DEVELOPMENT OF GROUNDWATER ABSTRACTION MODEL FOR SHALLOW WELLS, USING DISPLACEMENT PRINCIPLE TECHNIQUE

BY

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MATRIC. No. 2005/21651EA

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BEING A FINAL YEAR PROJECT REPORT SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF A BACHELOR OF ENGINEERING (B. ENG.), IN AGRICULTURAL AND BIORESOURCES ENGINEERING, FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA, NIGER STATE.

JANUARY, 2011

DECLARATION

hereby declare that this project work is a record of a research work that was undertaken and written by me. It has not been presented before for any degree or diploma or certificate at any University or Institution. Information derived from personal communications, published and unpublished works were duly referenced in the text.

Okoro, Cynthia Kusin

26/01/2011

Date

CERTIFICATION

This is to certify that the project entitled "Development of Groundwater Abstraction Model for Shallow Wells using Displacement Principle Technique", by Okoro, Cynthia Kusin, meets the regulations governing the award of the degree of Bachelor of Engineering (B. ENG.) of the Federal University of Technology, Minna and it is approved for its contribution to scientific knowledge and literary presentation.

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Supervisor

24.01.2011
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24/01/2011
Date

External Examiner

13/01/2011
Date

DEDICATION

This project work is dedicated to my family for their unquantifiable support. Despite my imperfections, you never stopped believing in me.

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My most profound gratitude goes to God Almighty for his unending flow of mercy and favour towards me, seeing me through the hurdles of life and most especially for loving me beyond measure.

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ABSTRACT

Groundwater abstraction model was designed for lifting water from open wells to the surface by manually turning the wheel, the model was developed using displacement principle. The design is aimed at reducing the rate of contamination and pollution of withdrawn groundwater, drudgery and also cost associated with withdrawing groundwater. The model was designed with 90% efficiency; it lifts a volume of $98.19cm^3$ groundwater per turn and maintains a static water head of 0.3125m per stroke. The scope is limited to shallow wells, that is wells with a depth of between 6m to 30 m. It is recommended that a motor be incorporated into the design to further increase the rate of withdrawing groundwater and modifications should be done to make it suitable for other types of well.

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CHAPTER ONE

1. INTRODUCTION

1.1 Background to the Study

Water is the most abundant resource on earth (about 80 percent of the earth's surface is covered by water) next to air; water is the most important requirement for life to exist. The earth is presently the only known planet that has water in its Free State and this explains why the earth is the only known planet that supports life dwelling on it (Kemper, 2004).

Water in its pure states is colourless, tasteless and odourless. It has the unique property of existing in three forms; solid (ice), liquid (water) and vapor (steam) respectively, it also has the ability to dissolve to some degree.

Water occurs in three (3) main sources, sea/ocean, surface and groundwater. Rain is the major source of water to the atmosphere and to the land. And this is achieved through various stages and processes like evaporation, transpiration, evapotranspiration, infiltration, laminar and turbulent flows (Kemper, 2004).

1.1.1 Groundwater

Groundwater is an important natural resource. Worldwide, more than 2 billion people depend on groundwater for their daily supply (Kemper, 2004).

Groundwater is water located beneath the ground surface in soil pore spaces and in the fractures of lithologic formations, and has a pressure greater than atmospheric pressure. A unit of rock or an unconsolidated deposit is called an aquifer when it can yield a usable quantity of water. The depth at which soil pore spaces or fractures and voids in rock become completely saturated with water is called the water table. Groundwater is recharged from, and eventually flows to, the surface naturally; natural discharge often occurs at springs and seeps, and can form oases or wetlands. Groundwater is also often withdrawn for agricultural, municipal and industrial use by constructing and operating extraction wells. Typically, groundwater is thought of as liquid water flowing through shallow aquifers, but technically it can also include soil moisture, permafrost (frozen soil), immobile water in very low permeability bedrock, and deep geothermal or oil formation water. Drinking water is often thought of coming from water faucets, bottles, city or municipal wells, reservoirs, and private wells. But water comes from the atmosphere as rain and can be pumped out of the ground from a well. Water is not manufactured for us to drink. It is a finite resource that we need to respect and protect. In addition and no matter what the source is, we should always be concerned about its quality (Kovalevsky, 2004).

Water from lakes, ponds, and reservoirs is the easiest to find. But a good source of water from underground, called groundwater is not always easy to find. The placement of a well is often contingent upon finding a location for drilling the well (Kovalevsky, 2004).

1.1.2 **Water Abstraction**

Water abstraction, water extraction, or groundwater abstraction is the process of taking water from any source, either temporarily or permanently. Most water is used for irrigation or treatment to produce drinking water.

Depending on the environmental legislation in the relevant country, controls may be placed on abstraction to limit the amount of water that can be removed. Over abstraction can lead to rivers drying up or the level of groundwater aquifers reducing unacceptably. The science of hydrogeology is used to assess safe abstraction levels.

1.1.3 **Ergonomics**

Ergonomics is the science of designing the job, equipment, and workplace to fit the worker. Proper ergonomic design is necessary to prevent repetitive strain injuries, which can develop over time and can lead to long-term disability.

The International Ergonomics Association defines ergonomics as follows:

Ergonomics (or human factors) is the scientific discipline concerned with the understanding of interactions among humans and other elements of a system, and the profession that applies theory, principles, data and methods to design in order to optimize human well-being and overall system performance.

Ergonomics is employed to fulfill the two goals of health and productivity. It is relevant in the design of such things as safe furniture and easy-to-use interfaces to machines.

1.1.3.1 Engineering psychology

Engineering psychology is an interdisciplinary part of ergonomics and studies the relationships of people to machines, with the intent of improving such relationships. This may involve redesigning equipment, changing the way people use machines, or changing the location in which the work takes place. Often, the work of an engineering psychologist is described as making the relationship more "user-friendly."

Engineering psychology is an applied field of psychology concerned with psychological factors in the design and use of equipment. Human factors are broader than engineering psychology, which is focused specifically on designing systems that accommodate the information-processing capabilities of the brain.

1.2 Statement of the Problem

Over the years, it has been discovered that scooping water from the conventional open wells is tedious and in the process foreign bodies (like sweat, polythene, dusts, insects and creeping animals, to mention a few) tends to fall into the well, thereby capable of either polluting or contaminating the water content. The containers used to scoop water from these wells also contribute in making the withdrawn water less portable.

1.3 Objectives of the Study

The objectives of this work are,

1. To design and construct a prototype of a manually operated machine, capable of withdrawing water from a shallow well, using simple hydraulic principles.
2. To reduce drudgery, contamination and pollution associated with scooping water from wells especially by rural dwellers.
3. To cut down cost associated with accessing portable water especially by rural dwellers and local farmers.

1.4 Justification of the Study

This project will reduce the rate of contamination and pollution of groundwater drawn from shallow well, since the well is completely sealed, the likely possibility of foreign bodies being introduced into the well will be checked. The cost of installing a borehole is quite expensive, therefore making access to water expensive yet a basic necessity, especially by rural dwellers. This project will reduce the cost of getting water, since the materials used are readily available and affordable materials. Most importantly, the process of lifting water from an open well is very tedious, therefore the entire process, starting from dipping the scooping material to turning the water into a receiver until full, is summarized into the simple process of turning the handle of the machine.

1.5 Scope of the Study

The scope of this work is to develop a model which could be adopted for a shallow well. It should therefore be noted that this project can only be adopted efficiently for a shallow well (that is with a depth of between 6m to 30m); therefore all calculations as regards the design are based on shallow wells.

CHAPTER TWO

2. LITERATURE REVIEW

2.1 The Origin and Occurrence of Groundwater

The principal source of groundwater is meteoric water, that is, precipitation. However, two other sources are occasionally of some consequence. These are juvenile water and connate water. The former is derived from magmatic sources, whereas the latter represents the water in which sediments are deposited. Connate water is trapped in the pore spaces of sedimentary rocks as they are formed and has not been expelled. Rainfall that infiltrates the soil and penetrates to the underlying strata is called Groundwater. The quantity of water surface that can be accommodated under the surface depends on the porosity of the sub-surface strata. The water bearing strata, called aquifers, can consist of unconsolidated materials like sandstone and limestone. Limestone is relatively impervious, but is soluble in water and so frequently has wide joints and solution passages, that make the rock in its capacity to hold water and act as an aquifer (Kovalevsky, 2004).

.The water in the pores of the aquifer is subject to gravitational forces and so tends to flow downwards through pores of the material. The resistance to this underground flow varies widely, and the permeability of the material is a measure of this resistance. Aquifers with large pores such as coarse gravels are said to have high permeability and those with very small pores such as clay, where the pores are microscopic, have a low permeability (Kovalevsky, 2004).

As the groundwater percolates down, the aquifer becomes saturated. The surface of saturation is referred to as the groundwater table or the Phreatic surface. This surface may slope steeply and its stability is dependent on supply from above. It falls during dry spells and rises in rainy weather. The water in the aquifer is slowly moving towards the nearest free water surface such as lake, or river or the sea.

However if there is any impermeable layer underlying the aquifer and this layer outcrops on the surface, then the groundwater will appear on the surface in a seepage zone or as a spring. It is equally possible for the aquifer to be overlain with impermeable material and so be under pressure, such an aquifer fed from a distance is called a confined aquifer and the surface to which the water would rise if it could is called the piezometric surface. Another name for wells drilled into such confined aquifers is Artesian wells. If the piezometric level is above the ground level as an artesian well, it is called a flowing well.

Groundwater is the essential component of the hydrological cycle which facilitates the unique behaviour of water on the continents: water continues to flow on the land surface and sustain large plant communities during the periods without rainfall. This is due to the continuous supply of slow-moving and long turnover time groundwater. This is well known scientifically, but in practice it is not duly recognized by many engineers, policymakers and social leaders, whose attention typically focuses on the visible surface water, ignoring the hidden to sight, underground diffuse water flow. The consequence has been a form of freshwater resources development and management, and even of Nature protection, which is highly biased since it uses and takes advantage of only a part of the water cycle. Some exceptions are found in arid and semiarid lands, where the scarcity and irregularity of surface water has in the past fostered the primitive but ingenious and challenging development of relatively small quantities of groundwater needed for urban supply and socially-complex agricultural communities. These works are mentioned in Babylonian and Sumerian documents.

2.1.1 **Groundwater Relevance**

Water as a natural resource has important economic and social value. In the last few decades, an outstanding, almost spectacular, increase in the use of groundwater has been achieved in most arid and semi-arid countries. This has come about with very little governmental control. That is the main reason why, together with very important benefits, some drawbacks have been resulted, which have very often been exaggerated by the media. The UN Millennium Declaration has proposed, among its main goals, to halve the number of people without access to potable water or who suffer from malnourishment by 2015. Groundwater development is a keystone for reaching both goals. It is well known that water is an essential element for the existence of any form of life. In fact, about two-thirds of the human body consists of water, which is renewed every six to eight weeks. Water is also an essential element for many economic undertakings such as irrigated agriculture, which is the way approximately 40 percent of the food consumed by human beings is produced (Ramon, 2002).

The relevance of water extends well beyond utilitarian examples of this kind. It often assumes an importance that is difficult to quantify. Notions of the intangible value of water can rest on its importance to the environment, as well as its symbolic relevance to most cultures and religions. As a consequence, conflicts over water resources often involve an additional emotional factor. Some historians use the term 'hydraulic' to describe the first civilizations. These civilizations were born between six and seven thousand years ago in great valleys in large arid regions such as the Nile in Egypt or the Tigris and the Euphrates in Mesopotamia. Nomadic hunters became farmers and began to manage local water resources through small infrastructures. However, building and managing these works required a collective effort, which naturally led to structured societies living in the same '*Civis*' (towns). This tradition, or even necessity, of managing water resources collectively has continued to the present day. Just about all major hydraulic works within the last 100 years have been under the financial and operational control of government agencies or institutions. On the other hand, groundwater resources can be developed by means of minor works such as wells and galleries, thus allowing individuals or small communities to take control (Ramon, 2002).

In the early part of the first millennium B.C., Persians built elaborate tunnel systems called *qanats* for extracting groundwater in the dry mountain basins of present-day Iran. Qanat tunnels were hand-dug, just large enough to fit the person doing the digging. Along the length of a qanat, which can be several kilometers, many vertical shafts were dug to remove excavated material and to provide ventilation and access for repairs. The main qanat tunnel sloped gently down to an outlet at a village. From there, canals would distribute water to fields for irrigation. These amazing structures allowed Persian farmers to succeed despite long dry periods when there was no surface water to be had. Many *qanats* are still in use in Iran, Oman, and Syria (Lightfoot, 2000).

From ancient times until the 1900s, the main focus of groundwater science has been finding and developing groundwater resources. Groundwater is still a key resource and it always will be. In some places, it is the only source of fresh water (Nantucket Island, Massachusetts and parts of Saharan Africa, for example), (Charles, 2002).

2.2 **Hydrologic Cycle**

The hydrological cycle is the most fundamental principle of hydrology. Water evaporates from the land surface, carried over the earth in atmospheric circulation as water vapour, precipitates again as rain or snow, intercepted by trees and vegetation, provides runoff on the land surface, infiltrates into soils, recharges groundwater, discharges into streams and ultimately flows out into the oceans from which it will eventually evaporate once again. This immense water engine fueled by solar energy, driven by gravity, proceeds endlessly in the presence or absence of human activities (Maidment, 1992).

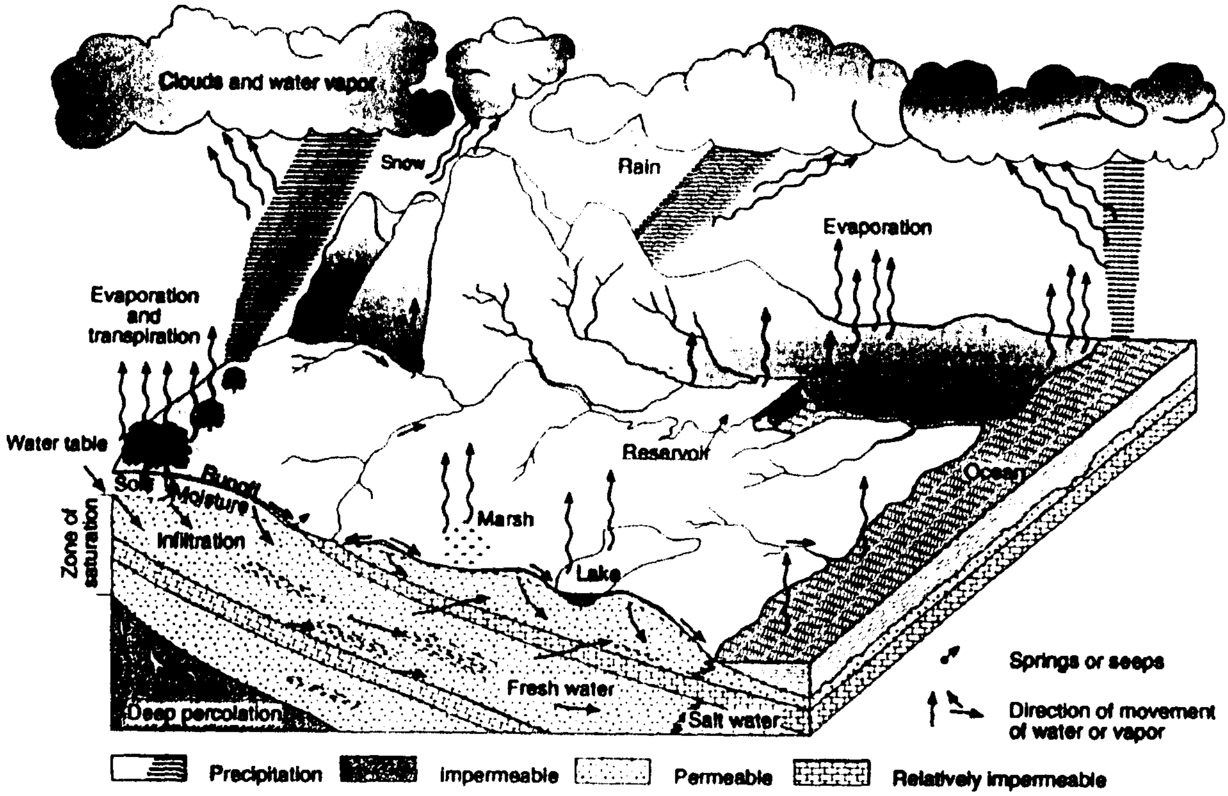


Fig. 2.1 The hydrological cycle (De Wiest, 1965)

Water on land masses is always in motion, either moving quickly (vapour transport, precipitation, and surface flow) or slowly (groundwater flow, glaciers). The slowness of groundwater flow means that most fresh water is in the form of groundwater. Consequently, groundwater is the main storage reservoir of fresh water, while surface water can be considered as the surplus precipitation that could not infiltrate, or that has been rejected as overflow from the groundwater reservoir (springs and other outflows).

2.2.1 **Groundwater Movement**

The amount of water that infiltrates into the ground depends on how precipitation is dispersed; on the proportions that are assigned to immediate run-off and to evapotranspiration, The remainder constituting the proportion allotted to infiltration/percolation.

i. Infiltration refers to the seepage of surface water into the ground, percolation being its subsequent movement, under the influence of gravity, to the zone of saturation. In reality, one cannot be separated from the other. The infiltration capacity is influenced by the rate at which rainfall occurs (which also affects the quantity of water available), the vegetation cover, the porosity of the soils and rocks, their initial moisture content and the position of the zone of saturation.

ii. The retention of water in soil depends on the capillary force and the molecular attraction of the particles. As the pores in the soil become thoroughly wetted, the capillary force declines, so that gravity becomes more effective. In this way, downward percolation can continue after infiltration has ceased but the capillarity increases in importance as the soil dries. No further percolation occurs after the capillary and gravity forces are balanced. (Lerner et al, 1990)

2.2.2 The Water Table or Phreatic Surface

The pores within the zone of saturation are filled with water, generally referred to as phreatic water. The upper surface of this zone is therefore known as the phreatic surface but is more commonly termed the water table. Ground water is widely sought after because it is:

i. Free from pathogenic organisms.

ii. Free from radioactive contaminants.

iii. A heat exchange medium because of its constant temperature.

2.2.3 **Aquifer Types**

Aquifers are typically saturated regions of the subsurface which produce an economically feasible quantity of water to a well or spring (e.g., sand and gravel or fractured bedrock often make good aquifer materials). Aquifers can occur at various depths, those closer to the surface are not only more likely to be exploited for water supply and irrigation, but are also more likely to be topped up by the local rainfall, the economical availability of water in an aquifer system is controlled majorly by its porosity and permeability. (Leopold, 1994).

Aquitard is a zone within the earth that restricts the flow of groundwater from one aquifer to another, an aquitard can sometimes, if completely impermeable, be called an aquiclude or aquifuge it can also be summarized that aquitards comprise layers of either clay or non-porous rock with low hydraulic conductivity. (Leopold, 1994).

There are basically three kinds of aquifers

2.2.3.1 **Confined Aquifers**

They are completely saturated permeable beds, sandwiched between two impermeable layers. Water could exist under great pressure also known as "artesian condition" artesian flow is more common in the confined aquifers, this occurs when well is drilled through the aquifer, the water flows out naturally to the surface. However, when the top permeable bed is not perfectly impervious, the pressure could be lower than that to artesian condition such that the water does not reach the surface, this is known as sub-artesian flow (Charles, 2002).

2.2.3.2 **Unconfined Aquifers**

They are sometimes also called water table or phreatic aquifers, because their upper boundary is the water table or phreatic surface. Unconfined aquifers usually receive recharge water directly from the surface, from precipitation or from a body of surface water (e.g., a river, stream, or lake) which is in hydraulic connection with it. Typically (but not always) the shallowest aquifer at a given location is unconfined, meaning it does not have a confining layer (an aquitard or aquiclude) between it and the surface (Charles, 2002).

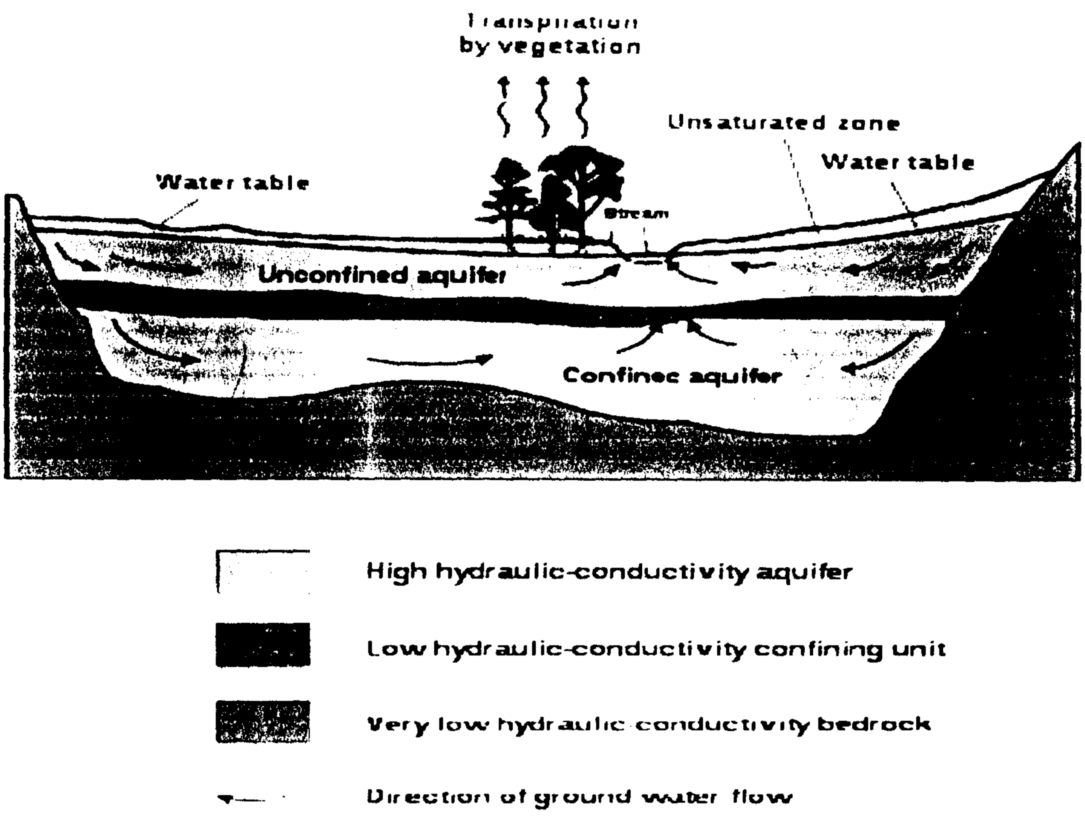


Fig. 2.2 Flow Direction in a Cross-Sectional View of a Simple Confined/Unconfined Aquifer System (Bell, 1993)

Fig. 2.2 indicates a typical flow direction in a cross section view in a simple confined/unconfined aquifer system. The system shows two aquifers with one aquitard (a confining or impermeable layer), between them, surrounded by the bedrock aquiclude, which is in contact with a gaining stream (typical in humid regions). The water table and unsaturated zone are also illustrated.

2.2.3.3 **Hardrock Aquifers**

They are aquifers found in crystalline rocks, crystalline rocks are usually not good aquifers rather they are usually aquitards because they retard the flow of groundwater. This is caused by extreme variation of lithology and structures in this area coupled with highly localized water producing zones that make geological exploration of groundwater relatively difficult.

Groundwater potential in any geological terrain is controlled by certain, factors, such factors are

1) The degree, nature and extent of fracturing
2) The degree and thickness of weathering of the crystalline rock
3) The absence or minimal presence of clay at the top of weathered zones to allow infiltration of surface water into the aquifer (Oteze, 1976).

2.3 **Structural Control of Groundwater**

Certain features controls the groundwater potential in a geological terrain, these features are deformational structures present on these hard rock that make up the basement complex control groundwater flow within them. It could be the flow, yield and even rate of recharge. The structures were formed from the tectonic activities during the formation of the rock and continuous geologic activities. (Gabriel et al 2003)

Fractures (faults and joints) are formed as a result of stress normally caused by compression and tensional forces as a result of tectonic activities e.g. orogenesis.

Fractures formed by tensional forces are more likely to live crevices for water accumulation than fractures formed by compression forces. (Gabriel et al 2003)

Weathered zones are areas where there has been exclusive weathering of rocks. This could be physical, chemical or biological depending on the process and the rocks are usually insitu during weathering.

So fracture and weathered zones are usually targets for geophysical survey during groundwater exploration. This is because of the secondary porosity and permeability created by these structures. (Gabriel et al 2003)

2.3.1 Porosity and Permeability

Porosity and permeability are the two most important factors governing the accumulation, migration and distribution of groundwater. However, both may change within a rock or soil mass in the course of its geological evolution. Furthermore, it is not uncommon to find variations in both porosity and permeability per meter of depth beneath the ground surface.

Porosity: The porosity, *n*, of a rock can be defined as the percentage pore space within a given volume.

Permeability: Permeability may be defined as the ability of soil or rock to allow the passage of fluids into or through it without impairing its structure. In ordinary hydraulic usage, a substance is termed permeable when it permits the passage of a measurable quantity of fluid in a finite period of time and impermeable when the rate at which it transmits that fluid is slow enough to be negligible under existing temperature–pressure conditions (Bell, 1978).

2.3.2 Flows through Soils and Rocks

Water possesses three forms of energy, namely, potential energy attributable to its height, pressure energy owing to its pressure, and kinetic energy due to its velocity. The latter can usually be discounted in any assessment of flow through soils. Energy in water usually is expressed in terms of head. The head possessed by groundwater in soils or rocks is manifested by the height to which it will rise in a standpipe above a given datum. This height usually is referred to as the piezometric level and provides a measure of the total energy of the water. If at two different points within a continuous area of groundwater, there are different amounts of energy, then there will be a flow towards the point of lesser energy and the difference in head is expended in maintaining that flow. Other things being equal, the velocity of flow between two points is directly proportional to the difference in head between them. The hydraulic gradient, i, refers to the loss of head or energy of water flowing through the ground. This loss of energy by the groundwater is due to the friction resistance of the ground material, and this is greater in fine- than coarse grained soils. Thus, there is no guarantee that the rate of flow will be uniform, indeed this is exceptional. However, if it is assumed that the resistance to flow is constant, then for a given difference in head, the flow velocity is directly proportional to the flow path (Freeze and Cherry, 1979).

2.3.3 **Factors Affecting Groundwater Flow**

The flow of groundwater takes place through a porous media. The pore through which movement takes place can be very small indeed and generally are between the limits of 2 and 0.02mm. The movement is slow by standards of surface runoff and the flow is usually laminar.

The important factors affecting groundwater flow are;

i. Density and viscosity of liquid,

ii. The media through which the liquid moves and

iii. Boundary conditions.

2.4 Energy and Hydraulic Head

Water flows from one place to another in response to uneven distributions of mechanical energy within the water. Water always flows from regions with higher mechanical energy towards regions with lower mechanical energy. As water flows along its path, it loses some of its mechanical energy to internal viscous friction. This energy lost to friction adds heat to the geologic medium, but this heat is usually very minor compared to other heat sources. The mechanical energy in water can take on three forms:

i Elastic potential energy,

ii. Gravitational potential energy, and

iii. Kinetic energy.

Elastic potential energy is gained by compressing water, gravitational potential energy is achieved by lifting water to higher elevation, and kinetic energy stems from the velocity of water. These forms of mechanical energy were first quantified by Daniel Bernoulli in 1738.

The Bernoulli Equation is a fundamental equation of fluid mechanics for relatively incompressible fluids like water. This equation describes the mechanical energy, E of water with mass m, pressure P, elevation z, volume V, and velocity v. The Bernoulli equation assumes that the water is in the vicinity of earth's surface, where the acceleration of gravity *g* can be taken as a constant. The SI unit of energy is the joule. One joule in more fundamental metric units equals $kg{\cdot}m^2/sec^2$ or Nm. The energy predicted by this equation can be thought of as the work required to compress, elevate, and accelerate a mass *m* of water to its current state from a reference state where $P = z = v = 0$. Another form of the energy equation is the energy per mass of water; a quantity termed the fluid potential φ by Hubbert (1940).

For analysis of water flow, a more convenient parameter is energy per weight of water. Taking the Bernoulli's equation and dividing each term by the weight of water, (mg) gives a new quantity called the hydraulic head, h.

Conveniently, hydraulic head has the simple unit of length. The three terms on the right side of Eq.2.4 are called the pressure head, elevation head, and velocity head, respectively. The hydraulic head, h is also called head, the head and hydraulic head are synonymous. Water always flows towards regions of lower hydraulic head, the same way heat flows towards regions of lower temperature.

2.5 Groundwater Collection

The simplest and oldest way of collecting groundwater is by digging a hole in the ground that penetrates the water table. If the quantity of water that can be taken from the hole is not adequate, then the hole must be extended either horizontally or vertically.

If the hole is extended horizontally, it becomes an open collecting ditch. Alternatively, it could be underground as a collecting tunnel. These horizontal collectors must be used if the aquifer thickness is small and if the drawdown due to abstraction has to be limited, for example, when a layer of fresh water overlies a layer of salt water.

The vertical extension of a hole makes it a dug or drilled well, or a borehole. This method can be used when the aquifer is of sufficient thickness and in any case, when the aquifer is more than about 6m below ground level.

Dug wells are usually 1m or more in diameter and so the shaft acts as a reservoir for a short term, high rate abstraction. The large diameter is also useful when the entrance velocity of the water into the shaft has to be kept low. For example, in fine grained sands (Todd, 1980).

2.5 **Water Wells**

Water wells can be defined as an excavated hole or shaft, usually vertical in the earth for bringing groundwater to the surface. Wells can also be used for subsurface exploration and observation, artificial recharge and disposal of waste water. Many method exist for constructing wells, the selection of a particular method depends on the purpose of the well, the quantity of water required, depth of groundwater, geological condition and economic factor (Todd, 1980).

Open wells are regarded as the simplest and cheapest method of lifting groundwater. Water can be lifted up by manual or mechanical means, such as Pumps, Persians, Archimedean screws etc. Where electric energy or diesel is not available then animal power such as buffalo are used to lift water from wells. Open wells are prominent in rural and urban areas in which water can be lifted manually by using rope and bucket in a wide shallow well. Open wells can be operated up to a depth of 100metres, although they rarely exceed 45metres and can last for very long time without maintenance (Kennedy and Rolgers, 1985).

2.5.1 **Types of Wells**

There are different types that are commonly used depending on their requirement and their nature of geological formation and also the methods used to construct them.

2.5.1.1 **Dug Well**

This is the oldest type of well. It is a hole dug in the ground using a shovel or backhoe until the incoming water exceeds the digger bailing rate. Typically hand dug wells range from 1 to 2 metres in diameter and is much shallower than boreholes, usually 5 to 30 metres deep. Modern hand dug wells have an improved design and provide sustainability for projects. Hand dug wells are inexpensive and can be constructed using local skills and materials; community participation is easy to organize.

In additional, the operation of hand dug wells requires only little external energy and few skills, and the pumps maybe maintained by local technicians (Michael and Ojha, 2003).

2 5.1.2 **Tube Well**

These are wells whereby, water is tapped from lower depth, smaller diameter pipes are used, ranging from 6cm to 30cm tube wells can also be installed perennial rivers, making use of the natural filtering properties of sandy soil of the rivers by drawing water through the river beds, instead of the rivers themselves. The wells constitute a good means of obtaining water from areas with relatively coarse sand

2.5.1.3 **Drilled Well**

This method of drilling, a cable tool of precision method of drilling is based upon the principle of applying sufficient energy to pulverize the soil or rock. The energy applied is varied by controlling the length of the stroke and the weight of the drill stem and bit. The bit is connected to a cable and by means of a rocker arm on the drill rig; it is raised and released to exert its energy on the bottom of the hole.

2.5.1.4 **Bored Well**

This is dug with an auger, either manually or mechanically. The soil usually remains in the auger which is rained and cleaned periodically.

2.5.1.5 **Driven Well**

In this method, a driving point is attached to a strainer to the perforated section of a driving pipe. The drive friction may be obtained by making the point lower than the casing. During construction, care is taken so that the well holes remain vertical and straight.

2.5.1.6 **Shallow Wells**

Shallow wells are usually dug, are often low in dissolved minerals and produce good quality water if protected from biological hazards.

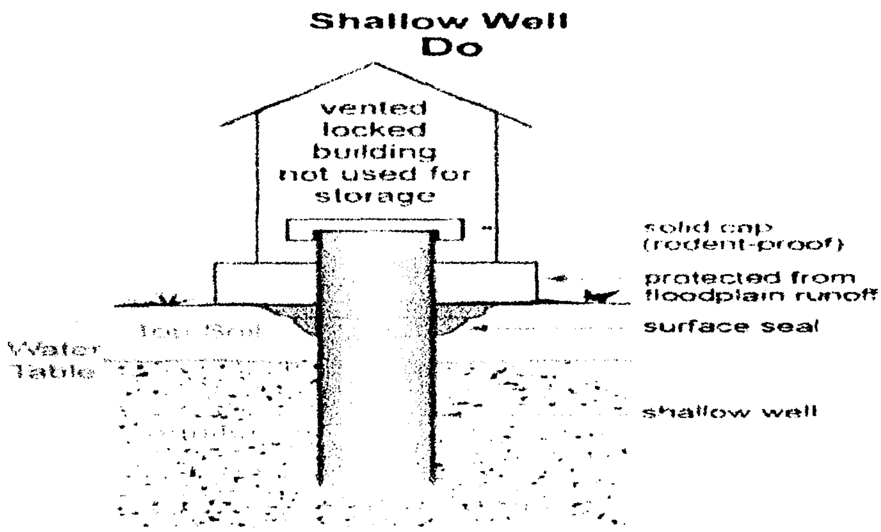


Fig. 2.3 Proper construction of shallow well

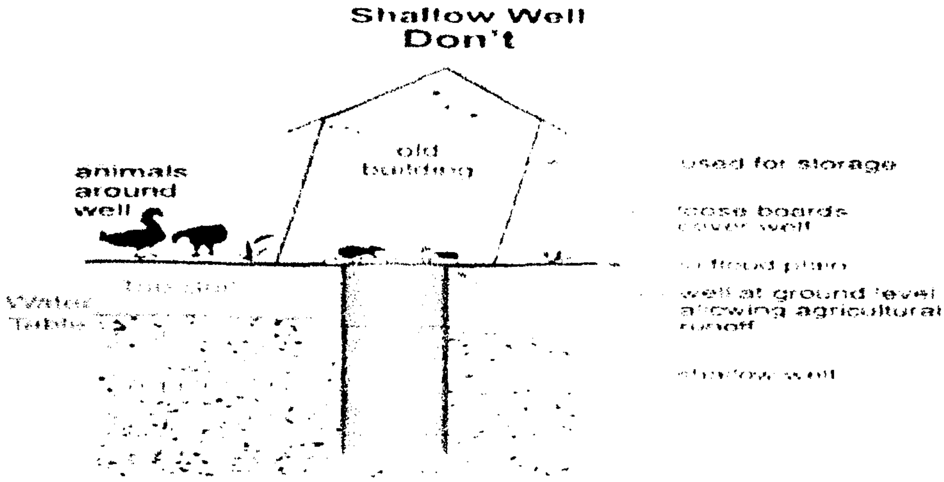


Fig. 2.4 Improper construction of a shallow well.

2.5.2 General Construction Tips for Wells

2.5.2.1 Surface Seals

Make sure that the area between the well casing and the ground is sealed.

To make a surface seal for a well:

i. Make the well, one-third to half a meter (1–2 feet) larger than well casing.

ii. Place dried clay or bentonite (highly absorbent clay) alongside casing.

The clay absorbs water and expands to act as a seal that prevents surface runoff and pathogens from entering through the outside of the well.

2.5.2.2 **Well Seal**

Well caps should have a tight-fitting seal to prevent contaminants from entering the well. On large-diameter dug wells it may be necessary to construct a lid. It should be fitted with a rubber seal to prevent contamination by rodents, insects, or surface water. If a vent cap is necessary, it should be fitted with a fine-mesh screen.

2.5.2.3 Pump House

An important part of construction is the well or pump house. The pump house should be vented to allow the escape of gases that may come from the well, and the vents should be screened against rodents and insects.

Pump houses with unsealed doors and windows make wonderful winter homes for rodents whose droppings can be the source of disease.

Cross section of a shallow well

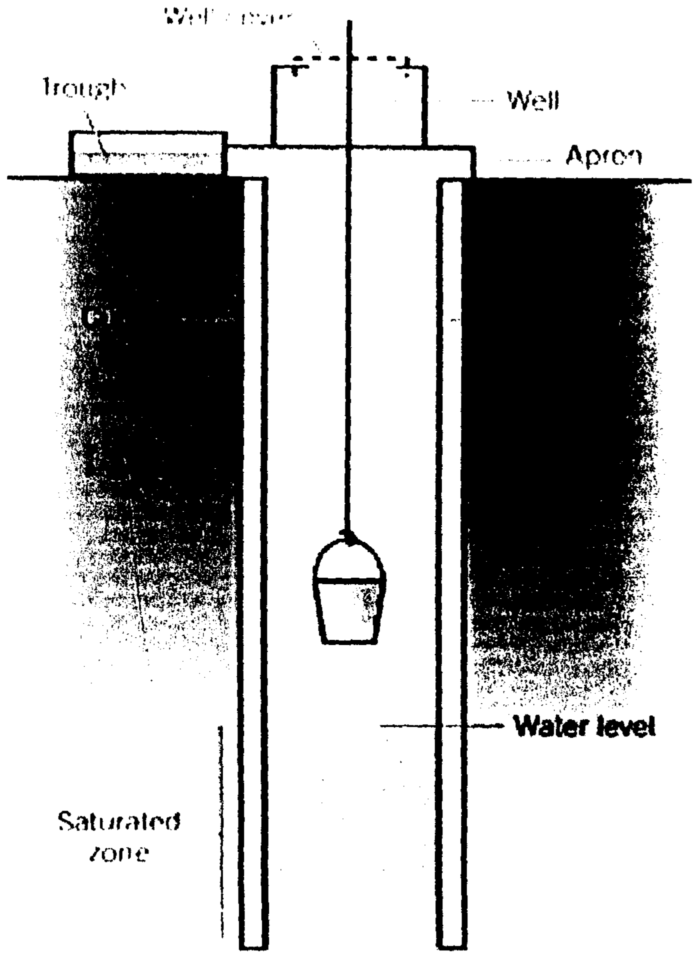


Fig. 2.5 Cross Section of a Conventional Shallow Well

A shallow well, as we use the term, is hand dug water well. 10 to 20 ft. deep and about 6 ft. diameter. It is lined with locally made bricks and sealed with a concrete top slab. A simple hand powered pump could be installed in the top slab to allow people to pump the water.

The drawing below shows a cutaway view of a shallow well. The villagers dig the hole; using whatever primitive tools they have available. These typically are limited to hoes, buckets and sometimes a stub of a shovel or a pick if they are lucky. They are to dig until there is about 6 ft of water standing in the well. Then the bottom is lined with stones to minimize dirt or sand clogging the foot valve. While this picture does not show it, the bottom diameter of the well was enlarged - sort of like a bulb - to give a larger reservoir space and to have enough space at the bottom for reworking if that ever becomes necessary. Bricks are laid around the perimeter - building up a wall. The first 5 courses of bricks are laid without using mortar so that water can get into the well. From the 6th layer and up mortar is used for strength. On the lower half of the well, the space behind the brick wall is filled with small stones so that water can come in and filter down to the bottom of the well. From the mid-point on up to the surface, the space behind the bricks is filled with clay, such as from an anthill, to seal out surface water and prevent contamination. The brick wall is built up above the surface to a level of 18 to 24 inches. A previously made top slab of concrete is then placed on top and mortared in place. The outside of the bricks above ground is plastered with concrete to seal and protect them. An apron, 1 meter wide, is built around the well on the surface. The apron is to prevent surface water from getting down beside the well and possibly contaminate it. A drain runs out from the apron to carry any excess water or rain water away from the well, also to prevent contamination.

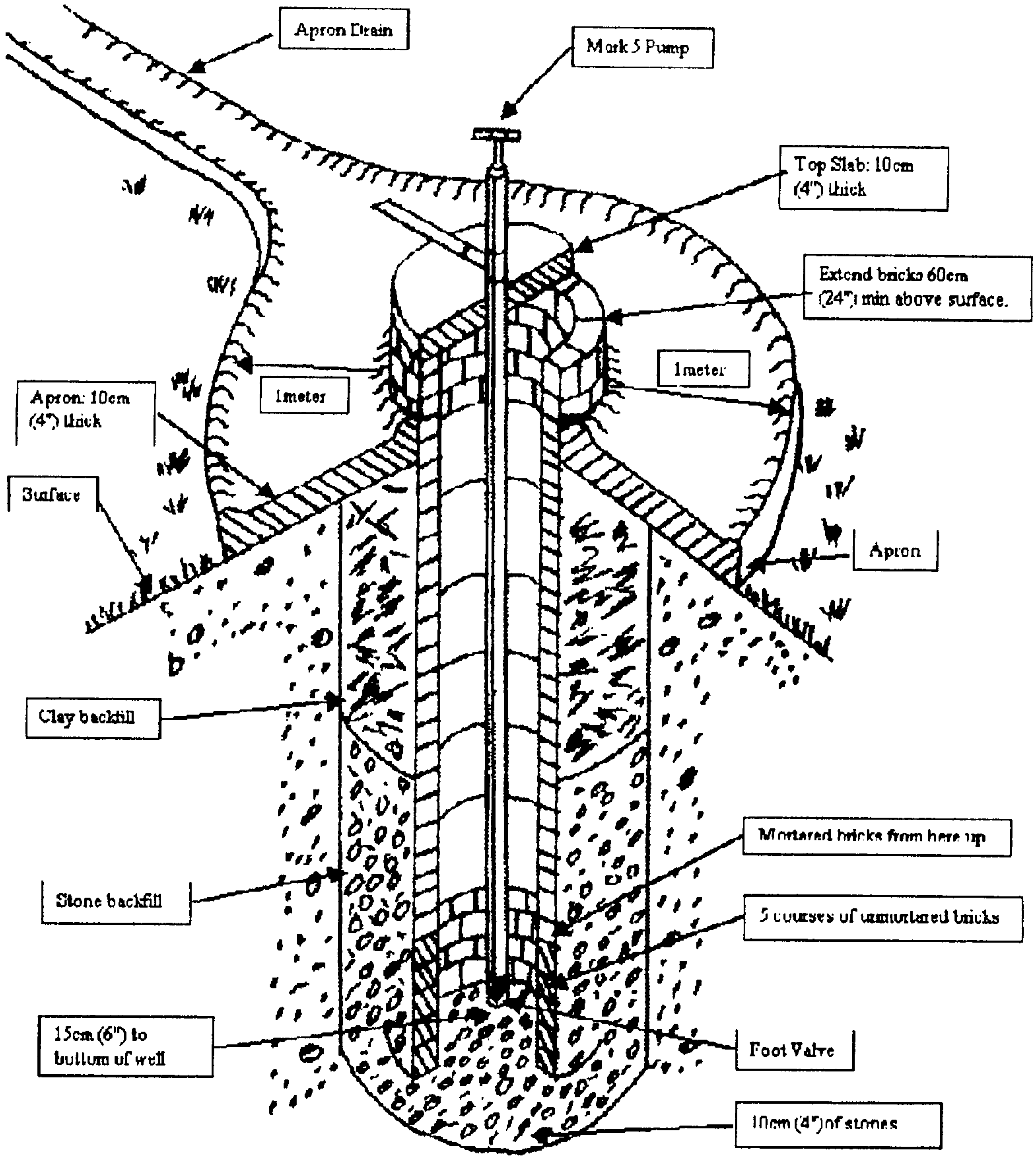


Fig 2.6 A Cutaway View of a Shallow Well

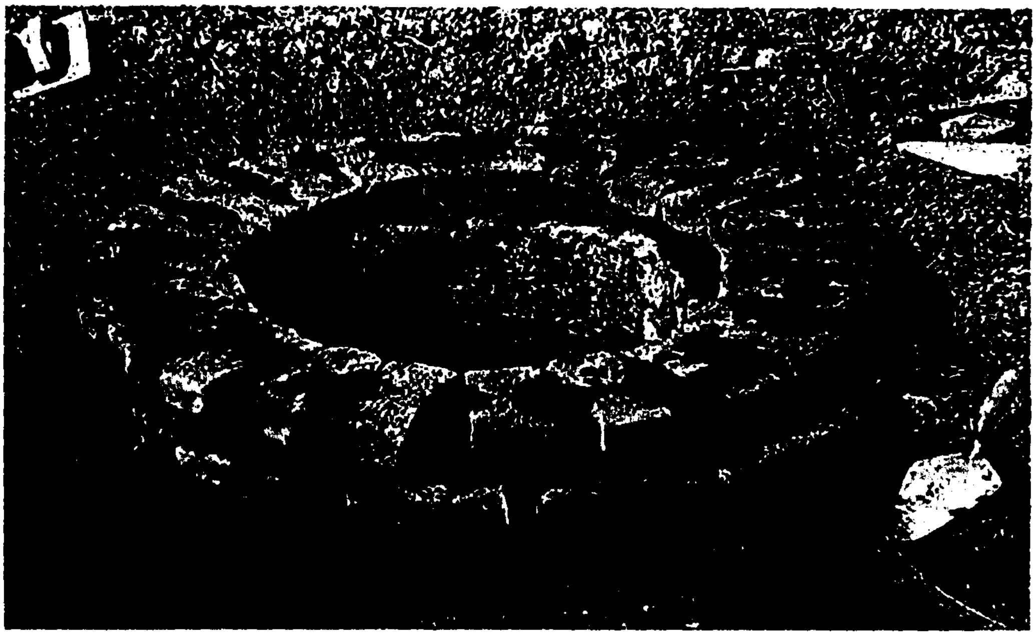


Plate 2.1 A shallow well bricked up just above surface.

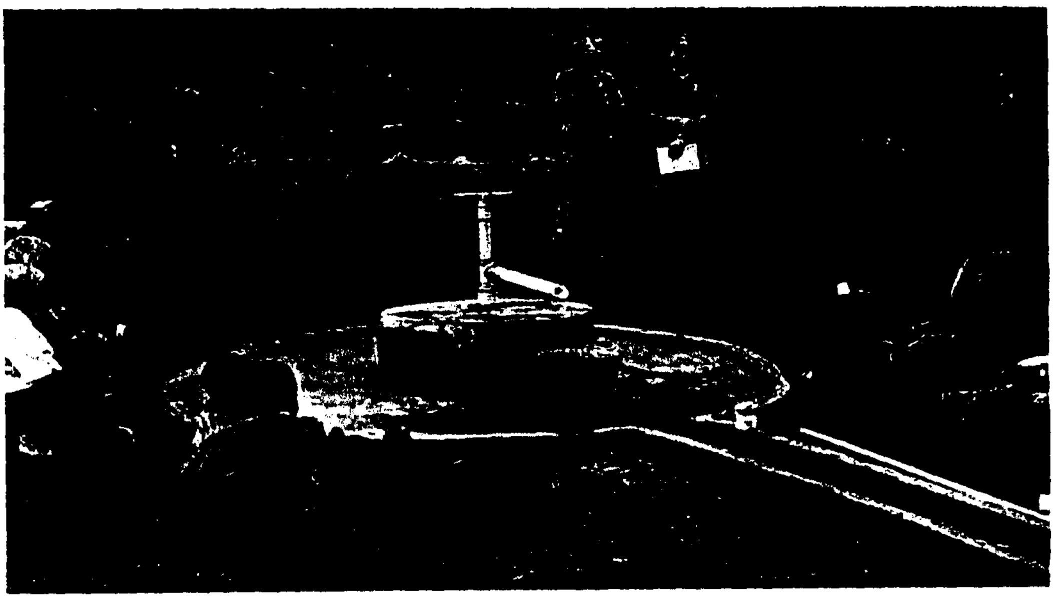
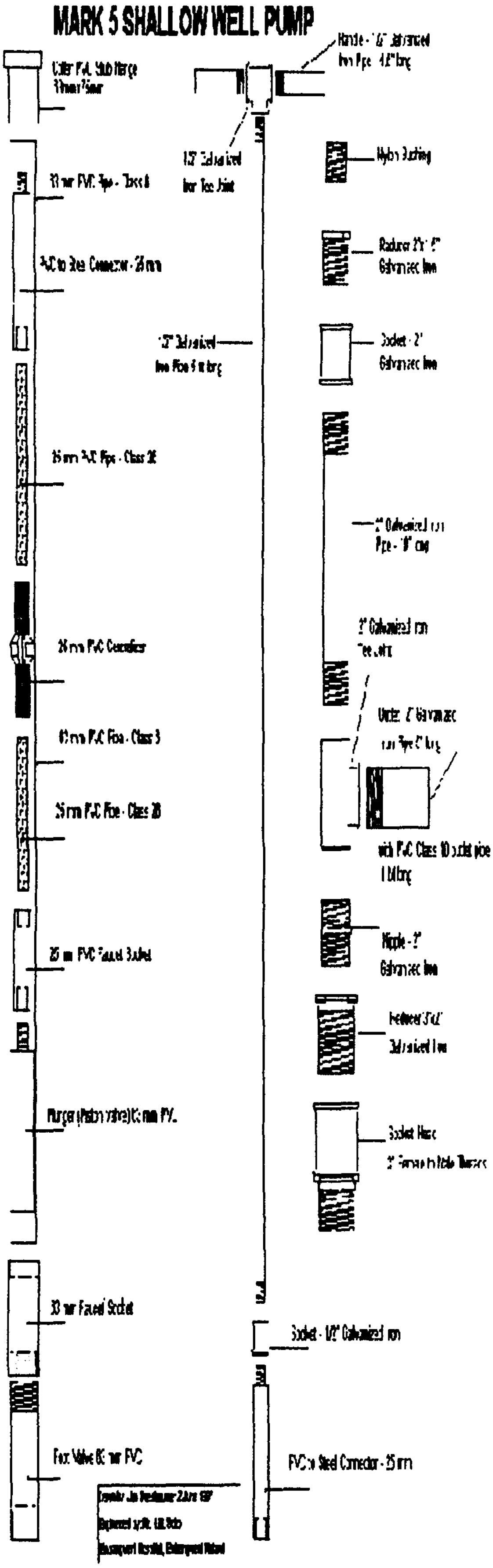


Plate 2.2 A completed shallow well.



The pump used here is a Mark 5 hand pump. This pump has been used in Africa for many years but is still one of the simplest and easiest to manufacture pump available. The pump and all of its parts are made in Africa by Africans.

The portion of the pump visible above ground is made from galvanized pipe. The above ground portion is actually manufactured locally - cutting and threading the galvanized pipe in the workshop.

The portions of the pump below ground are made of PVC, both the pipe and the fittings. The PVC pipe is extruded locally - in Malawi that is done in Lilongwe. The PVC down hole parts (foot valve, plunger etc) are made in a machine shop in Lilongwe. The pump is just a straight up and down motion - like a bicycle pump. This keeps everything simple and easier to build and maintain. Since the depth of the well is limited to 20 ft, this is within the ability of the people, mostly women and children to pump. If the wells were much deeper than 20 ft, then the weight of the water would require a different design.

2.6 **Pumps**

Prior to dealing with the background for the concept of novel piston pump design, it is good to recount on the basic concept of the piston pumps. It is obvious that piston pumps are used to move or compress the fluid, liquids or gases, the syringe is a simple example. The Greek inventor made pump with two cylinders coupled to rods to form single piece which was connected to hand operated and rocking beam.

Thus, pump is a device used for raising water from one level to another. There are numerous examples of such devices used by Persian and Roman water wheels. The famous Archimedean screw developed by Archimedean of Syracuse used pump device for draining water from ships. The RO-SHE-RA y/g is another hand pump used in rising water from wells, (ESME, 1998).

Pumps with long chains were also developed in Cairo, Egypt in the 17^{th} century to lift water from over 90m depth for irrigation. Some famous scientists of Alexandria, developed reciprocating pumps made of bronze were used for lifting water from wells. Pump designs had undergone various methods and skills in construction by Italians, Egyptians and Romans up to 18^{th} century, when pump development received closer attention hence modifications.

These designs include:

i. Three head suction pumps by a single crank powered (triple Ram Pump),
ii. A suction pump working by atmospheric pressure,
iii. Vacuum pumps and many more (Cherkassky, 1980).

Most of these pumps developed were reciprocating pumps used by New Comer of Great Britain for raising water from mining holes. Condensed vapour pressurized in a cylinder was the device used by mining engineers. This device was called Genis and used for actuating pump compressors. New Comer improved on the reciprocating pumping engine in the early 18th Century to increase the discharge at a higher head (Cherkassky, 1980).

Further works were done on the reciprocating pumps (Frolo pumps) in the 19th century by Italians. In 1818, Andrews of USA built a single stage centrifugal pump which John Gwine of Great Britain improved upon to build double suction centrifugal pump, using curve impellers technology. A Russian engineer, V.O. Dalio designed electric motor with high speed in 1888 for centrifugal pump, (Cherkassky, 1980).

Since the 17th century to date, several works had been done and more are still going on perfecting the performance of various types of pumps. Also lots of research works are going on by many researchers and students, few of which have been sited above and several works are still required to improve on pump efficiency, in delivering little and large quantity of liquids at economical cost.

2.6.1 **Pump Classification**

Pumps can be classified on the basis of the application they serve, the material from which they are constructed, the liquid and the fluid they handle and even their orientation in space (the way they can be installed). Pump classifications are limited in scope and tend to substantially overlap each other. The basic system of pump classification is upon the principles by which they exert energy on the fluid. That is, the means by which energy is imposed and the specific geometry employed. However, the two common criteria used are the principles of operation and application or field operation.

Pump classification based on principle of operation are divided into two major categories, 2.6.1.1 **Dynamic Pumps**

This type of pumps are used in inducing energy continuously into fluid to increase velocity of discharge the most common types of dynamic pumps are the centrifugal type. They have rotating blades called impellers that develop pressure, which cause pumping action by centrifugal force. Dynamic lift or momentum exchange of energy is continuously impacted to the liquid resulting in radial, axial or mixed flow according to the impeller designs housed in a box.

2.6.1.2 **Positive Displacement Pumps**

These are the types of pumps that discharge volume of liquid by the stroke of a reciprocating piston or revolution of rotating vane action. Energy is added intermittently, impacted by altering or displacing the confined volume of liquid in the cylinder (pump cavity). The piston or plunger and the diaphragm pumps operate by means of reciprocating motions. Other common types include gear, screw, vane and lobe pumps.

2.6.2 **Dynamic and Displacement Pumps Applications**

Pump classification or application depends on the field operations. These classes include water pumps, sewage pumps, irrigations, sumps, chemical dosing, booster (surface, submersible and fluid) and shallow wells. This project focuses on the use of displacement pumps in lifting water from shallow wells.

2.7 Mode of Operation of Machine

When the handle is turned, this rotational motion of the handle is then transmitted through the shaft to the crank mechanism, which in turn converts the rotational motion into a translational up and down motion of the connecting rod. A piston is attached to the other end of the connecting rod.

During the downward stroke of the piston, caused by the downward movement of the connecting rod, an amount of pressure is exerted on the air space just above the water surface; this pressure is then transmitted through the mass of water. Since the well is sealed, that is airtight; the water undergoes a corresponding pressure by the air under the pressure of the piston, which then causes an upward rise of the water in the suction pipe, displacing an amount of air.

During the upward stroke, the pressure in the suction pipe decreases, the valve in the piston opens and allows an amount of air into the pressure pipe. The water head is retained due to the non-returnable valve.

These processes are repeated for a continuous up and down stroke of the piston and the head of water continues to increase successively in the suction pipe, until it reaches the delivery nozzle, where the water will be collected in a container.

2.8 **Ergonomics of Design**

i. This model is such that can be used by both a right hander and a left hander, in that whether it is turned clockwise (right hander) or anticlockwise (left hander), the same amount of water is attainable. This eliminates inconvenience during use.

ii. The wheel of the machine is made of a light material and a large diameter, as such, reducing the amount of pressure applied in turning the wheel, thereby reducing the pain felt on the arm of the user.

iii. The shaft used is already incorporated to a bearing, to aid smooth turning of the shaft and avoid stiffness of shaft. With this, energy used in overcoming friction is reduced; this reduces pain felt on the arms during turning.

CHAPTER THREE

3. MATERIALS AND METHODS

3.1 Materials

Table 3.1 **Materials Used**

COMPONENTS	MATERIALS
1. Frame	**Mild steel**
2. Air flow channel	**PVC pipe**
3. Water outflow channel	**Transparent hose tube**
4. Connecting rod	**Stainless steel**
5. Flywheel	**Mild steel**
6. Frame	**Mild steel**
7. Bearing support	**Mild steel**
8. Water tank	**Plastic**
9. Crank shaft	**Mild steel**

3.2 Methods

3.2.1 Principle of Operation

This machine converts mechanical energy, that is the mechanical effort used in whirling, to potential energy known as pressure energy, which is the pressure exerted by the compressed air and subsequently, this energy is converted into kinetic energy, that is the upward movement of water in the delivery pipe due to the pressure of the compressed air.

3.2.1.1 **Bernoulli's Equation**

Subscripts 1 and 2 denote two points A and B. For a liquid flowing from A to B,

$$\frac{P_1}{\rho g} + \frac{V_1^2}{2g} + Z_1 = \frac{P_2}{\rho g} + \frac{V_2^2}{2g} + Z_2 \qquad (3.1)$$

Where

P = Pressure of fluid (N/m^2)

V = Velocity of fluid (m/s)

ρ = Density of fluid (kg/m^3)

g =Acceleration due to gravity (m/s^2)

Z = Height above reference point (m)

3.2.1.2 **Continuity Equation**

The Bernoulli's equation alone is usually insufficient to solve problems on pipe flow. Therefore a second equation based on a liquid being incompressible is adopted. The volume of the liquid passing section per second must therefore be the same. Denoting the cross-sectional area of the pipes by A_1 and A_2, the volumetric flow is given by,

$$Q = A_1V_1 = A_2V_2 \qquad (3.2a)$$

Or

$$\frac{V_1}{V_2} = \frac{A_2}{A_1} \quad (3.2b)$$

This equation is known as the equation of continuity, and when the pipe dimensions are known, it gives the ratio of the velocities at any two points in the pipe. The equation states that the velocity of flow is inversely proportional to the area of pipe section (Hannah and Hillier, 1995).

3.2.1.3 **Frictional Loss**

Frictional loss is another condition to be considered in fluid movement especially in the pipes or conduits structures. Frictional losses affect the mass or volume of fluid flow rate. Frictional losses are attributed to frictional forces (viscous drag affected by material surface roughness and head). Other losses at the bends and fittings are resistance in terms of pipe diameter, equipment inlets and outlet or contractions and expansions in the pipes.

Frictional losses can be determined from Darcy's equation as stated below;

$$H_f = f\frac{L}{D}\frac{V^2}{2g} \quad (3.3)$$

Where

L = length of pipe (m)

D = diameter of pipe (m)

V = velocity of flow (m/s)

f = frictional factor (a function of the Reynolds number of the flow and the relative roughness of pipe).

The Reynolds number, N_R, of flow given by

$$N_R = \frac{DV}{v} \tag{3.4}$$

If N_R is less than 2100, the flow is laminar; if over 3000, the flow is turbulent; between these values a transitional type of flow exists. The relative roughness e/D of a pipe depends on the absolute roughness, e, of the interior surface and the diameter, D (Linsley, 1984).

3.2.2 **Expectancies of Displacement Pumps**

The performance of a displacement pump can be defined in terms of its Volumetric and Mechanical efficiency.

3.2.2.1 **Discharge**

The theoretical discharge is a function of the volume swept by the piston during the down stroke, the stroke length and the number of strokes per unit time, and it is given by;

$$Q_t = \frac{\pi}{4(D_p{}^2 N L_s)} \tag{3.6}$$

Where

Q_t = theoretical discharge (m^3/min)

D_p = piston (cylinder) diameter (m)

N = stroke speed (stroke/min)

L_s = stroke length (m)

Generally, actual discharge (Q_a) is different from the theoretical discharge (Q_t). Actual discharge is usually less than the theoretical discharge, because of possible leakage through the piston seals and valves, but could at times be equal with the theoretical discharge.

The volumetric efficiency (V_e) is defined as the ratio of the actual discharge to the theoretical discharge as given by the equation,

$$V_e = \frac{Q_a}{Q_t} \tag{3.7}$$

This equation can be used to determine the useful work (W_o) obtained per stroke;

$$W_0 = \rho g \left[\frac{V_e \pi}{4 D_p{}^2 L_s}\right] H_s \tag{3.8}$$

Where

G = gravitational acceleration (ms^{-2})

ρ = density of water (Kg/m^3)

H_s = delivery (static) head (m)

The mechanical efficiency (M_e) is the ratio of the useful work done per stroke (W_i) to the actual work done to lift the water. It is a measure of the wastage of pumping effort as given in the equation below,

$$M_e = \frac{W_0}{W_i} \tag{3.9}$$

3.2.2.2 **Capacity of Cylinder**

The capacity of displacement pumps can be determined by,

$$C_p = \frac{d_c{}^2 h}{4} \qquad (3.10)$$

Where

d_c = diameter of cylinder (m)

h = height of cylinder (m)

3.2.3.3 **Pressure on Cylinder**

Pressure on cylinder can be given by,

$$\frac{Force}{Area} = \frac{F}{\pi dt} \qquad (3.11)$$

Where

F = force on the cylinder (N)

d = diameter of cylinder (m)

t = thickness of cylinder (m)

3.2.3.4 **Volume per Stroke**

To ensure efficient performances of the pumps, the sizes of the pressure and delivery pipes must be determined. Hence, volume of water per stroke, V is given by

$$V = \frac{\pi d^2 L}{4} \tag{3.12}$$

Where

V = volume of water per stroke (m^3)

d = diameter of piston (m)

L = length of stroke (m)

3.2.3 **Design Analysis**

3.2.3.1 **Force Analysis**

In the conventional hand pumps, the total forces required to lift the piston during the upward stroke is equal to the sum of the following (Peter, 1986).

$$F_L = F_r + F_p + F_w \tag{3.13}$$

Where

F_p = force due to weight of the piston (N)

F_r = force due to static head of water (N)

F_w = inertia force of piston (N)

Therefore, force due to static head of water can be calculated using the following equation (Peter, 1986).

$$F_L = \frac{\pi {d_r}^2}{4} \rho_{rm} L + \frac{\pi {d_p}^2}{4} \rho_{rm} g h + \frac{\pi {d_c}^2}{4} \rho_w H_{st} \tag{3.14}$$

Where,

d_p = piston diameter (m)

ρ_{rm} = density of rod material (kg/m^3)

g = acceleration due to gravity (m/s^2)

d_c = diameter of pipe (m)

ρ_w = density of water (kg/m^3)

h = height of piston (m)

d_r = piston connecting rod diameter (m)

L = length of rod (m)

H_{st} = static head of water (m).

3.2.3.2 **Stress Analysis**

The piston rod diameter can be obtained from the equation given by Hylowenko (1980)

$$\boldsymbol{d_r = \left(\frac{4F}{\pi\sigma_a}\right)^{\frac{1}{2}}} \qquad \textbf{(3.15)}$$

From the equation 3.15,

$$\boldsymbol{\sigma_a = \frac{4F}{\pi d_r^2}} \qquad \textbf{(3.16)}$$

Where

F = weight of water

σ_a = allowable stress which is limited to 45 N/mm²

3.2.3 **Design Calculations**

The following calculations are based on the working principles of the designed machine and the dimensions used are the actual dimensions used for a shallow well.

3.2.3.1 **Volume of Water Displaced (V_d)**

From equation 3.10, volume per stroke is given by

$$V = \frac{\pi d^2 L}{4}$$

Therefore,

$$V_d = \frac{\pi D^2 L}{4} \quad (3.18)$$

From design,

Stroke length, L = 5cm

Diameter of pressure pipe, D = 5cm

$$V_d = \frac{3.142 \times 0.05^2 \times 0.05}{4}$$

$$V_d = 9.8188 \times 10^{-5} m^3 \quad (3.19)$$

3.2.3.2 **Mass of Water Lifted**

The relationship between density, mass and volume shown in equation 3.20, can be used to calculate the mass of water lifted.

$$\rho = \frac{m}{V} \tag{3.20}$$

$$m = \rho V \tag{3.21}$$

Where V≡ V_d and $\rho \equiv \rho_w$

Therefore mass of water lifted m is calculated using equation 3.22

$$m = \rho_w V_d \tag{3.22}$$

Density of water, $\rho_w = 1000\,kg/m^3$

From equation 3.16, $V_d = 9.8188 \times 10^{-5} m^3$

$$m = 1000 \times 9.8188 \times 10^{-5} \tag{3.23}$$

$$m = 0.09819kg \tag{3.24}$$

3.2.3.3 **Weight of Water Displaced**

From the equation,

$$W = mg$$

From equation 3.21, $m = 0.09819kg$

Acceleration due to gravity, $g = 9.81\,m/s^2$

Therefore,

$$W = 0.09819 \times 9.81$$

$$W = 0.9632N \quad (3.25)$$

3.2.3.4 **Water-head per Stroke**

Since the weight, W of water displaced is equal to the force, F causing the water rise, from Archimedes' principle, therefore,

$$W = F \quad (3.26)$$

Hence,

$$F = \rho g A h \quad (3.27)$$

Therefore, the water-head in the delivery pipe per stroke is calculated from equation 3.28,

$$h = \frac{F}{\rho g A_2} \quad (3.28)$$

Where;

A_2 = area of delivery pipe (m^2)

g = acceleration due to gravity (m/s^2)

ρ = density of water (kg/m^3)

$$A_2 = \frac{\pi d^2}{4} \quad (3.29)$$

$$A_2 = \frac{3.142 \times 0.02^2}{4}$$

$A_2 = 3.142 \times 10^{-4} m^2$ (3.30)

$$h = \frac{0.9632}{1000 \times 9.81 \times 3.142 \times 10^{-4}}$$

$h = 0.3125m$ (3.31)

From the above value in equation 3.31, the total number of turns required to lift the water up the delivery pipe immediately before discharge can be calculated.

The height of the delivery pipe used is 2m. If 0.3125m head is achieved per stroke, and only the downward stroke causes water rise, thus, in one turn the same head will be achieved.

Therefore,

If, $0.3125m = 1turn$

Then, $2m = \frac{2 \times 1}{0.3125}$

$= 6.4\ turns$

$\approx 6\ turns$ (3.32)

3.2.3.5 **Total Force Required to Lift Piston**

From equation 3.2, the force due to static head of water can be calculated using the following equation,

$$F_L = \frac{\pi {d_r}^2}{4} \rho_{rm} L + \frac{\pi {d_p}^2}{4} \rho_{rm} g h + \frac{\pi {d_c}^2}{4} \rho_w H_{st}$$

Given data,

$\rho_w = 1000\, Kg/m^3$

$L = 20cm = 0.2m$

$d_r = 12mm = 0.012m$

$d_p = 5cm = 0.05m$

$d_c = 5cm = 0.05m$

$h = 40mm = 0.04m$

$H_{st} = 0.3125m$

$$F_L = \frac{3.142 \times 0.012^2}{4} \cdot 7830 \times 0.2 + \frac{3.142 \times 0.05^2}{4} \cdot 7830 \times 9.81 \times 0.04 + \frac{3.142 \times 0.05^2}{4} \cdot 1000 \times 0.3125$$

$F_L = 0.1771 + 6.0336 + 0.6137$

$$\boldsymbol{F_L = 6.8244N} \quad (3.33)$$

3.2.3.6 **Volumetric Efficiency**

From equation 3.19, the volume per stroke was calculated to be 9.8185×10^{-5} m^3, equivalent to 98.185 cm^3 and this is the same volume attained per unit rise in head. Therefore after six (6) initial turns, the same volume of water is discharged; as such the discharge per second can be calculated from equation 3.34

$$\boldsymbol{Q_t = \frac{V}{t}} \quad (3.34)$$

$$Q_t = \frac{98.185}{1}$$

Therefore,

$$\boldsymbol{Q_t = 98.185\, cm^3/sec} \qquad (3.35)$$

With the actual discharge, Q_a measured as $88\, cm^3/sec$ during testing, the volumetric efficiency, V_e can be calculated as

$$V_e = \frac{8.8}{9.8185} \times 100$$

Therefore,

$$\boldsymbol{V_e = 90\%} \qquad (3.36)$$

CHAPTER FOUR

4. RESULTS AND DISCUSSION

4.1 Presentation of Results

The volumetric efficiency of the machine is 90% from equation (3.36), the force required to lift the piston is 6.8244N from equation (3.33) and the head attained per turn is 0.3125m from equation (3.31). The volume of water displaced per turn is 98.188cm^3 from equation (3.19).

Table 4.1 BILL OF ENGINEERING MATERIALS EVALUATION

MATERIALS	QUANTITY	COST (#)	AMOUNT (#)
Angle Iron	2 Lengths	1500	3000
PVC Pipe	1 Meter	400	400
Hose	2 Meter	150	300
Wheel & Handle	1	1000	1000
Connecting Rod	1	300	300
Cylindrical Bearing	1	500	500
Epoxy Glue	1 Tube	800	800
Pump	1	3000	3000
Bucket & Fittings	1	800	800
Square Rod	1 Piece	300	300
Bolts & Nuts	½ Dozen	30	180
Paint	1½ Litre	1200	1800
Paint Thinner	2 Bottles	150	300

MATERIALS	QUANTITY	COST (#)	AMOUNT (#)
Pipe Fittings	3 Pieces	250	750
PVC Cap	1 Piece	400	400
Clips	2 Pieces	20	40
Valves	2 Pieces	200	400

Total cost = Material cost + Labour cost + Overhead cost (4.1)

Where labour cost = 60% of material cost and overhead cost is 25% of labour cost.

The material cost can be calculated from table 4.1, by summing the amount column.

Therefore Material cost = #14270

Labour cost = $\frac{60}{100} \times 14270 = \#8562$

Overhead cost = $\frac{25}{100} \times 8562 = \#2140.5$

Hence,

Total cost = #(14270 + 8562 + 2140.5)

Total cost = #24972.5 (4.2)

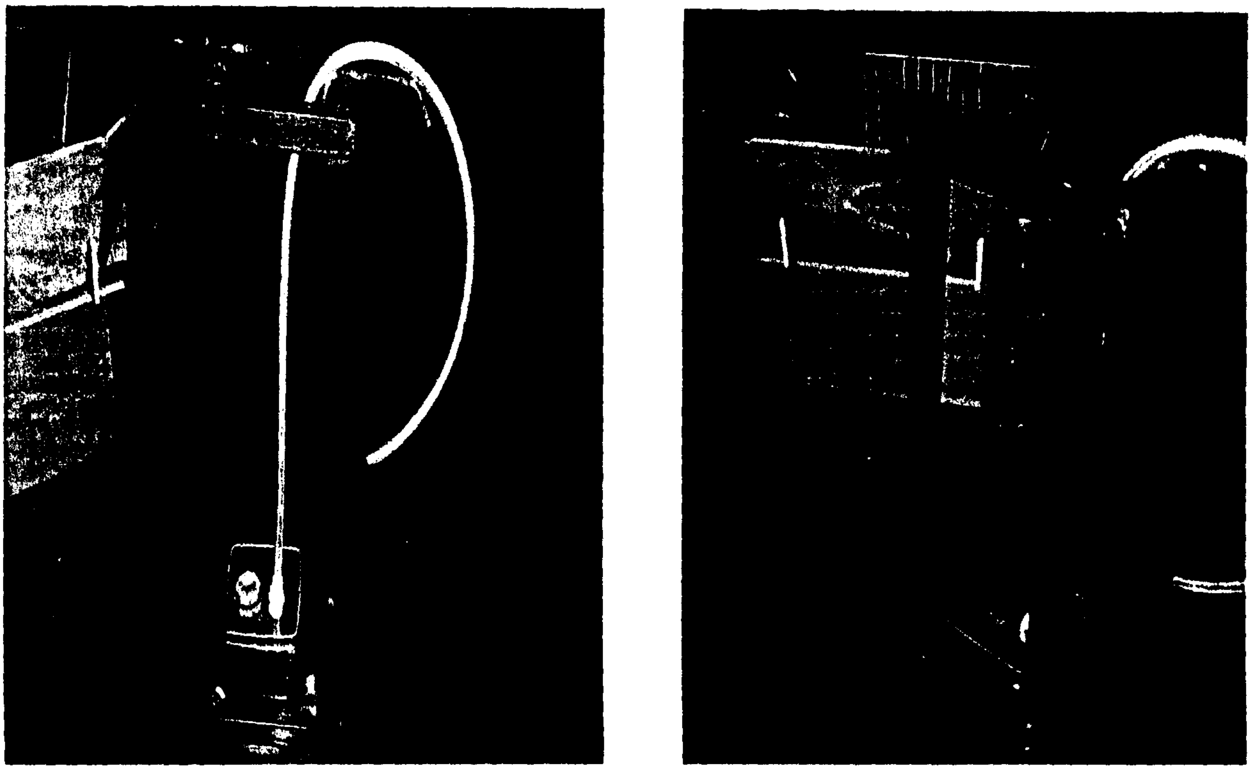


Plate 4.1 Groundwater abstraction model under construction

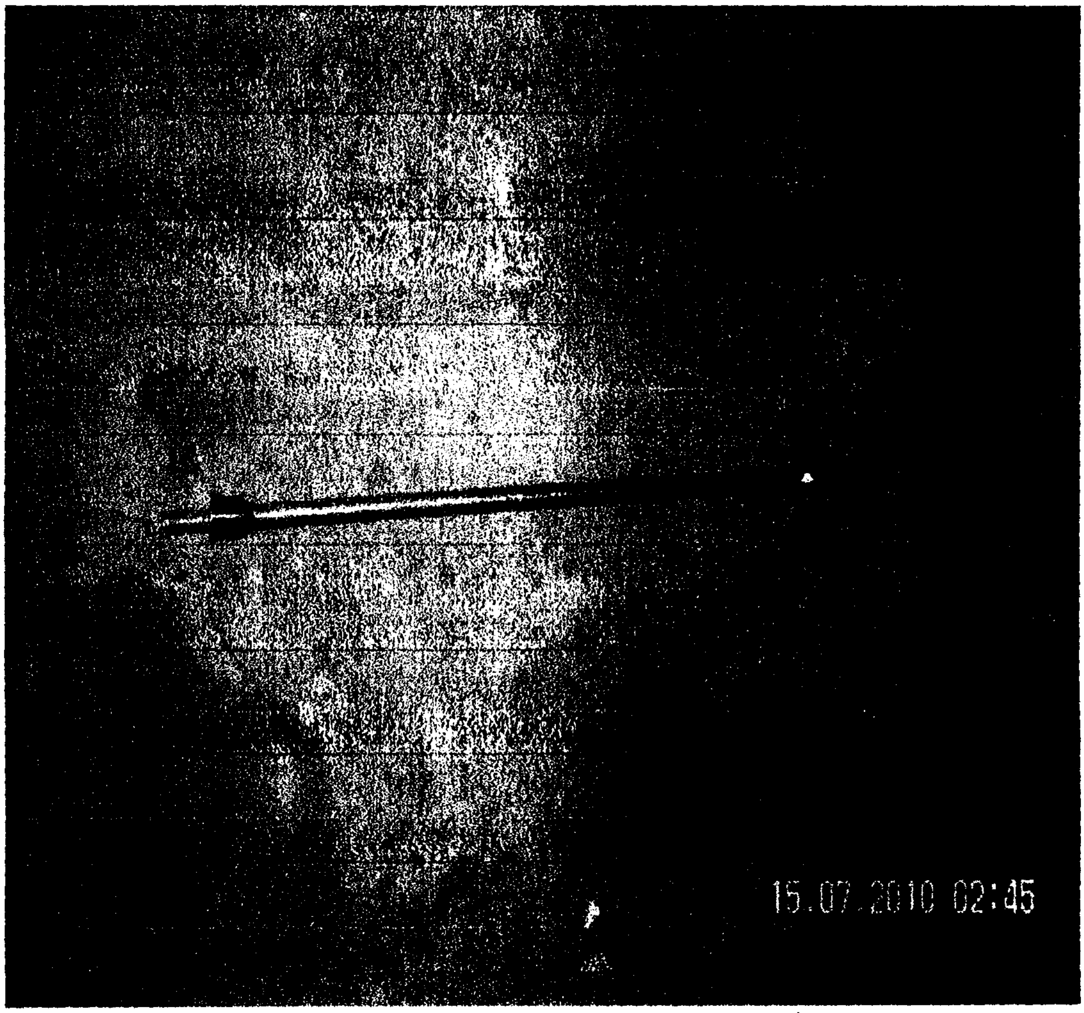


Plate 4.2 Valve component in the pressure pipe

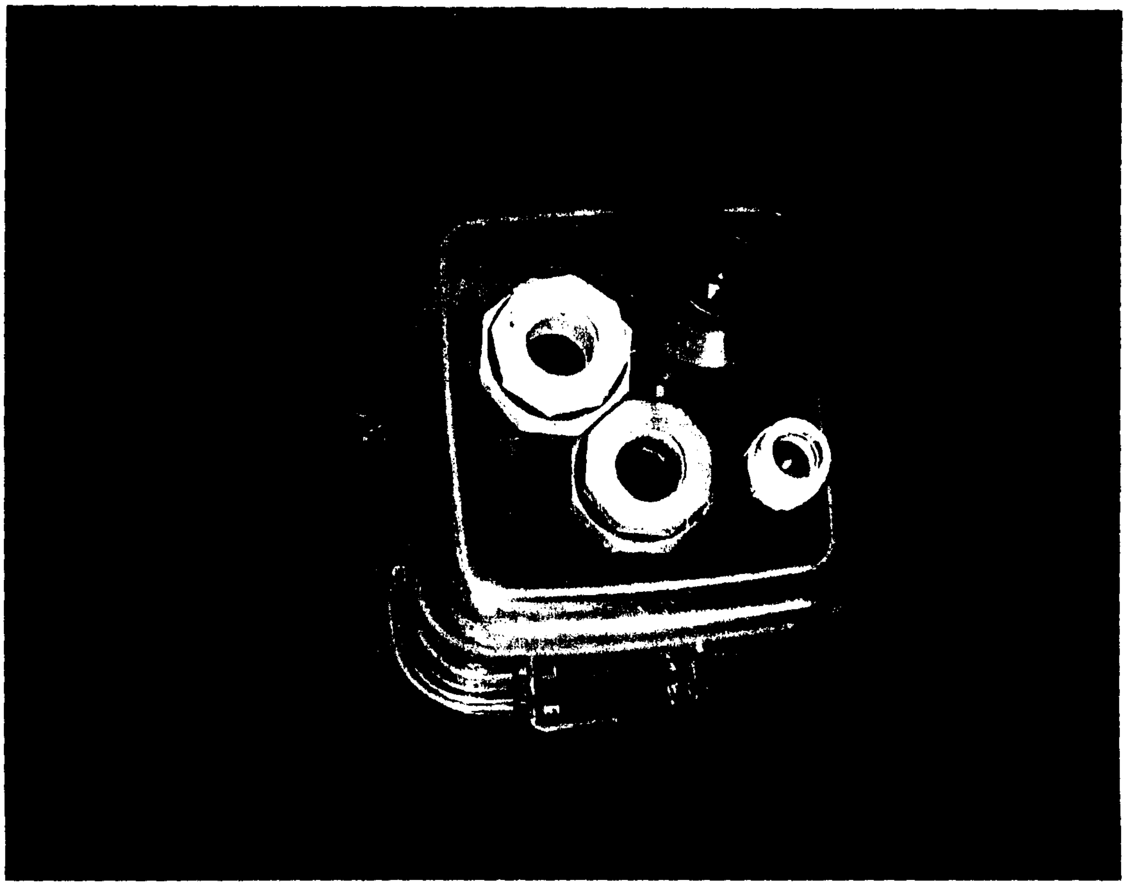


Plate 4.3 Bucket and fittings used in construction.

4.2 **Discussion of Results**

From the calculations in chapter three, the volumetric efficiency was calculated to be 90 percent in equation 3.36; this shows that the model can effectively be adopted for use in shallow wells.

Total force required to lift the piston was 6.8244N and this signifies that a very minimal force is required to turn the wheel. Thereby reducing drudgery and enhancing the ergonomics of the design, as regards pain felt in the arm when withdrawing water from the well.

Equation 3.31 shows that for every downward stroke of the piston, a head of 0.3125m is attained. From equation 3.32, a total of approximately 6 turns will be required to lift the water to the upper end of the delivery pipe, just before discharge. Since the head of water is maintained, further turns will ultimately result to immediate water discharge. This helps to reduce time consumed when scooping water from the well.

The table 4.1 shows the cost evaluation of the materials used and from equation 4.2; we observe that only a minimal cost of 24,972.5 naira is required to develop the model.

4.3 **Limitations**

i. Upthrust buildup by test volume of water was not sufficient to maintain valve opening during downstroke, as a result of higher water pressure on the valve.

ii. Throw length of crank mechanism being 50mm was insufficient to generate a sizeable volume of water displacement per turn.

iii. Using air pressure to displace the water in the well with a manual system is not effective, considering the well has to be completely sealed in order to allow the pressure build up in the well. Also the volume of air delivered per stroke of the piston is insufficient to create the required pressure to displace water in a short time.

CHAPTER FIVE

5. CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The groundwater abstraction model which can be adopted into a shallow well has been designed, constructed and tested, and has proven to be efficient for use especially by rural dwellers and small scale farmers, who cannot afford even a community borehole. Its efficiency is 90%, thus, it will reduce the drudgery as well as cost associated with acquiring portable water for both consumption and other domestic uses. The model shows that the well is to be completely sealed, thereby reducing the rate of pollution and contamination of the withdrawn groundwater.

The machine has been designed with durable and rust resistant materials, thereby affording it a long life span with only minimal maintenance required in order to keep it running in its designed efficiency.

5.2 Recommendations

This design has the following recommendations;

i. Introduction of a motor with a pulley system to turn the wheel instead of the manual operation, as this will go a long way to further reduce drudgery and enhance the ergonomics of the design. But most importantly, it will increase groundwater yield, and;

ii. Further modifications to make it possible to adopt for other types of wells.

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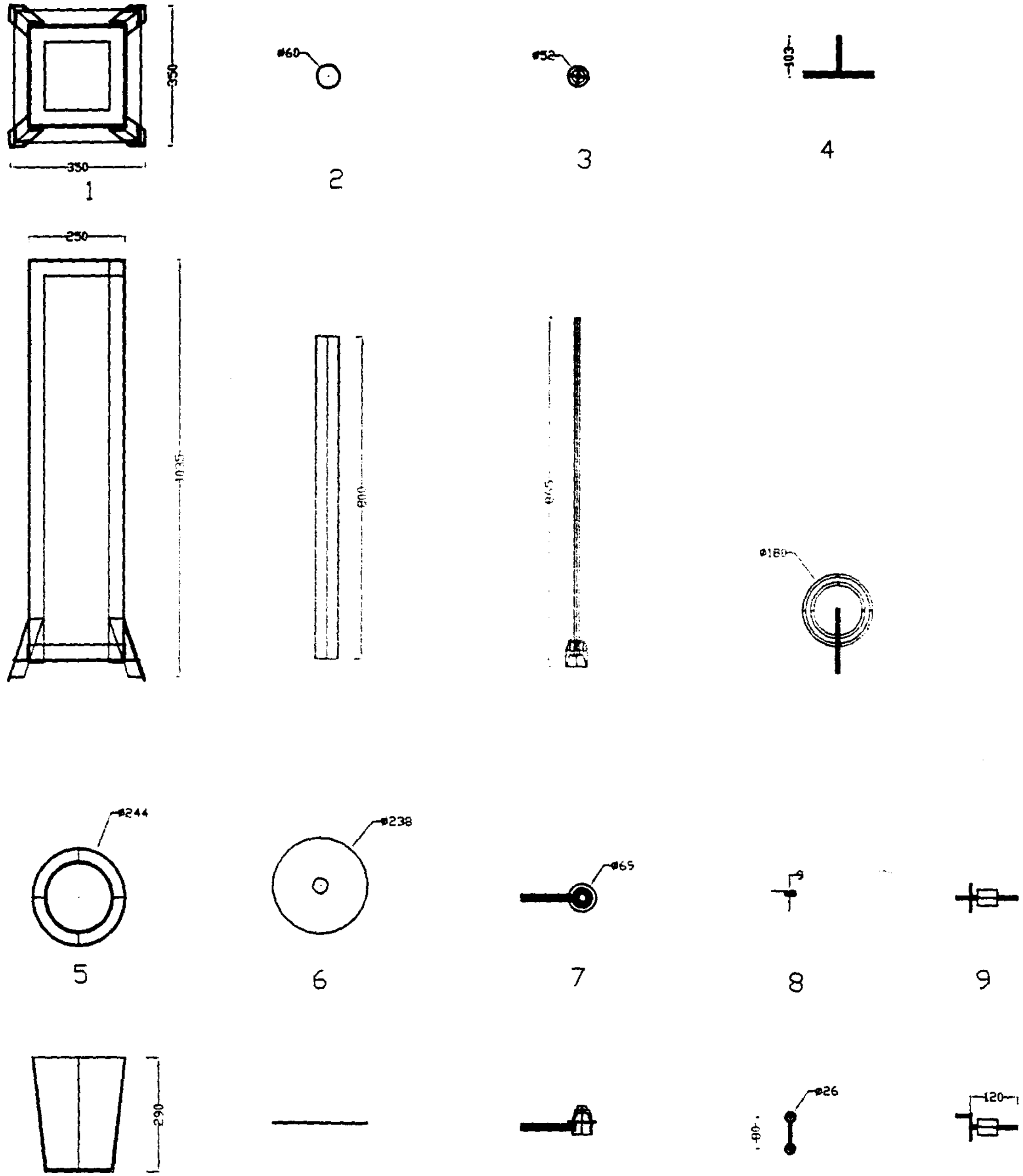
APPENDICES

Quantities Used in Design calculation	Abbreviation
Volume	V
Mass	m
Density	ρ
Acceleration due to gravity	g
Stroke Length	L
Area of suction pipe	A_1
Area of delivery pipe	A_2
Discharge	Q
Water head	h
Weight	W
Force	F
Torque	T
Diameter of delivery pipe	d
Diameter of pressure pipe	D



S/no	PART	MATERIAL
9	BEARING	STEEL
8	CONNECTING ROD	MILD STEEL
7	WATER OUTLET	ALUMINUM
6	COVER	PLASTIC
5	BUCKET	PLASTIC
4	TURNING HANDLE	MILD STEEL
3	VALVE	BRASS
2	PIPE	PVC
1	FRAME	MILD STEEL

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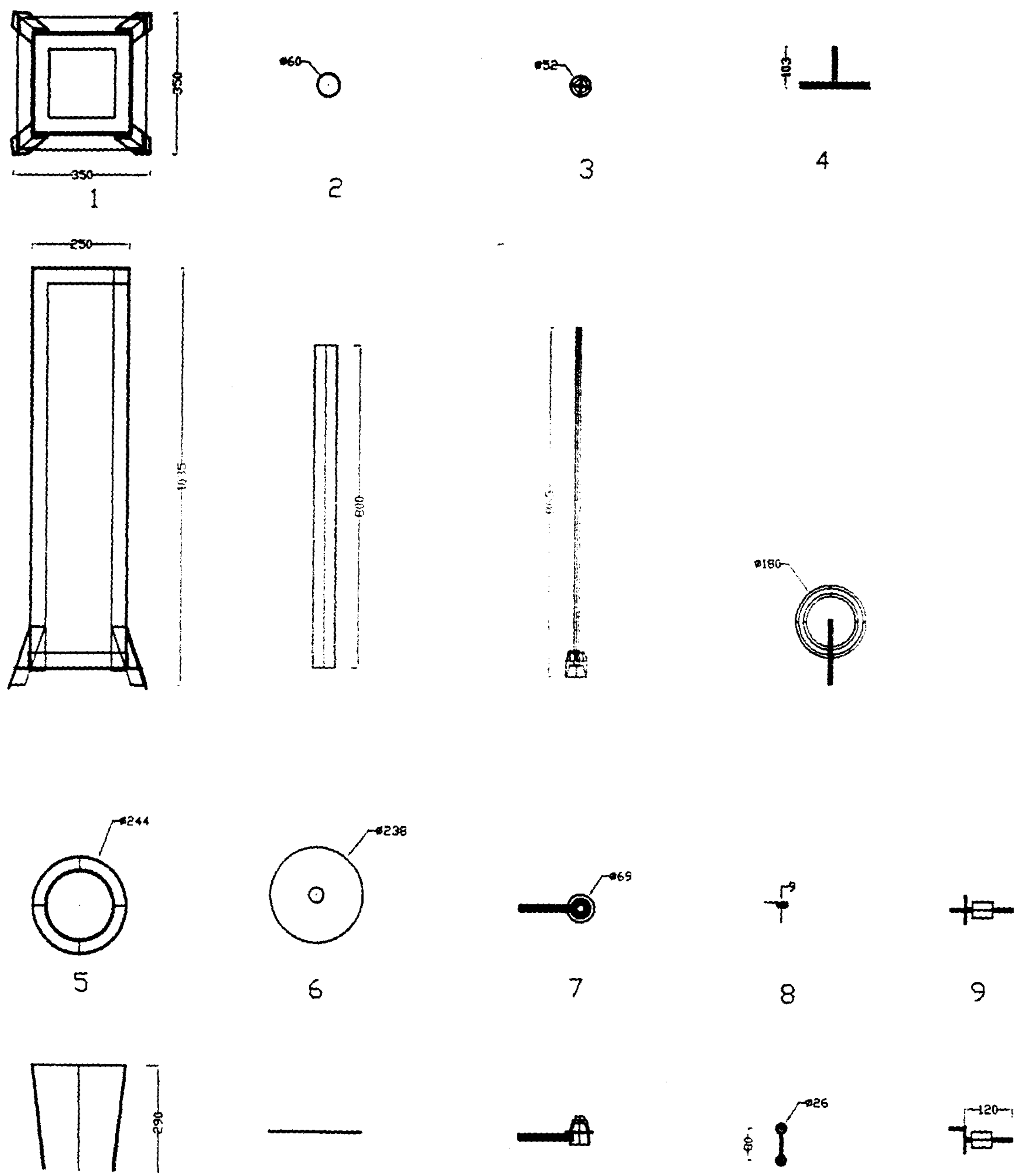

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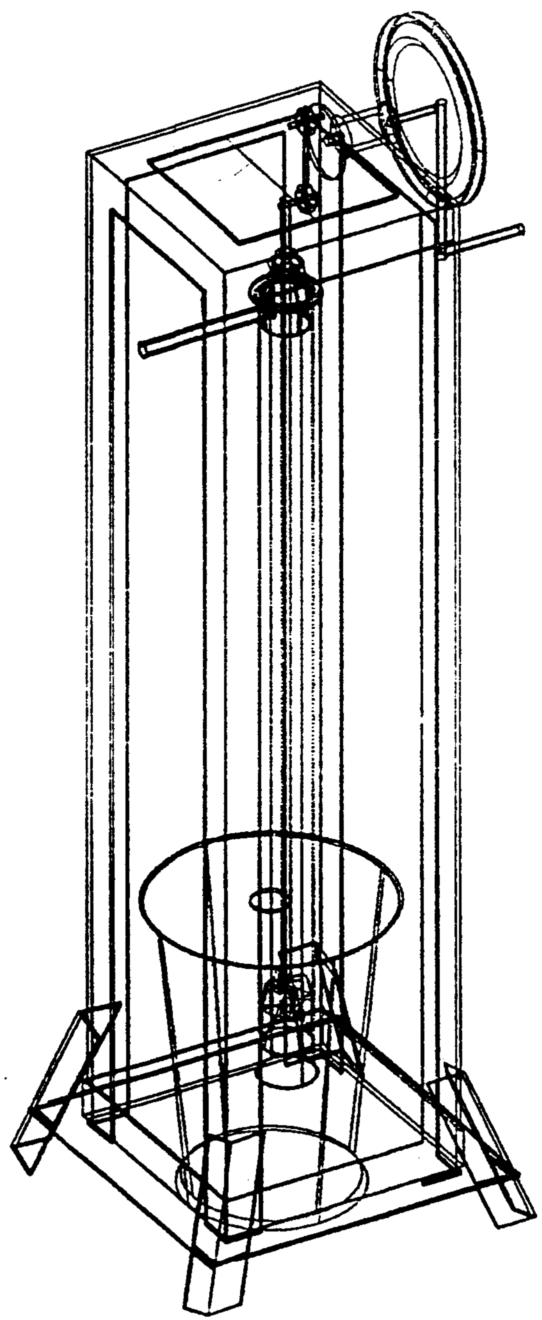

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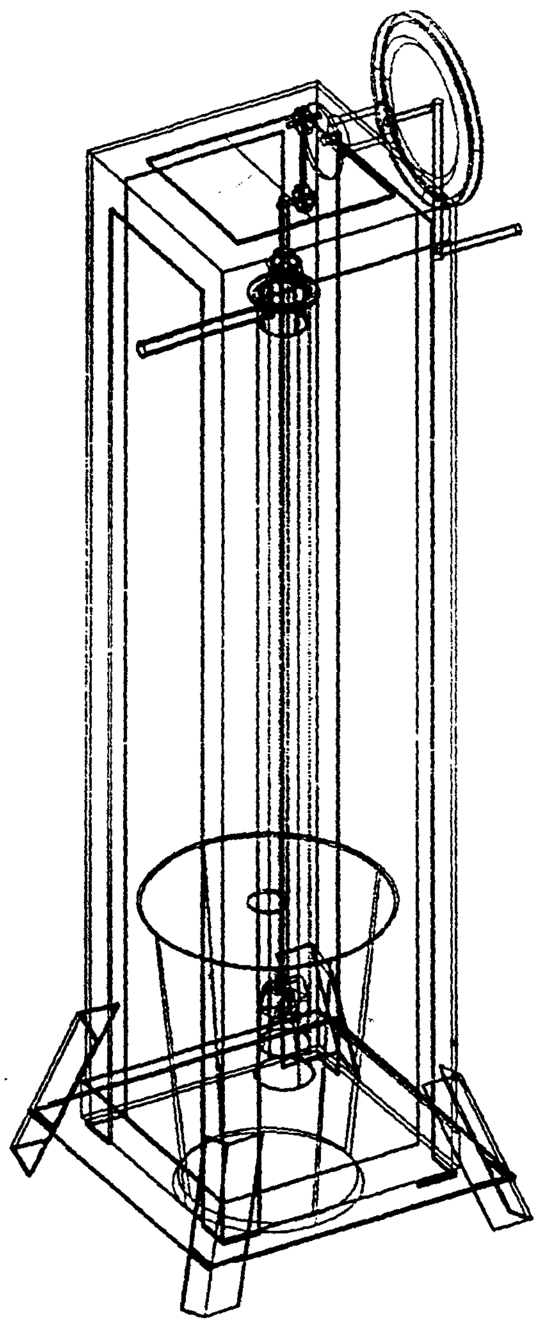

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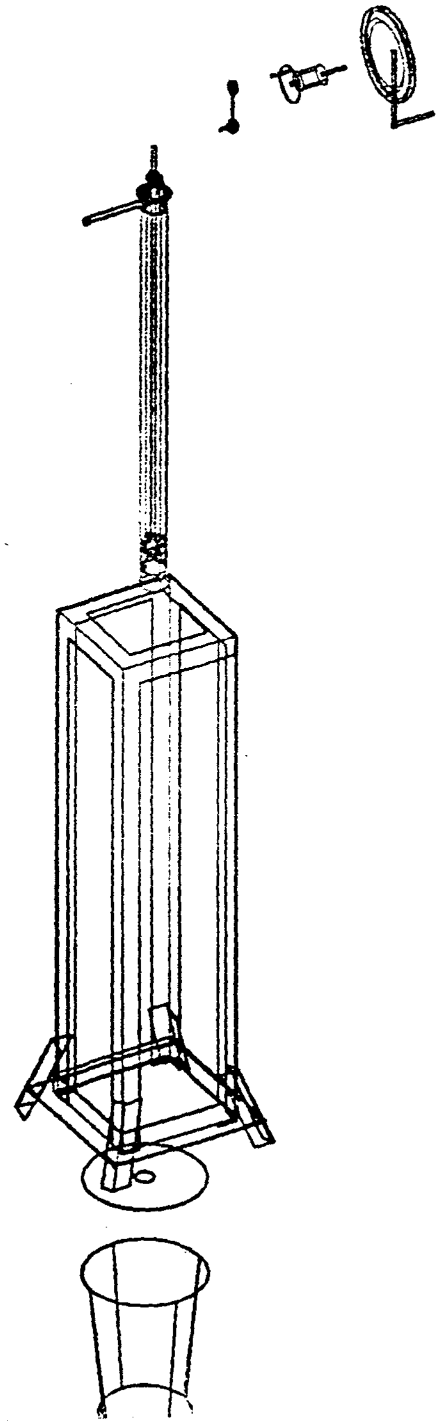

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