbulent and lamina frictional flow

KT = Summation of form losses

V = Mean square velocity

ad = Area of delivery pipe

U = Coefficient of Kinematic Viscosity

but

Kinematic viscosity VK = U/p– – -4.26

Where, P = Coefficient of dynamic viscosity

Therefore,

for lamina and turbulent flow Re $\leqq$ 1990

since ad is known; then,

Friction Factor ff = U/KTV = ad/Re

for the real design, the friction factor ff is given by;

ff = ad/Re – – -4.27

Where,

Re = evad/u =(3.16x10-2 x 3.892 x 0.608)/0.8x10-4 = 934.7

From the value of Re, the flow is turbulent. Going back to equation 4.27, substitute for Re, i.e

ff = ad/Re = 3.16×10^{-2}/934.7 = 3.4x10-5

Coefficient of friction = KT + CSL = 3.892 + 35 = 38.892

Where, CSL = Chosen suction lift value for the pump

Recalling equation 4.21

Hd = Hatm + Hi + $(V^2dEK)/2g$

Hd = 10.15 + 35 + (0.39x38.892)/2x9.81 = 45.923m

Gauge pressure head, hdg = Hd - csl = 45.923 - 35
=10.923m

Therefore, assumed loss head delivery friction (Hdf) = 0.932m

4.3 PUMP CAPACITY

This is the discharge rate of the pump per stroke/sec or litre/minute pumping rate per minute will be

$Q = Nq$. Assumed stroke (N) = 30.

q = discharge rate

Athough, this unit is designed for a maximum speed of 60 strokes per minute.

Therefore 30 strokes per minute is recommended for longer service life.

At this speed, discharge is

$Q = 0.39 \times 10^{-3}\ m^3/s \times 30$

$= 0.0117 m^3/s$

= 11.7 litre/minute.

4.4 POWER REQUIREMENTS AND THE EFFICIENCIES

The power required to pump the water and the efficiencies of the pumping, e.g, Hydraulic, volumetric and mechanical efficiency are as follows.

4.41 POWER REQUIREMENTS

Dynamic power is the power to keep all the moving parts in motion from the connecting rod.

$M = \rho \times V$ - - - 4.29

where, M = Mass, ρ = Density and V = Volume

For the connecting rod;

the actual mass M'cR = McR - up thrust

:. $M'cR = Pst \times Vst - pw \times Vw$ - - - - 4.30

where

M' CR = actual mass

MCR = apparent mass

VW = Volume of Water

Vst = Volume of Static Water

Pst = density at static level

$\rho st = 85\ 00 kg/m^3$, $\rho w = 1000 kg/m^3$

M'CR = 17.65kg

for the piston massp = 0.5 kg

Total Mass MT = MCR + MP

= 17.65 + 0.5 = 18.15 kg

Therefore, Dynamic power (PMP) = F x velocity of piston

PMP = (M'CR xg) Vp 4,30

= (17.65 x 9.81) x 0.94 x 0.21 = 35.78w

Horse power chosen = 0.21 hp

Theoretical pumping power (pth) = PwxgxQthxHd
Where;
Pw= Density of water
g = gravity
Qth = Discharge
Hd = Pump head delivery
But from equation of discharge rate;
Q=0.0117m^3/s or 11.7litre/min. , and Pw = 1000kg/m^3
Pth = 1000 x 9.81 x 11.7 x 45.923 = 53.77w

4.4.2 EFFICIENCY OF THE SYSTEM

(I) Volumetric efficiency V.E: This is the percentage of the swept volume that is actually pumped per stroke; allowing for 15% leakage in the theoretical discharge, volumetric efficiency (V.E) is given by;

V.E =((Qth - S)x 100)/Qth

Where S = Leakage quantity

hence,

S = (Qth x 15%)/100 = (11.7 x 15%)/100 = 1.76 litre/min.

thus,

$$V.E. = \frac{11.7 - 1.76}{11.7} \times 100\% = 85\%$$

(ii) HYDRAULIC EFFICIENCY

$$H.E. = \frac{Hd \times 100}{Hd + Hl}$$

Where

Hl = Head losses

Hd = Pump head delivery

thus,

$$H.E. = \frac{45.923 \times 100\%}{45.923 + 3.892} = 92.2\%$$

(III) MECHANICAL EFFICIENCY

$$M.E = \frac{Pt}{Pa} \times 100$$

Pt = Power Torque or ideal torque

Pa = Power of moving components

Pl = Power loss

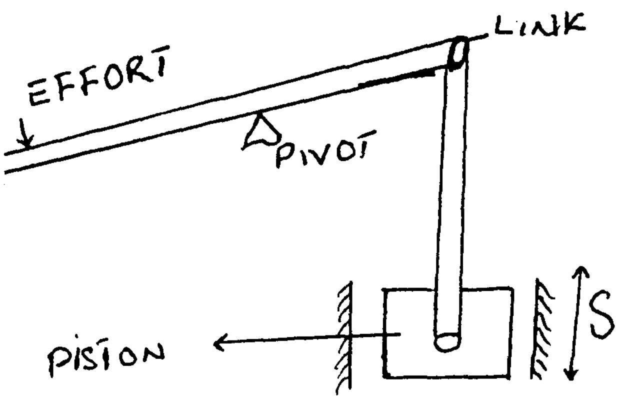
Pa = Pt + pl = 164.4w

M. E = 79.4%

4.4: DESIGN LOAD

During the operation of the pump water would be lifted to the surface that is over 35m. The water in the pipe constitute a load on the members components especially the piston and connecting rod. When the pumping is stopped, the weight of the water from 35m below head would be acting because leakage is almost zero.

This load will be a static load acting on all the member components.



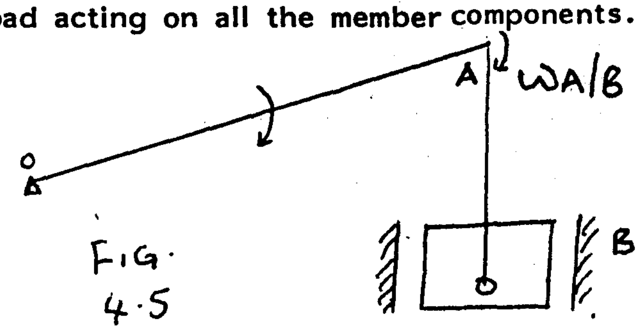
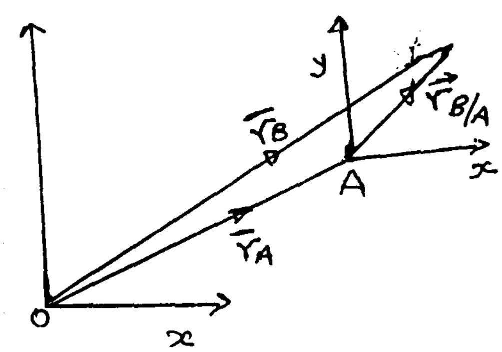


FIG. 4.5



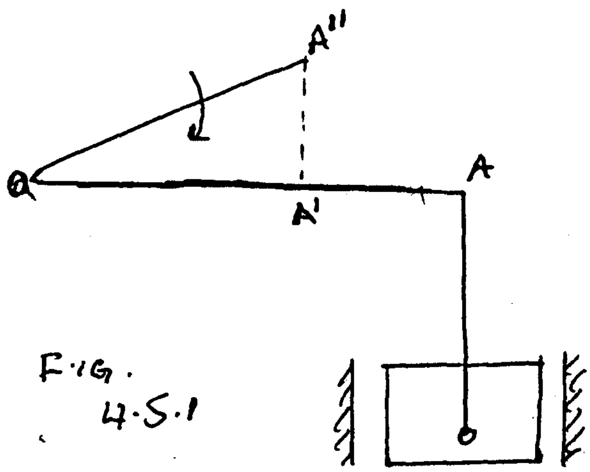
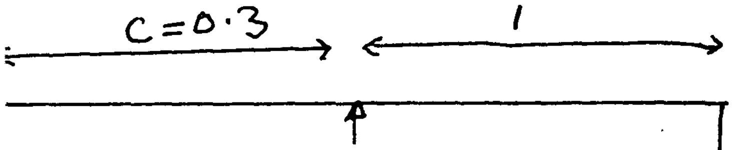


FIG. 4.5.1



Once the pumping is resumed again force could be needed for inertia; that is, force to over come the reluctance of the water column from moving. As the movement of the water column starts, the required force would only be to keep the load moving.

This load is the design load and it is used in designing all the other structural members like connecting rod, Axle, the cotter pin e.t.c. Before going further in the design, it is necessary to know the acceleration of the system.

4.4.1 VELOCITY AND ACCELERATION OF THE SYSTEM

Using vector methods, the kinetic diagram of the system is shown in figure 4.5 and thus is a slider crank mechanism.

The design uses 60 strokes per minute which is 1 stroke per second. The angular displacement per pumping stroke = 2 x 60 = 120 $= \frac{2\pi}{3}$ rad

$\therefore$ Average angular velocity WA $= \frac{2\pi}{3}$ rad/s = 2.05 rad/s

considering figure 4.5 the motion of member OA is observed. The motion is annular through A',A,A" .

For a full pumping circle, the total linear displacement S of A relative to B is 4.5.S = 0.27 m

S = 0.135m

Angular speed of A relative to B is given by

$$OA/B = \frac{S}{rA/B}$$

WA/B $= \dot{O}A/B \approx$ 0.135/35 = 0.0038 rad/s, for the velocity consideration, we are going to consider motion at point A and A' because A' and A" will be the same except for direction.

Motion at A' relative to O figure 4.5 position vectors,

$\overrightarrow{rB} = \overrightarrow{rA} + \overrightarrow{rB/A}$ – – – – – 4.41

$\overrightarrow{rA} = 0.150i + 0.140j$ – – – – 4.42

and

$rB/A = 37$ – – – – 4.43

Differentiating equation 4.41 i.e

$\dot{r}B = \dot{r}A + \dot{r}B/A$ – – – – – – 4.44

$\dot{r}B = WA \wedge rA + WA/A \wedge rB/A$

$\dot{r}B = WAK \wedge (0.150i + 0.140j) + (0.003k) \wedge - 37i$

$= - 0.375i + 0.294j - 0.0038$

$= - 0.375i + 0.294j$

$rB_1 = \sqrt{(0.294j)^2 + (0.375i)^2} = 0.47m/s$

Motion at A relative 0 from figure 4.5 position vector is;

$\overrightarrow{rB} = \overrightarrow{rA} + \overrightarrow{rB/A}$ – – – – – – 4.45

Where

$\overrightarrow{rA} = 0.3i$ and $\overrightarrow{rB/A} = - 0.37j$

Differentiating equation 4.45

$\dot{r}B = \dot{r}A + \dot{r}B/A$

$\dot{r}B_2 = WA \wedge rA + WA/B \wedge rB/A$ – – – – – 4.46

$= - 0.24j \wedge . 0.3i + (-0.0038k) - 37j$

$= - 0.477i - 0.37j$

$\dot{r}B_2 = \sqrt{(0.477i)^2 + (0.37j)^2} = 0.603m/s$

Therefore,

Average velocity $= rB = (rB1 + rB2)/2$ – – – – – – 4.47

$$= \frac{0.47 + 0.603}{2} = 0.54m/s$$

From the acceleration expression, we differentiate equation 4.44, i.e

$\dot{r}B = \dot{r}A + \dot{r}B/A$

$\ddot{r}B = WA \wedge rA + WA/B \wedge rB/A$ – – – – – – 4.48

$\ddot{r}B/0 = dA \wedge rB + WA \wedge (WA \wedge rB) + dB/A \wedge rB/A + WB/A \wedge (WB/A \wedge rB/A)$ – – – – – 4.49

$rB/0 = \alpha A.rA(-\hat{k}j) + w^2.ArA(-\hat{k}(-\hat{k}j) + \alpha B/\hat{A} rB/A.$
$(-\hat{K}-j) + w^2.B/A.\ rB/A\ (-\hat{k}(-k-j)$ 4.50

$AB/o = E(\ ArAj - w^2 ArAj) - E\ (B/A\ .\ rB/Ai + W^2.B/A.\ rB/Ai)$

E = Summation

The motion at A is assumed to be simple harmonic

WA = 2.05 rad/s, WA0 = 0 rad/s, t = 0.3 sec

WA (peak value) = 3.58 rad/s, peak wave = 0.603w

$$A = \frac{WA(\text{Peak value})}{\text{time}} = \frac{3.58}{0.3} = 11.93 \text{ rad/s}$$

similarly for WB/A i.e

WB/A (peak) = 0.0057 rad/s at time t = 0.14 sec and B/A = 0.038 rad/s.

therefore,

$AB/0 = (-3.58j - 3.46j) + (6.89 \times 10\text{-}4i - 1.075i)$

$AB/0 = \sqrt{(-3.58 - 3.46)j)^2 + (6.89 \times 10\text{-}4 - 1.075)i)^2} = 7.12 \text{m/s}$

4.4.2 DESIGN LOAD

Mass of piston (Mp) = 0.5kg

Load on piston Lp = wg (hd + hdf) A

Where,

MP = Mass of piston

Lp = Load on piston

Pw = Density of water

g = gravity

hd = Pump head delivery

hdf = Delivery pipe friction

A = Area of piston

Lp = $1000 \times 9.81\ (45.923+0.923) \times 26.483 \times 10\text{-}4 = 121.7010\text{N}$

Equivalent inertia on pistion (Mi) = $Lp/g = \frac{(12170.05)\text{kg}}{1000 \times 9.81} = 1.24\text{kg}$

Tension T. required to lift water is,

T = (mi + m) AB/0 + (mg + lp)

= (1.24 + 0.5) 7.12 + (4.905 + 121.701) = 126.62N

CONNECTING ROD

Using mild steel 46 with yield strength YS = 250m/m^2 and safety factor of 1.7 (Wagner, 1960).

Design strength (D.S.) = Y.s/s.f = 250/1.7 D.S. = 147.1 MN/M^2

Diameter of rod dcr = 4 x T/ Ds = 3.79×10^{-3} m = 40mm

In the construction, connecting rod of 38 mm diameter was used because, it is easily available and overcome notch effort caused during threading.

4.6 COTTER JOINT DESIGN

This is found at the point of connecting the piston and the connecting rod. It is not a rigid joint, allowance for the connecting rod angular motion which was the consideration for making it a non-rigid joint. Grade 46 mild steel was used. Therefore $Ys = 250MN/M^2$ and safety factor F of 1.7 as in connecting rod. Design stress is also the same, that is, $200MN/M^2$ and shear stress is $\frac{1}{2}$ SD = $100MN/m^2$. The load P = 990N as average ergonomic factor of the double shear of pin.

(1) Double Shear of Pin

$$D = \sqrt{\frac{2P}{\pi t}} \text{ ---------------4.59}$$

$$= 3.79 \times 10^{-3} \text{ m}$$

$$= 4.\text{mm}$$

Diameter of Pin = 4mm

(ii) Tension on connecting rod

$$D = \frac{4P}{Td\pi} \text{ ---------------4.60}$$

Diameter of connection rod = 4mm

(iii) Shear in piston valves

$$tplp = \frac{P}{4t} \text{ -------------- 4.61}$$

$$= 4.25 \times 10 - 6$$

If tp = lp, then
tp = thickness of piston, lp = length of piston
tp = lp = 0.00195m ------------ 4.62

= 2mm

(iv) Shear of the yoke

$$tyly = \frac{P}{4t}$$

Assuming ty = ly then
ty = ly = 2mm
ty = thickness of yoke

(v) Tension failure in yoke net area bp, by =p + ad/2tydq

Where,

bp	=	Tension in yoke net area (upper stroke)
by	=	Tension in yoke net area (lower stroke)
ad	=	Area of delivery pipe
p	=	Power (preal)
dq	=	maximum deflection of yoke pin

bp = P/2t ydq + ad = 5.69 x 10^{-3} m = 6mm

Therefore, the design parameters for the joints are as follows;

Diameter of pin d = 4mm

Diameter of connecting rod = 4mm

ty = ly = tp = lp = 2mm

by = bp = 6mm

4.7 LEVER DESIGN

A square cross - section lever with the following dimension was used; Length, breadth and thickness being 29.4mm x 234mm x 4mm

Moment of area (Lv) = 1/12 (a4-(a-2t)) 4- - -4.71 (Allen, Gibson, 1961)

= 1/12 (4(29.4) - (29.4-2)4) 9 = 3.2 x 10 - 4 M^3

Assume the lever is a fixed cantilever with maximum load and average effort of 899N and 187.5N acting at the ends. When the system is in equilibrum,

Efy = 0 = -899 - 185.5+R = 0

Therefore, reaction at the axle R= 1086.5N for an allowable bending stress of 146 MN/M^2 ($146N/MM^2$). Maximum stress which occurs at the axle is;

dmax = Lc/2 = 899 x 0.2/2 = 9.59 x $10^3 N/M^3$

Where: L = load, C = fixed cantilever maximum.

This is quite safe, because it is not up to the design of steel ($146MN/M^2$ with S.F = 1.7. The deflection of the load is, Y = Lc^2 (C + 1)/3EI

Where,

Y = Maximum deflection of the load
L = Load
C = Fixed cantilever maximum
E = Young modulous
i = inertia moment.

Thus,

Y = 3.05 X 10-7m = 0.0003mm

The maximum deflection between pivot and effort is;

$$Ymax = \frac{LCT^2}{146.5Ei} \text{ at } x = 0.61$$

$$= 2.83 \times 10-7m = 0.003mm$$

The deflection at each end of the lever is small, this makes the cross section chosen very suitable. It could withstand the stress and would not deflect significantly.

4.8 AXLE DESIGN

The lever reciprocates about a pivot which is designed with due regard to bending with stresses. The axle length is 29×10^{-3}m which can carry maximum load of 1086.5N. And It is assumed to be pinned at both ends. Maximum bending moment;

$$Mmax = 1/8 \ L \ a = 4.2Nm$$

Where

La = Length of axle.

using the (A.S. ME 1967) code forcommercial shaft diameter d^3;

$$D^3 = 16/\Pi T \sqrt{(kb \ Mmax)^2}$$

Where

$T = 73.3MN/M^2$, kb = 3.0, due to wide fluctration

$$D^3 = 16/73.3\pi \sqrt{(3.0 \ Mmax)^2}$$

$$d = 7.23 \times 10-3 \ m$$

4.9 VALVE DESIGN

As earlier said, the design of valve was a compromise between a heavy valve (difficult to open but closes well) and light one is the opposite of the other.

4.9.1. FOOT VALVE

Since the worst condition for operation is to have the cylinder of length 0.28m under water, the weight of the valve is such that a column of water 0.28m should be lifted. Pressure in the cylinder; $Pc = h \times g \times p$

When

$h = 0.28m$, $g = 9.81\ m/s^2$, $pw = 1000kg/m^2$

$Pc = 27468\ N/m^2$

Weight of valve wc

P x As (Area of suction pipe)- - - - 4.76

$As = 7.167 \times 10^{-4} m^2$

$Wc = 1.96822\ N$

Mass of foot valve = 0.20kg

Where

Wg = mass of foot valve.

4.9.2 PISTON VALVE

During the down ward stroke, water is transfered from beneath the piston to the upper part and the pressure developed beneath must be such that it does not cause buckling of the pumping rod. A minimum diameter is therefore necessary for the piston part, (Hawkes, watl, 1984).

Moment of area $L = \pi r^4/4 = 6.807 \times 10^{-11} m$

r = radius

$K = 1/A = 3.2 \times 10^{-3} m$

K = Down ward stroke

Area of connecting rod d (12mm) = $9.82 \times 10^{-3} m^2$

$$\text{Ratio} \quad L/K = \frac{6.807 \times 10^{-11}}{3.2 \times 10^{-3}\ m} = 2.1 \times 10^{-8}$$

Therefore Euler's formular is hereby employed, load is

$Pcr = 0.891N$

$$\text{Pressure } Pr = \frac{pcr}{Ac} \text{ ------ } 4.80$$

$Pr = 401 N/M^2$

This pressure Pr must be converted to a velocity head so as not to buckle the connecting rod then,

$$Pr = \frac{Pv\text{-}^{2}\ cr}{2} \quad - - - - - \; 4.81$$

$$V\text{-}2cr = \frac{2Pr}{\rho} \quad - - - - \; 4.82$$

$Vcr = 0.984 m/s$

Using down stroke (idle) speed of 0.50m/s

Then from continuity equation

$$D = AV \quad - - - - \; 4.83$$

$$\frac{D^2}{Dv^2} = \frac{Vcr}{V} \quad - - - \; 4.84$$

$$Dv = \frac{Dv^2}{Vcr} \quad - - - - \; 4.85$$

Where

D = continuity of the flow of liquid

A = Area of pipe

V = Velocity

DV = Diameter of piston valve port

Vcr = Velocity of pump cylinder

DV = 38.6mm

Hence the piston valve port would have a diameter of 40mm.

4.9.3 FABRICATION, ASSEMBLY AND MACHINE OPERATION

This was done according to the procedure established during the design stage. Thus fabrication started with the first components itemised serially in the diagram included in appendix 4. The assembly was also done in the order of the design.

Since the pump is a machine or device that is to raise a liquid that is relatively compressible fluid to high level surface; the pump must be primed before it starts working. This was done by allowing the cylinder to be completely immersed in a reservoir, while pumping [illegible] of the handle and pump rod for few strokes. This above the inlet valve. The low pressure area draws water in through the inlet valves, as the piston moves upward to the top dead centre (T.D.C) of the pump cylinder.

At the top dead centre, the inlet valve closes to prevent water from escaping back into the suction riser pipe. During the down ward movement of the piston, the water beneath the piston pass through the synthetic rubber disc into the area above the piston. At this point the piston is at bottom dead centre (B.D.C).

Most of the water above the piston rises up through the riser pipe into water tank and is discharged out through the sprout (Ejup, PACEY, 1965).

5.0 PERFORMANCE TEST

A performance test of the prototype pump fabricated was carried out and the result is presented below.

5.1 PROCEDURE

The pump after fabrication was raised over a filled reservoir with water holding capacity of 150 Litre (0. 15m³). A 25 litre bucket was placed on a stool. The pump was mounted at about one metre above the reservoir. The pump was lifted such that the suction head was approximately 75cm. From the bottom of the reservoir.

The time intervals selected for the determination of the discharge of water through the sprout were 0,30 35, 40, 45, 50 and 60 seconds. The quantity of discharge at each time and depth of cylinder under water were recorded with constant displacement of 0.300.

After measuring the water dischargedin the bucket, it was returned into the reservoir so that a constant water level is maintained. The result is presented in the table below.

TABLE OF RESULTS

30 Secs.

DEPT	STROKE(M)	DISCHARGE(M^3)	AVERAGE DISCHARGE
100mm	0.300	0.3454	0.3481
150mm	0.300	0.3460	
200mm	0.300	0.3470	0.3481
250mm	0.300	0.3475	
300mm	0.300	0.3480	
350mm	0.300	0.3488	

35Secs.

100mm	0.300	0.4473	
150mm	0.300	0.4484	
200mm	0.300	0.4492	0.4493
250mm	0.300	0.4499	
300mm	0.300	0.4501	
	0.300	0.4509	

40Secs.

DEPT.	STROKE	DISCHARGE(M³)	AVERAGE DISCHARGE
100mm	0.300	0.5873	
150mm	0.300	0.5881	
200mm	0.300	0.5894	0.5827
250mm	0.300	0.5912	
300mm	0.300	0.5920	
350mm	0.300	0.5929	

45 Secs.

100mm	0.300	0.6113	
150mm	0.300	0.6121	0.6131
200mm	0.300	0.6129	
250mm	0.300	0.6134	
300mm	0.300	0.6142	
350mm	0.300	0.6153	

50Secs.

100mm	0.300	0.7792	
150mm	0.300	0.7801	
200mm	0.300	0.7821	
250mm	0.300	0.7830	0.7828
300mm	0.300	0.7842	
350mm	0.300	0.7850	

60Secs.

100mm	0.300	0.9903	
150mm	0.300	0.9911	
200mm	0.300	0.9922	0.9928
250mm	0.300	0.9934	
300mm	0.300	0.9943	
350mm	0.300	0.9951	

Fig. 3

5. 1.2 DISCUSSION OF THE RESULTS.

The pump was operated by on average man of weight 59.3kg for six different time (i.e 30, 35, 40, 45, 50, and 60 Secs) The quantity of the discharges and number of the strokes were recorded against time. Table 5.1.2.

The result got in the test analysis compared favourably with the design calculation for the discharge rate of the pump.

The discharge rate of water at the time of design calculations was 11.7litre-minute where-as the amount of the water discharged as measured during the practical test was $0.0099m^3/S$ (9.9litre-minute). The result showed that the amount of water collected at each time interval increase with time in fig. 3.

5. 1.3 EFFICIENCY

To obtain the efficiency of the pump, the designed capacity was $0.00117m^3/S$ (11.7litre-minute). However during the test the discharge obtained was $0.0099m^3/S$ (9.9litre/mm).

Now,

The efficiency of the prototype pump, $\frac{\text{Effective capacity}}{\text{Theoretical Capacity}} \times \frac{100}{1}$

$$= \frac{0.009910}{0.00117} \times 100$$

$$= 90.12\%$$

$$= 90.\%$$

A higher efficiency then 90% was not obtained due to the leakage of the pump at cylinder cap.

It should be noted that the materials used for the fabrication were gathered from scraps. The real installation of the pump for the rural communities will be possible if some modifications are made and the construction is made to actual pump discharge rate as determined by the test, i.e 9.9litre-minute with an estimated efficiency of 90%.

5. 1.4 CONCLUSION

A hand pump was designed and fabricated using available materials and fabrication techniques.

The prototype fabricated was tested using a reservoir of about 150 litre. The results showed that using real materials instead of scrap and fabricating to the actual dimension, the installation at the rural level is feasible with some modification.

The pump discharge as determined from actual testing and evaluation was $0.0099m^3/S$ (9.9litre/minute) and the efficiency is determined to be 90%.

5. 1.5 RECOMMENDATION

From the findings of the study the following recommendation can be made.

(1) The brass valves may be replaced with plastic valves in view of the

a. Elasticity of material

b. Hardness of material

c. Durability

d. Cost effectiveness

e. Availability of plastic as compared to brass.

It is noted also that the brass used in construction was a scrap and at long run will wear and tear away. This implies that it is not going to be durable.

(2) The link between handle and the connecting rod, may be replaced with chain links so, as to reduce the effort from the user and enhance performance. It is envisaged that chain force will be transmitted from one link to the other effectively. The mild steel rod used is scrap and will later wear away, as such it should be replaced. When replaced at the long run, it could have significant effect on the discharge rate and enhance the performance of the hand operated water pump.

6.0 REFERENCE

ADERIBIGBE, BAYO, LADIPO (1987): The development of the Niger pump (made (Ho - $_z$) a hand operated deep suitable for the rural communities, proceedings of the annual conference. pg. 156 - 174.

ABDULLAI G.N. (1992): Water level recordiing manual Niger State water board (Niger State Printing Press). at Minna. Pg. 14.

ARUSH, R.E. (1981); Developing world wáter arosurver, world water educational development council. Pg. 64

ALLEN, GIBSON, SINGER (1961) Machine design (scharrom's outline series) By Mcgraw-hill. Pg. 128 - 149.

BAMIRO O.A (1987) Design and construction of hand water pump for rural water supply proceeding annual conference of N. S. T. ~~at~~ Ibadan, Pg. 9 - 12.

EJUP, PACEY A. (1965) Hand book of essential engineering information and data (Mcgraw-hill). Pg. 111 - 121.

EYANGAN, R. (1961) Shallow wells and hand dug wells (McGraw - hill) Pg. 4 - 10.

GANA .L.L. (1993): Kwara State UNICEF Hand book (Kwara State Government Printing Press) At Ilorin. Pg. 6 - 8.

JIMADA .Z. (1993) Kwara ADP hand book (Kwara State Government Printing Press). At Ilorin, Pg. 11 - 17

HAWKERS WATT. S.B. (1984) Engineering design process (Mcgraw - hill) Pg. 175 - 180.

MCJEUKIN E.G. (1987) Hand Pumps, Technical paper Series No. 10(W.H.O International reference centre for communities water supply). At India. Pg. 124 - 130.

MUHAMMED A, B, (1980) Agricultural Mechanization handbook M. xi No. 11 (Winter). At India. Pg. 7 - 10.

ROGAR, K, (1982) Applied fluid mechanics (Mcgraw - hill) Pg. 124 - 129.

STRAHLER, A, N, STRAHLER A, H, (1980) Geography and Man's enviroment (willey) Pg. 111 - 134.

TYLER G. (1980). Standard handbook for civil engineering (Mcgrow-hill)

WAGNER E.G. (1959) Village Technology hand book (Mcgraw-hill). At Egypt. Pg. 11 - 18.

APPENDIX 1

COST ANALYSIS

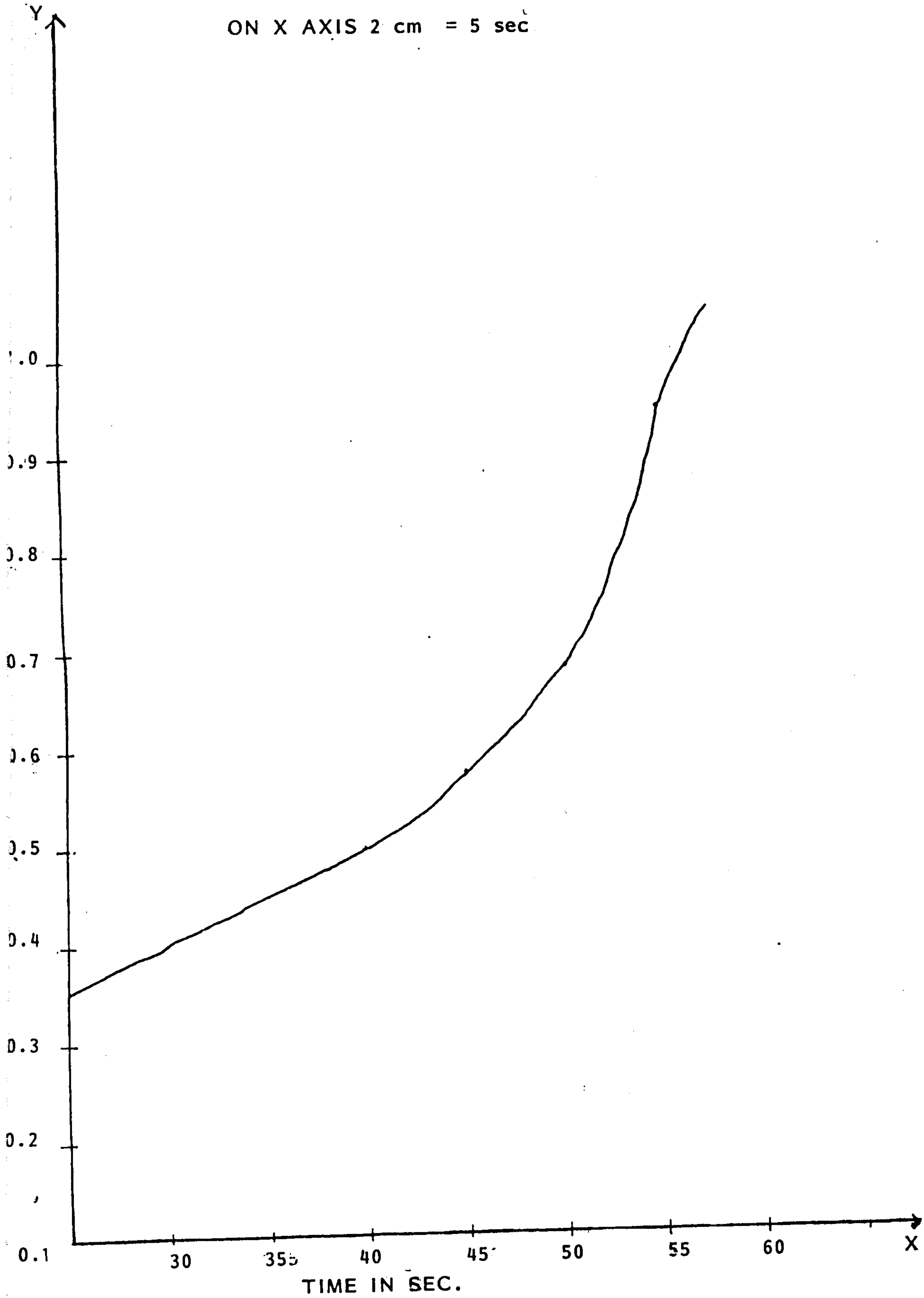
This is the statement of expenditure on each item used in the project tabular fomat.

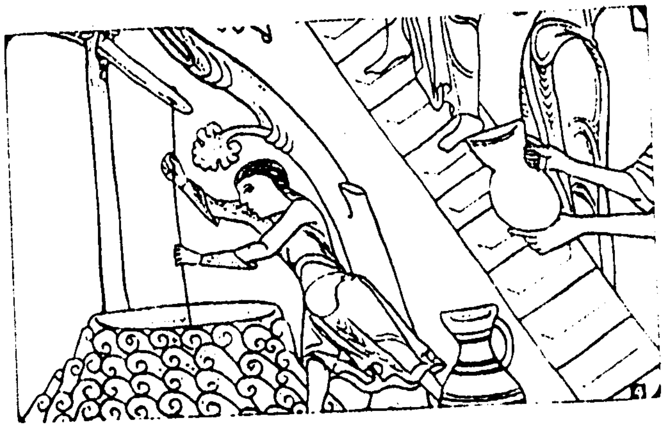
S/NO.	COMPONENT	MATERIAL	SPECIFICATION	QUANTITIES	UNIT PRICE(₦)	AMOUNT (₦)
1	Pump Cylinder	Galvanised Steel pipe	63mm x 280mm	1	2,300.00	2,300.00
2	Pump Rod	Galvanised Steel Rod	10mm x 0.7mm	2	150.00	300.00
3	Flap(outlet)	Synthentic Rubber	60mm x 6mm	1	200.00	200.00
4	Seal(inlet valve	Synthentic Rubber	48mm x 6mm	1	200.00	200.00
5	Riser pipe	Galvanised Steel pipe	60mm x 750mm	1	2,000.00	2,000.00
6	Handle	Mild steel rod	650mm x 50mm	1	500.00	500.00
7	Handle support	Mild steel plate	25mm x 1000mm	1	700.00	700.00
8	Sprout	Galvanised steel pipe	2mm x 35mm	1	250.00	250.00
9	Cylinder cap	Galvanised steel pipe	63mm x 40mm	2	250.00	250.00
10	Discharge valve	Brass	43mm x 26mm	1	800.00	500.00
11	Inlet valve	Brass	40mm x 20mm	1	800.00	500.00
12	Bolts/nut		m7	8	25.00	200.00
					Sub-total	7,950.00
13	Labour at 40% of cost of materials					3,180.00
14	Over head at 20% cost of materials					1,590.00
					Overall Total	₦ 12,720.00

GRAPH OF DISCHARGE RATES AGAINST TIME

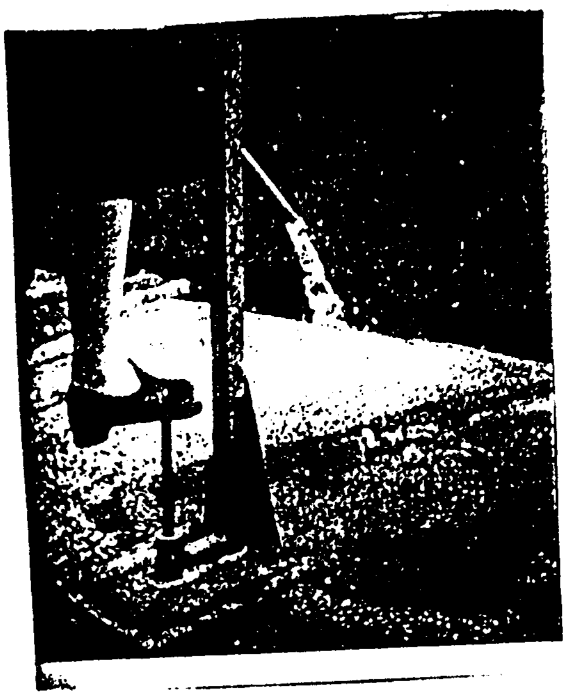
ON Y AXIS 2 cm = 0.200 m^3/s

ON X AXIS 2 cm = 5 sec

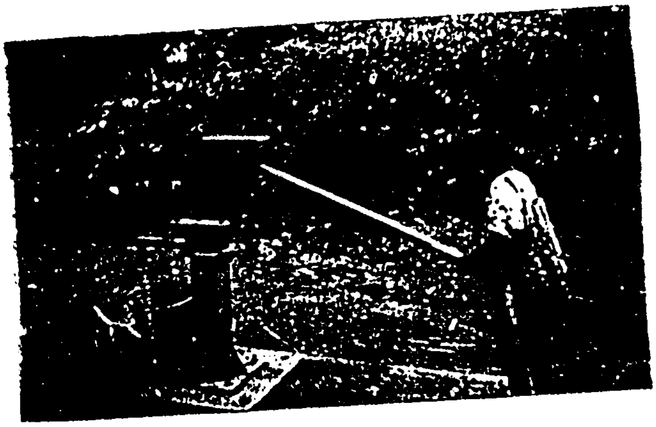




SHADOFF PUMP (Arush, R.E (1981)



VERGNET FOOT-OPERATED PUMP (Arush, R.E (1981)



INDIAN MARK II PUMP (Eyangan R.; 1961)

OLD VERSION INDIA MARK II PUMP (Eyanga R. 1961)

ANIMAL OPERATED PUMP (Arush, R.E., 1981)

WINDLASS PUMP (Muhammed A.B., 1981)