# DESIGN AND CONSTRUCTION OF A PORTABLE WATER SPRINKLER

BY

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2003/ 14769EA

**A Project Report Submitted in Partial Fulfillment of the Requirement for the Award of Bachelor of Engineering (B. Eng). Degree in Agricultural and Bioresources Engineering, Federal University of Technology, Minna, Niger state Nigeria.**

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# DECLEARATION

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 Information derived from personal communication, published and unpublished works of others were duly referenced in the text.

03/03/09

BABALOLA O ABDULAFIZ

DATE

2003/ 14769EA

# CERTIFICATION

This is to certify this project titled "DESIGN AND COSTRUCTION OF A PORTABLE WATER SPRINKLER" was carried out by Babalola.O.Abdulafiz under the supervision of Mr. Peter Adeoye and submitted to the Agricultural and Bio-resource Engineering Department, Federal University of Technology Minna in partial fulfillment of the requirement for the award of Bachelor of Engineering (B.Eng) degree in Agricultural and Bio-resource engineering

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Date

External examiner

Date

# DEDICATION

This project is dedicated to Almighty Allah the Alpha and Omega, my creator the one who has given me the privilege to witness this moment, also this project is dedicated to my lovely super mum and dad.

# ACKNOWLEDGEMENTS

My sincere gratitude to Almighty Allah for his mercy, and assistance throughout the course of my studies and for his assurance that it shall be perfectly well with me.

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# ABSTRACT

This work was done to solve problems faced by most farmers in very part of Nigeria. These problems could be deduced as the general situation which most farmers find themselves in irrigating their farm land. A lot of fatigue is imposed on the farmers as a result of the crude constructional mode of the sprinklers since they have to move from one part of the field to another while carrying the heavy sprinkler about. The design and construction of this portable sprinkler should be able to reduce the stress faced by farmers since it design to be light, mobile and durable in construction. It also will prove to be cheap in design, making use of available materials use as P.V.C pipes which as the characteristic of un-corrosiveness and also replaceable. Summing all properties of sprinkler, the evaluation of the sprinkler will be a perfect option of irrigation method. such as the hydraulic efficiency, uniformity co-efficiency and rate of application which is calculated for, from the data gotten when carrying out the experiment.

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# CHAPTER ONE

## 1.0 INTRODUCTION

### 1.1 Background Study

By definition, irrigation is the act of supplying the land or the crops with water by means of rivers, water- channels, overhead pipes or the construction of reservoirs and canals for the distribution of water. Water is a limited natural resource and the most valuable asset to irrigation management and maintenance programs. The availability of water resources varies both in space and in time. Different regions of a country have different amounts of water which can be made available to users; and in the same region these amount of water may vary from season to season and from year to year. This fact is backed up by the earth's hydrologic cycle which keeps water circulating over the year.

In the past, farmers to a large extent depended upon crude implement and tools for their farm-irrigation. However, with the improvement in technology, a lot of modern equipments are developed among which we have the water sprinkler system. Sprinklers are devices used for sprinkling water in form of shower of finer spray onto land surfaces. It may also be used in buildings or households to fight fire outbreak but usually this system is fitted to the house rather than being a mobile portable design, the sprinkler therefore suffer limitation in this regard.

### 1.2 STATEMENT OF PROBLEM

A lot of fatigue is imposed on the farmers as a result of the crude constructional mode of the sprinklers since they have to move from one part of the field to another while carrying the heavy sprinkler about. Thus, the design and construction of a self propelling sprinkler system to eliminate this problem becomes very important. Our design of the water sprinkler system is applicable to small garden, nursery, lawn and small farms. Its source of water is a water tap or an overhead water reservoir. The system has been designed such that the energy of the running jet of water is tapped to trigger the rotations of the sprinkler arms thereby making it self-propelling.

## 1.3 JUSTIFICATION

This is to design and construct a portable head water sprinkler system with a stand to give rigidity with a view to improve upon the crude sprinkler design. In addition, this is to evaluate and producing as cheaply as possible a prototype of the design. Various agricultural development programs have been launched and are being implemented by the federal government of Nigeria so as to ensure sufficient food production, for the entire populace of the nation. As a result of the government participation, peasant farmer are encouraged. However, these farmers are still faced with a number of problems, one of which is inadequate irrigation technique.

This project is therefore intended as a contribution to be agricultural revolution which is foreseen as one of the backbone of our economy in the near future. This project will help to eliminate fatigue imposed on the farmers as it has its own stands. The design should prove to be a very useful and a cheaper means of irrigation as it will lead to local production of the sprinkler, using readily available materials and also stemming down the cost of importation. As a way to increase the productivity of a pleasant farmer, innovation just like this can be a helping tool to assist the farmer.

## 1.4 OBJECTIVES OF THE PROJECT

The objectives of this project are as follows;

1. To design a portable water sprinkler irrigation system
2. To construct the sprinkler irrigation system
3. Conduct a performance evaluation of the constructed irrigation system

## 1.5 SCOPE OF STUDY

This project will be in phases, the basic of machine design would be essential, which are availability of the materials, mechanical properties as well as cost of materials are greatly considered. The first phase would be design consideration with appropriate diagram, next phase the analysis of forces within the members which leads to the construction of the sprinkler. Construction procedure such as cutting, machining and welding will prove to be eminent also the testing the sprinkler will be done to complete the project scope.

# CHAPTER TWO

## 2.1 LITERATURE REVIEW

### 2.1.0 Brief History

Irrigation is the artificial watering of land to sustain plant growth. Irrigation is practiced in all parts of the world where rainfall does not provide enough ground moisture. Earliest records date the first use of irrigation by Egyptians along the Nile River about 5000 BC, by 2100 BC elaborate systems were in use, one of them a 19-km (12-mi) channel that diverted Nile floodwaters to Lake Moeris. The Sumerians relied heavily on irrigation to water fields in southern Mesopotamia (now southern Iraq) as early as 2400 BC. The Chinese had irrigation by 2200 BC. Peruvians also built sophisticated systems before the time of Christ, and early Native Americans at the same time had more than 101,000 hectares (250,000 acres) of irrigated land in the Salt River valley of Arizona. (Bill Grange, 1994)

Agricultural communities exist only in better-water region, that is, areas of highest annual rainfall and along the rivers. This confirmed the early man's total dependency on rainfall. However, as time went on and with the increase in the population of the communities, the early man come to realizes that he would not be able to meet their needs in time , all the year round if they were to solely rely on the natural forces to dictate the farming periods. They found out that food production has to be increased if there was to be continuous existence of mankind. This was how the question of irrigation came up to supplement insufficient seasonal rainfall which to the early man meant manual splashing of water on land.

Irrigation in every early time was practiced by the Eygptians, the Asians and the Indians of North America. For instance, Eygptians claim to have the world largest dam built some 5000 years ago. Many years later the concept of vorag watering-can was developed, areas of civilization came to be associated with communities that are able to feed themselves. In dry areas, such as the southwestern United States, irrigation must be maintained from the time a crop is planted. In areas of irregular rainfall, irrigation is used during dry spells to ensure harvests and to increase crop yields. (Bill Grange, 1994)

Sprinkler irrigation is a method of applying irrigation water similar to rainfall. Water is distributed through a system of pipes usually by pumping. It is then sprayed into the air and irrigate entire soil surface through spray heads so that it breaks up into small water drops which fall to the ground. Sprinklers provide efficient coverage for small to large areas and are suitable for use in all types of properties. It is also adaptable to nearly all irrigation soils since sprinklers are available in a discharge capacity. Sprinklers that spray in a fixed pattern are generally called spays or spray heads. Sprays are not usually designed to operate at pressures above 200kPa, due to misting problems that may develop. Higher pressure sprinklers that rotate around themselves are driven by a ball drive, gear drive, or impact mechanism (impact sprinklers).

These can be designed to rotate in a fall or partial circle. Some sprinklers are also known as floppy sprinkler; spray pop-ups, pulsating sprinklers due to their water stream and revolutionary new concept having no rotating or moving parts. Rain-guns are similar to impact sprinkler, except that generally operate at very high pressure of 275 to 900kPa and flows of 3 to 76L/s, usually with nozzle diameters in the range of 0.5 to 1.9 inches (10 to 50mm). In addition to irrigation, guns are used for industrial application such as dust suppression and logging. Many irrigation sprinklers are buried in the ground along with their supporting plumbing, most irrigation sprinkler are functioned through electric and hydraulic technology and are grouped together in zones that can be collectively turned on and off by actuating a solenoid-controlled valve. Underground sprinklers (Generally used for high end home lawns and garden) function through means of electronic and hydrolic technology.

A 220 volt supplied, or sprinkler box sends a pre-determine 24 volt signal to an awaiting solenoid valve buried in the yard. This valve and the entire sprinkler that will be activated by this valve are known as zone. Upon activation, the solenoid, which sits on top of the valve, is magnetized lifting a small stainless steel plunger in its center. By doing this, the activated plunger allows air to escape from the top of a rubber diaphragm located in the center of the valve. Water that has been charge and waiting on the root of this same diaphragm now has the higher pressure and lifts the diaphragm.

This pressurized water is then allowed to escape down stream of the valve through a series of PVC pipes. Along these pipes and flush to grade level are pre measured and spaced out sprinkler. These sprinklers can be fixed spray heads that have a set pattern and generally spray between 7 and 15 feet, full rotating sprinkler that can spray a broken stream of water from 20 to 40 feet. Or small drip emitters that release a slow, steady of water on more delicate plants such as flowers and shrubs

The importance of good water management shouldn't be under emphasized, with the concepts in the mind from chapter one, it is clear that water for use in irrigation practice must be a measureable quantity due to its scarcity. Harm (1997) described the hydrologic cycle as consisting of a circulation system that brings moisture from the ocean surfaces to land area.

Condensation, cloud formation and precipitation occur over the land and runoff, seepage and evaporation return the moisture to the oceans. This is the hydrologic cycle; with the aid of this cycle water is maintained throughout the year. The hydrological system of the any given geographical area which is comprised of the fluvial erosion system and surface drainage system, makes same areas to have water throughout the season some intermittently while others not having at all.

Information concerning the relationship between water, soil, and plants cannot be utilized irrigation practice without the measurement of water on the field. The accurate measurement of irrigation water permits more intelligent use of it. According to Michael (1998) such measurement tends to reduce excessive waste and allows the water to be distributed among users according to their needs and right. The effect use of water requires that flow rates and volume be measured and expressed quantitatively and this achieved by the use of a water measuring devices. The water measuring device can be employed to accurately measure the quantity of the water obtain at the irrigation water system and distributed among users on the irrigation fields.

It is the data collected from the water meter become the essential planning and management tool for the operation of irrigation water supply scheme it helps to evaluate the performance of the system in detecting any defect or possible change caused by either decreased or increased flows of water or some changes in the system as the result of pipeline leakage, breakage or pump wear. Looking at various irrigation schemes in the some parts of Nigeria someone can easily estimate the huge losses our farmers are often made to encounter on irrigating Agriculture annually. Some of the schemes even if they have one method of water measurement or another are not being put into use due to the technical know-how of their modes of operation that have been lacking or the method itself is too cumbersome to be carried out due to the complication of the meter itself.

A successful irrigation practice can not be achieved without a proper identification of a reliable water source. Irrigation water is obtained from a variety of surface and groundwater source. The surface sources include streams, lakes, reservoir, dams, canals and wasted water while the primary sources for groundwater are the wells and the springs.

To determine whether a particular water source is suitable for a given irrigation method depends on several factors including legal constraints, the quality of the water as well as the ability of the source to supply the total irrigation requirement and seasonally varying irrigation requirement year after year. It is the detailed analysis of the above factors that are required for the determination of the total volume and volumetric flow rate (volume per unit time) that a water source cans reliably year after year (Crocker, 1995).

The following are the different type of irrigation water sources;

I. Surface sources

II. Groundwater sources

### 2.1.1 SURFACE SOURCES OF IRRIGATION WATER

#### 2.1.1a Lakes

Lakes are a surface source of water for irrigation. Gravity, diversion and pumping plants are used to withdraw water from the lake to irrigation field.

#### 2.1.1b Streams

Flowing streams are an important source of irrigation water. Where stream flows are large enough to meet irrigation demands throughout both dry and wet periods, water needed for irrigation could be directly withdrawn from the streams. Gravity diversion structures divert stream flow into open canal and pipeline. Pumping plants are used when it is necessary to lift stream flow to a higher elevation.

### 2.1.1c Water Organization Distribution Facilities

Water delivery facility owned and operated by water user organization are a major source of irrigation water. Irrigators belonging to those organization share construction, operating and maintenance costs of sometimes extremely large diversion dams, reservoirs, canals, pipeline and pumping machines. Diversion structures are used to remove water from the delivery system. (Crocker, 1995).

### 2.1.1d Waste Water Source

Sewage and industries waste water are also being for irrigation especially in the areas where the availability of other water source is limited. The quality of waste water is closely evaluation and frequently checked to protect human health and to prevent damage to the crops.

### 2.1.2 Groundwater Source

Groundwater is the water that occupies the void within the rocks and the soil.

### 2.1.2a Wells

Irrigation well is a conduit that conveys water from an aquifer to the ground surface. Aquifers are portions of the zone of saturation that yield significant qualities of water. They are said to be unconfined if there is water table, while they are confined if there is absence of water table. Drainage wells are wells that penetrate unconfined aquifer, while artesian wells are those that tap confined aquifer. Combination well result when a well obtain water from confined and unconfined aquifer simultaneously. (Crocker, 1995)

### 2.1.2b Springs

Springs are concentrated discharge of ground water appearing at the ground surface as flowing water. Spring can be as a result of non-gravitational forces such as those associated with volcanic rocks and deep fractures in the earth's crust. The composition of spring water varies with the character of the surrounding soil or rocks. Volume of flow of any given spring may vary with the season and amount of rainfall. Seepage springs often fail in periods of drought or little rainfall. Nevertheless, some springs have a fairly constant and even large volume of flow which can be used for irrigation. (Crocker, 1995)

## 2.2 CLASSFICATION OF WATER METERS

The term water meter refers to the several type of devices used for the measurement of the volume of flow or volumetric flow rate in conveyance medium open channels or pipeline. These measuring devices are categorized into two classes namely;

I. Quantity meters

II. Rate of flow meter

### 2.2.1 Quantity Meter

These are the meter that measure the total volume of water that flow through the meter in a given time measured and an average flow rate is obtained by dividing the total volume by time. The units include liters and cubic-meter.

### 2.2.2 Rate of Flows

These are also the class of instruments that measure the actual volumetric flow rate (volume per unit time). Flow rate is measured directly in liters or cubic-meters per seconds.

## 2.3 Methods of Water Flow Measurement and Devices Used

There are two main ways in which water be conveyed to irrigation. These include

I. The use of irrigation pipelines

II. The use of open irrigation channels

### 2.3.1 Flow Measurement In open Channel

The several methods used for measuring flow in open irrigation channels include among others, the volumetric, velocity -area, dilution.

### 2.3.1a Volumetric Method

A simple method of measuring small irrigation streams is to collect the flow in a container of known volume (e.g. an ordinary bucket for a measured period of time). The time required to fill the bucket is recorded with a stopwatch or the second's hand of a wrist watch. The rate of flow is obtained by dividing the volume of the container by the time required to fill it.

### 2.3.1b Velocity-area Method

The velocity-area approach involves measuring the velocity and cross section of the channel and using the following equation to compute the flow rate

$$Q = VA \qquad 2.1$$

Where

V is the velocity of flow

A is the cross sectional area of the channel

Q is the rate of flow of the water in the cannel

### 2.3.1c Dilution Methods

The dilution involves injecting a known amount of a chemical into the flow and measuring its dilution after it has flowed for enough downstream to mix completely with the water and produce a uniform concentration. No measurement of area or distance is required (since the total volume of flow is determined directly). This method is used to measure the discharge in a small channels where a limited number of measurement are required and other method would be impractical or too expensive (James, 1988)

### 2.3.1d Control Sections

This method involves the use of natural or constructed or installed control section with stable depth of flow versus discharge (volumetric flow rate) relationships. Under the control are the natural control, thin plate weirs, flumes and the orifice in pipeline (James, 1988).

### 2.3.2 Flow Measurement in Pipelines

Among the various meters employed for the measurement of volume of flow and the volumetric flow rate in pipelines including the differential pressure meters rotating mechanical meters and the ultra sonic flow meters.

### 2.3.2a Differential Pressure Flow Meters

This group of water metering devices includes venture, pilot, nozzle and orifice meter all of which may be integral with the pipeline formed by special insert. Their principle of operation depends upon the fact that when a field flows through a contraction it must accelerate, causing change consequently there will be a fall in pressure by a corresponding amount in accordance with the principle of conservation of energy. The pressure difference is proportion to the square of the velocity and is traditionally measure by mercury anemometer (Alayande, 1997). The above principle uses the follow equation to compute the pressure difference

$$\delta P = 1/2C \rho V^2 \qquad 2.2$$

Where

$\delta P$ is the change in pressure

$\rho$ is the density of fluid.

V is the velocity

### 2.3.2b Rotating Mechanical in Flow-meter

Those are the flow-meter which normally has a meter that revolves at a speed roughly proportional to the flow rate of the flowing water. The rotor can be a propeller make of metal, plastic or rubber or an axial turbine or vane wheel, all rotating in the vertical planes and geared to a totalized (dial) in such a manner that a numerical counter can totalize the flow in any desired volumetric units. Calculation tests are usually needed to accurately rotate rotor revolution to flow (King, 1998).

### 2.3.2c Ultrasonic Flow-meter

These are the type of device that use beams of ultrasonic to measure flow of velocity and hence volumetric flow rate. Most types of ultrasonic meter depend upon the fact that velocity of sound wave in a moving field is modified. Ultrasonic meter do not obstruct flow and this cause no loss of pressure and do not have mechanical part that wear.

## 2.3 Modern Irrigation System

### 2.3.1 Surface Irrigation System

This is the most widely spread form of modern irrigation technique. Here water is applied directly to the soil. it involves distributing to the soil. It involves distributing water to crops in border strips, check basins and furrows. The more important conditions for obtaining a high efficiency in surface irrigation are; properly constructed water distribution system to provide adequately controlled water to the fields, and proper land preparation to permit uniform distribution of water to the fields.

### 2.3.2 Sub-surface Irrigation System

In this method water is supplied to the root zone of the crop by maintaining an artificial water table at some depth depending upon the soil texture and depth of plant roots. This method depends on the capillary action of water to move to the root zone layer. Water may be introduced through open ditches or underground pipelines.

Sub-surface irrigation is suited to soil having reasonable uniform texture. The basic advantage of this method is that it can be used for soil having low water holding capacity and high evaporation rate.

The limitation however is that water having a high salt content cannot be used.

### 2.3.3 Drip Irrigation System

Drip or trickle irrigation is one of the latest methods of irrigation which is becoming increasingly popular in areas with water scarcity and high salt-content problem. This method, which is used with great success in the United States, Israel, and Australia, ensures a minimum loss of water through evaporation or percolation into the ground.

It involves watering plants in a pre-determined frequency and with a volume of water approaching the conceptive use of plant, thereby minimizing such loses through deep percolation runoff and soil water evaporation (SAVAGE, 1999). In this method, irrigation is accomplished by using small diameter plastic lateral line with a device called "emitters and drippers" at selected spacing to deliver water to the soil surface near the base of the plants. The system applies water slowly to keep the soil moisture within the desire range of plant growth its advantages over the others are as follows; Considerable water saving, It reduces salt concentration in the root zone also fertilizers can be applied through this method, and It saves energy requirement.

However it suffers these limitations as; the initial cost of drip irrigation equipment is very high and this limits its use to large scale farming, and it is not locally available.

## 2.4 SPRINKLER IRRIGATION SYSTEM

This method involves the application of water to land or plant in the form of fine shower (spray). This spray is developed by the jetted water under pressure through small orifices, that is, opening or nozzles. A variety of sprinkler system designs have been developed. The design used is determined by the source of water and the 'head' under which the system operates (HALL, 1997). There are portable rotating head and portable fixed head sprinklers.

The variations in the concept of sprinkler design are more or less determined by the these factors; (i) Area under coverage, (ii) Vegetation to be sprayed, (iii) Pressure and velocity of the water and, (iv) The source of water available.

### 2.4.1 Types of Sprinkler Design

The various types of sprinkler can be grouped into two;

1. Farm irrigation sprinkler.
2. Garden irrigation sprinkler.

#### 2.4.1.1 The Farm Irrigation Sprinkler

This is generally a large installation that requires the use of an infinite source of water a pump to force the water from the main and also serve as a means of controlling the pressure and water flow rate, it has movable feature as a means of moving the installation. It is mostly employed by big farm, many farmers use long, mobile sprinkler lines to water their crops. The primary advantage this irrigation system has over flood and furrow methods is that the flow and distribution of the water is far easier to control. (Bill Grange, 1994)

#### 2.4.1.2 Garden Irrigation Sprinkler

The supply of water for garden sprinkler is usually from the water supply network. This is become they are design to work under low pressure and velocity. They are made from light-weight materials and are generally small compared to the farm irrigation sprinkler.

## 2.5 COMPONENT OF A SPRINKLER IRRIGATION SYSTEM

The component parts of all sprinkler system are generally similar. Pumps provide the needed pressure to distribute the water through sprinkler nozzles. Supply mains and lateral pipelines convey the water to the sprinklers. Sprinkler system is usually composed of perforated pipe or revolving head sprinkler and may be high pressure (2Kg per square cm and more) or low pressure system (1.4Kg per square cm and less). As a rule, a perforated pipe system operates on the ranges, depending on the type of the rotator head used. A perforated pipe sprinkler system sprays the water out of small holes in the upper part of the lateral pipe. (Ojiha and Michael, 2002)

### 2.5.1 CLASSIFICATION OF SPRINKLER IRRIGATION SYSTEM

Sprinkler irrigation system can be further classified into 5 groups base on mode of distribution namely;

i. Perforated pipe system.

ii. Rotating head system.

iii. Semi- permanent system.

iv. Solid-set system.

v. Permanent system.

#### 2.5.1.1 Perforation Pipe System

This method consists of holes perforated in the lateral irrigation pipes in a specially designed pattern to distribute water fairly uniformly. The system is usually designed for low operating pressure of about 0.5 to 2.5Kg/cm$^2$. The pressure is low that the system can be connected to an overhand tank to obtain the necessary pressure head. The system is suited for irrigation of lawns, gardens and small vegetable fields and other plants when the height does not exceed 4 to 60cm.

#### 2.5.1.2 Rotation Head System

Small size nozzles are placed on riser pipes fixed at uniform interval along the length of the lateral pipe. The lateral pipes are usually laid in the ground surface, they may also be mounted on post above the crop height and rotated through 90$^0$, to irrigate a rectangular strip.

#### 2.5.1.3 Semi-permanent System

A semi-permanent system has potable lateral tines, permanent main lines and a stationary water source and pumping plant. The main lines and sub-mains are usually buried with T-joints and valves located at suitable interval. The rise pipes with the rotating heads are fixed on them.

#### 2.5.1.4 Solid Set System

A solid-set system has enough intervals to eliminate their movement. The laterals are positioned in the field early in the crop season and remain there through out the season. The system is used for crops requiring short and frequent irrigations.

#### 2.5.1.5 Permanent System

A fully permanent system consists of mains, sub-mains, laterals and stationary water source and pumping plants. Mains, sub-mains and laterals are usually buried. Sprinklers are permanently located on each riser, such system are costly and are suited to automation of the system with moisture sensing device.

## 2.6 ESSENTIAL OF DRAINAGE

The chief problem caused by continuous irrigation is that of salt accumulating in the upper layers of the soil and stunting or preventing plant growth. Nearly all irrigation water, whatever its source contains some salt, which percolates down to the water-table and makes it increasingly brackish. Where drainage is bad and the water table approaches root level, the concentrated salt makes plant growth impossible. Good drainage systems, therefore, which keep the water table well below the root level and allow water to flush salts through the topsoil, are now understood to be a crucial aspect of a successful irrigation system (Bill Grange, 1994). Drainage helps to reduce the salinity and sodality on land, making the level of water used by the plant roots balanced, the essential principle of any type of land drainage is to provide an open, adequate, and readily accessible channel through which the surface or subsoil water can flow.

# CHAPTER THREE

## 3.0 MATERIALS AND METHODS

### 3.1 Design Consideration

A sprinkler system to suit the conditions of a particular site is specially designed in order to achieve high efficiency in its performance and economy. The following are the specific steps involved in the planning and design of a sprinkler system. (Ojiha and Michael, 2002)

Inventory of resources and condition

i. **Topographic features**; it will comprise of the size shape and topography of the area and other details of the fields. The map should show details of roads, building, trees, and irrigated areas, water source, and possible pump location.

ii. **Water supply**; information on the source, availability and dependability of the water supply is required. It is important that irrigation stream of sufficient size is available to meet the maximum demand of crops. The water should be relatively clean and free of suspended impurities, so that the sprinkler lines and nozzles do not get clogged.

iii. **Climatic conditions**; the consumption use of a crop depend upon the climatic parameters such as temperature, radiation intensity humidity and wind velocity. A sprinkler system is designed for the daily peak rate of consumptive use of the crops irrigated by the system. There are two kinds of losses that take place during sprinkling. One is the evaporating of the spray and the other is interception of the sprayed water by the leaves, stem, and other parts of the plants.

iv. **Soil properties**; a sprinkler head should discharge water only at a rate which could be simultaneously absorbed by the soil. in other words the infiltration rate of the soil should not be lower than the water application rate.

v. **Power source**; the source of power to operate the pump is to be known in advance. Electric power is most convenient when the pump is stationary. Electric pumping sets are cheaper in initial and maintenance costs. Portable diesel engine pumping sets are convenient and practical for fully portable sprinkler system.

### 3.1.1 Depth of Irrigation

The depth of irrigation is calculation on the basis of available moisture holding capacity of the soil in the crop root zone in its different layers and the soil moisture extraction pattern of the crop in the root depth.

## 3.2 System Requirement

The system requirement or the pump capacity is calculated by the following equation.

$$Q = 278 \frac{A \times D}{F \times H \times E}$$

In which

Q = pump discharge, litres/second

A = area hectares

D = depth of application cm

E = field application efficiency (fraction)

F = irrigation interval, days

H = operation period per day hours.

### 3.2.1 Optimum Water Application Rate

The optimum water application rate is determined considering the soil type, crop cover and slope of the land. Optimum water rate can also be determined by actually measuring the infiltration rate of the soil by an Inflitrometer. Rotation cycle or shortest interval of irrigation, this is the time allowable between successive irrigation during the peak consumptive use of the crop.

$$\text{Rotation cycle} = \frac{\text{Total depth of application}}{\text{Rate of application per day}} \text{ (days)}$$

### 3.2.2 Sprinkler Spacing, Nozzle Discharge and Operating Pressure

There are different approaches to solve this problem, one method is to select a sprinkler head first and then the spacing of risers and the laterals. Then the spacing and discharge sprinklers are then determined by "trial and error". A direct approach to this problem is to individual sprinkler by the following formula;

$$q = \frac{(S_1 \text{ x } S_2)I}{1000}$$

q = required average discharge of individual sprinklers $m^3$/hr

I = predicted rate of application mm/hr

$S_1$ = spacing between sprinkler along the lateral (m)

$S_2$ = spacing between position of the laterals (m).

### 3.2.3 Number of Sprinkler

It is economical to select the widest possible sprinkler spacing which gives an acceptable value of uniformity coefficient.

$$\text{Application rate (m/hr)} = \frac{\text{Discharge of sprinkler} \times 360}{\text{Sprinklers spacing (m)} \times \text{lateral}}$$

An optimum combination of sprinkler spacing and lateral suiting the application rate for the soil and wind conditions is selected. Thus, on determination of the water application rate sprinkler head is selected for its nozzle sizes, pressure requirement and the wetted diameter to meet the design requirements.

### 3.2.4 Uniformity Coefficient

The concept "uniformity coefficient $C_u$" developed by J.E Christiansen is suitable to evaluation the efficiency of the sprinkler irrigation system. The Christiansen formula for uniformity coefficient ($C_u$)

$$C_u = 100\,(1.0 - \frac{\Sigma x}{mn})$$

In which;

m= average application rate mm/hr

n = total number of observation points

X = deviation of individual observation from the average application rate (mm/hr)

mn = total of all observations.

A uniformity coefficient of 100%, indicative of absolutely uniform application where as the water application is less uniform with a lower percentage. A uniformity coefficient of 85% or more is acceptable. (Ojiha and Michael, 2002)

### 3.2.5 Hydrualic Efficiency of the System

the hydraulic efficiency of the system is the ratio of the water discharge that passed through the system to the discharge of relating its head losses

$$He = \frac{Q \times 100}{Q + Hl}$$

Where $H_L$ = head losses

He = hydraulic efficiency

Q = water discharged

### 3.3 Steps of Operation

The following basic steps were considered right from the design stage of the sprinkler system;

i. Identification of functional parts

ii. Material selection

iii. Construction procedures

iv. Economic values

#### 3.3.1 The Function Parts

These are identified as follows;

The nozzles were attached to the lateral arms via a P.V.C 90° elbow. These were coupled to the raiser by the bearing that is enclosed in the bearing house. The stem is attached to the hose connecting pipe through a 90° elbow while the hose is attached to water source that will be responsible to power the system into action i.e. issuing out jet of water for the purpose of irrigation or wetting plants. Proportionality in terms of weight and dimensions were taken into consideration as could be seen in the parts list and assembly drawing.

#### 3.3.2 Materials Selection

The choice of materials were based on availability, duration, reliability in service, corrosion resistance, functional limitations machinability and cost effect. However system, the relative importance varies and in cases, some of the factions were ignored.

The table shows the analysis of list of various parts of the portable sprinkler with respect to materials selection for them.

| Serial number | Component parts | Materials used | Justification | Remarks |
|---|---|---|---|---|
| 1 | Nozzles | Mild steel rod | Readily available cheap, strong and easy to machine | Aluminum would have been used because its lightness, rigidity and high corrosion resistance but its use was totally restricted by factor of cost, available in the form of rod and available of spares. |
| 2 | Bearing housing | Mild steel rod | As above | As above |
| 3 | Lateral arm | P.V.C and galvanized cast iron rod | For P.V.C it is light, corrosion resistance, cheap. For galvanized cast iron is readily available with accessories | The lateral have to relate and as such should be light |
| 4 | Upper riser | P.V.C and galvanized cast iron rod | For P.V.C it is light, corrosion resistance, cheap. For galvanized cast iron is readily available with accessories with good machinability | The weight of the bearing housing and other parts above it will be transmitted to the stand through the riser pipe. Hence the need for a material that could withstand compressive load |
| 5 | Lower riser | Galvanized cast iron rod | As above | As above |
| 6 | Stand | Oak wood/ply wood | Rigidity cheap relatively light | The stand has to carry weight of other parts and so it |

| | | | | |
|---|---|---|---|---|
| | | | | must be rigid. |

### 3.3.3 Construction Procedures

A well planed constructional procedure is very important since a component is made up of various parts which will be fitted together. Therefore a sequence of construction was drawn. The sequence below was followed in the construction of parts.

#### 3.3.3.1 Pipe Construction

The pipe construction was divided into two since two different materials were used for piping, that is, Galvanized cast iron and polyvinyl chloride. The galvanized cast-iron pipe which is half inch of 30mm external diameter and 25mm internal diameter, while the polyvinyl chloride pipe is 30mm external diameter and 25mm internal diameter are used.

#### 3.3.3.2 Galvanized cast Iron Pipes

This was used for the upper and lower risers as well as the lateral arms of the sprinkler irrigation system. For the lower and upper risers were cut to length of 380mm and 1080mm respectively by the use of a hacksaw. After this, one end of each riser was threaded to the specified 14 thread per inch so as to fit into the 90°elbow and tee-joint respectively. An M20 die was used for the other end of the lower riser, the other end of the upper riser was turned slightly so that the pipe could be forced into the bearing.

The lateral arms were cut to a length 400mm long each with a hacksaw, and then they were threaded with the specified 14 thread per inch at both end of the pipe where one end will fit into the tee-joint and the other to the nozzles.

#### 3.3.3.3 Poly Vinyl Chloride (P.V.C) Pipe

The half inch P.V.C pipes were cut to the required length of 400mm for the lateral arms and 1080mm for the upper riser by means of a hacksaw, the rough cuts were smoothening out using a file. Since P.V.C pipes make use of special adhesives like tangit which needs to be threaded to fit in the tee-joint and elbow joints.

#### 3.3.3.4 Bearing Housing Construction

The bearing was made from a 2mm mild steel plate of 80mm by 80mm area. It was first turned to a diameter of 70mm with height of 20mm.Both end of the housing was joint by welding (electric arc), a 10mm drill was first used to drill through the rod followed by a 13mm drill. For about 30mm from one end, the 13mm bore was enlarged by means of a boring tool to a 25mm diameter hole.

The 25mm diameter hole was then threaded internally using an M20 tap to allow for the lower riser pipe to screw in, at the other end the housing was step turned down to a diameter of 40mm and a length of 30mm on a lathe. Bearings of 65mm diameter was placed in the housing at the top end because the other end has been welded, oil was added to cause lubrication between the bearings then the top cover was welded on the casing.

#### 3.3.3.5 Nozzles construction

The nozzles were constructed using a nipple, cone like cap, and a flat steel plate. Nipple has a diameter of 25mm, the cone like cap was made from a mild steel of slant height of 16mm, bigger diameter 20mm and small diameter 10mm,The nipple and the cone like cap were welded together, right in front of the specimen a flat steel plate of 40mm diameter was attached to it.

Reason for the steel plate, is when pressured water falls on its surface through the smaller diameter of the cone produces a spray of jetted water. Example of such principle is an herbicide spraying machine nozzle.

#### 3.3.3.6 STAND CONSTRUCTION

The stand consists of the disc made from plywood and the four legs made from oak wood. The plywood is about 2mm thick. It was cut out of square plywood with the use of saw. At the center of the disc a small hole of about 21mm was cut out to allow for the passage of the lower riser which when packed at the sides' stands firm. The legs are of about 5mm square dimension and a length of 300mm

### 3.4 Assembly

The sprinkler parts were assembled starting from the house connection pipe to the nozzles. Before assembly of the parts, the nozzles and the whole of the bearing housing were painted with a glossy black paint to prevent corrosion.

Starting with the hose connection pipe, this was screwed to a 90°elbow with yarn and potty taped round the threaded end using a spanner of size 19, using the same procedure the lower riser was screwed to the other end of the elbow. The lower riser was than passed through the 21mm hole at the center of the stand disc this (lower riser) was also screwed to the stand through the plate attached to it firm structure. The bearing was press fitted into the bearing housing and then the bearing housing consisting the bearing was already welded to the lower riser using electric arc welding.

The upper riser's unthreaded end was forced fitted into the bearing while the threaded part was screwed to the tee-joint using yarn, potty and spanner as before. The lateral arms are screwed to the nozzles and their other ends screwed to the tee-joint galvanized cast iron already having the other part of the sprinkler. The yarn and the potty used at the joints were to eliminate leakage of water when the sprinkler is in operation, this give the complete assembly of the sprinkler irrigation system.

# CHAPTER FOUR

## 4.0 Results and Discussion

### 4.1 Principle of Operation of a Sprinkler Irrigation System

The sprinkler irrigation system makes use of fluid kinematics which is a branch of fluid mechanics which deals with the study of velocity and acceleration of the particles of fluids in motion and their distribution in space without considering any force and energy (Rajput 2002). The motion of fluid can be described fully by an expression describing the location of a fluid particle in space at different time thus enabling determination of the magnitude and direction of velocity and acceleration in the flow field at any instant of time.

In nutshell it is the flow of water through pipes, this is, starting from the connecting pipe to which a hose is attached by means of a clip from the tap. This pipe delivers the water from the tap into the lower riser via a $90^0$ elbow; the elbow which is screwed at one end to the connecting pipe and at the other end to the lower riser serves to change the direction of flow from horizontal to vertical up the riser. The upper riser which is screwed to the lower riser at one end and the other to the tee joint which was connected to the lateral arms diverts the water into two way paths through the lateral arms, having an equal velocity flowing through the pipes (continuity of flow). The water is now ejected from the nozzles with a greater velocity which the nozzles have smaller diameter.

## 4.2 RESULTS

Test operation was carried out on the constructed model using a reservoir of water as a source of water supplied to the sprinkler. Regarding function-ability, data were taken on the source of water used in order to measure the velocity of water discharged at the outlet of the source. To achieve this, a container of a known capacity was filled repeatedly with water from the outlet and the time taken for each experiment and other values are shown in the table below using a stop watch.

Table 4.1: Velocity at Water Source

| Experiment NO | Volume timed ($m^3$) | Average time in seconds | Tap outlet area ($m^2$) | Quantity of water discharge ($m^3/s$) | Velocity (m/s) |
|---|---|---|---|---|---|
| 1 | $6.6 \times 10^{-3}$ | 9.20 | $3.142 \times 10^{-4}$ | $7.17 \times 10^{-4}$ | 2.28 |
| 2 | $6.6 \times 10^{-3}$ | 8.87 | $3.142 \times 10^{-4}$ | $7.44 \times 10^{-4}$ | 2.37 |
| 3 | $6.6 \times 10^{-3}$ | 9.40 | $3.142 \times 10^{-4}$ | $7.02 \times 10^{-4}$ | 2.23 |
| Arithmetic mean | $6.6 \times 10^{-3}$ | 9.16 | $3.142 \times 10^{-4}$ | $7.21 \times 10^{-4}$ | 2.29 |

$$Q = \frac{V}{t}$$

Where V = volume of water a source ($m^3$)

t = time taken in seconds

$$v = \frac{Q}{A}$$

A = cross sectional area of the tap ($m^2$)

V = velocity at exist of the tap (m/s)

Utilizing the data above the effectiveness of the nozzles was calculated as could be seen in the appendix. Furthermore, other tests were carried out on the water sprinkler itself in order to determine both its area of coverage and the difference between the velocity and the volume of the nozzles. The table below shows the data taken from the experiment by varying the pressure from the tap.

Table 4.2; Distance covered and Volume collected

| Test | Time taken (min) | Source pressure ($kN/m^2$) | Diameter covered (m) | Volume collected ($m^{-3}$) |
|---|---|---|---|---|
| 1 | 5 | 59.8 | 8.6 | 18 |
| 2 | 5 | 55.5 | 7.3 | 17 |
| 3 | 5 | 64.7 | 10.5 | 19 |
| Average | 5 | 60.7 | 8.8 | 18 |

Some assumptions were made to aid the solutions which were;

I. The fluid is incompressible

II. The force and energy are negligible;

The Reynolds's number could be calculated as $Re = \frac{\rho D v}{\mu}$

Where $\mu$ = viscosity of water = 0.798 (from appendix)

D = diameter of pipe = 33mm

$$Re = \frac{1000 \times 2.25 \times 0.33}{0.798}$$

$Re = 94.70$ which $Re < 2000$ flow is laminar.

Using the average figures from the data, the area covered by the nozzles is calculated as;

$$\text{Area 'A'} = \frac{\pi D^2}{4}$$

$$A = \frac{8.8^2 \pi}{4}$$

$$A = 60.83 m^2$$

### 4.3 Discussion

It could be observed from the tables above that increase in the pressure of water cause an increase in velocity and the distance covered by the sprinkler. Also the volume collected from point of observation decreases, this is to say pressure is directly proportional to velocity at the outlet of the nozzles, inversely proportional to that of volume collected

**Maintenance procedure**

Having carried out all the necessary construction on the project, we still believe that a lot could still be done to make it more durable, the following maintenance procedure is encouraged;

I. The sprinkler should be carefully carried from one place of use to another instead of being dragged.

II. Use only the stand to carry the sprinkler system.

III. The arms should not be used as rack or hanger and should not be rested upon.

IV. Periodically cleaning of the nozzles should be done to avoid clogging.

Fig 4.1: Showing the sprinkler in operation

FIG 4.2: Showing the complete assembly of the portable sprinkler

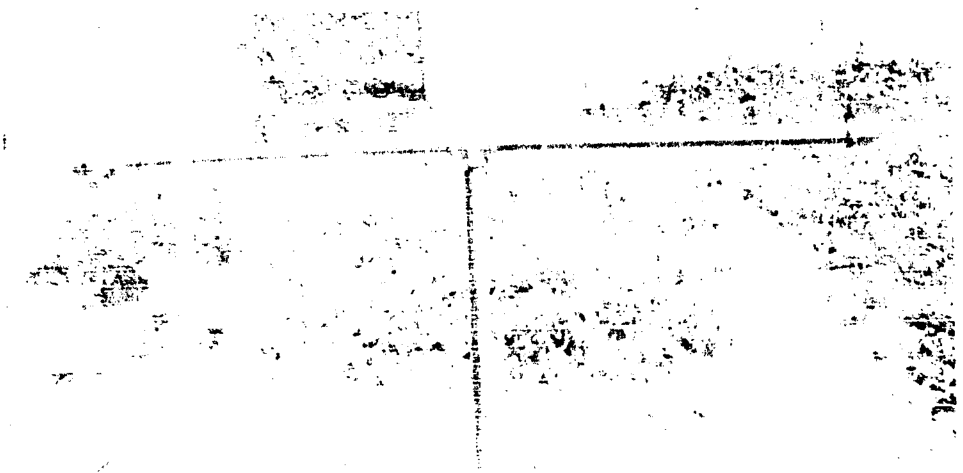

Fig 4.3 Showing the sectional view of the sprinkler (reverse angle)

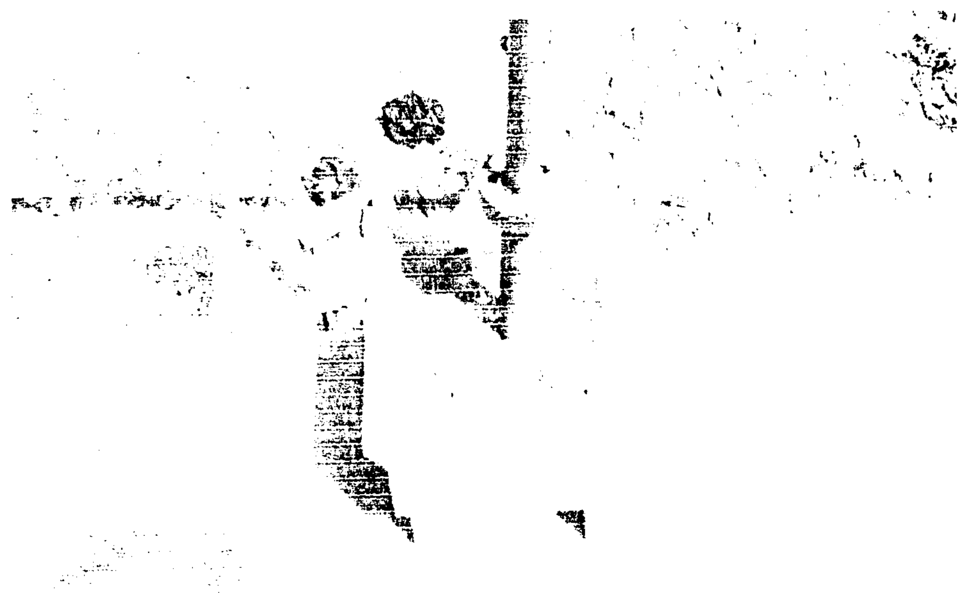

Fig 4.4: Showing the sectional view of the sprinkler (top view)

# CHAPTER FIVE

## 5.0 CONCLUSION AND RECOMMENDATION

### 5.1 Conclusion

The project has been designed, constructed and tested which give a satisfactory result needed to meet water requirement of garden plants or lawns of residential home with uniformity co-efficiency of 84% gotten from the appendix. Also the hydraulic efficiency of the sprinkler highly considerable in operation. This could be deduced to a conclusion that this project is creditably good enough to meet the statement of Bachelor in Engineering (B. Eng).

### 5.2 Recommendations

In order to obviate the problems we encountered during construction we would recommend that:

**On Improvement**

I. For easy movement and portability the legs of the stand should be provided with wheels, so that it could be rolled along the ground intend of being carried.

II. The dimensions of the parts may be increased for larger area coverage or height of water application.

III. This project is open to further modifications to aid its rate of water application on the farm

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# APPENDIX A

| Temperature °C | Density | viscosity | Kinematic viscosity | Specific weight | Surface tension | Vapour pressure | Modulus of elasticity |
|---|---|---|---|---|---|---|---|
| 0 | 999.8 | 1.781 | 1.785 | 9.805 | 0.0756 | 0.61 | 1.98 |
| 5 | 1000 | 1.518 | 1.519 | 9.807 | 0.0749 | 0.87 | 2.05 |
| 10 | 999.7 | 1.307 | 1.396 | 9.804 | 0.0742 | 1.23 | 2.10 |
| 15 | 999.1 | 1.139 | 1.139 | 7.98 | 0.0735 | 1.70 | 2.15 |
| 20 | 998.2 | 1.002 | 1.003 | 9.789 | 0.0728 | 2.31 | 2.17 |
| 25 | 997.0 | 0.892 | 0.893 | 9.777 | 0.0720 | 4.17 | 2.22 |
| 30 | 995.7 | 0.798 | 0.800 | 0.0712 | 9.764 | 3.24 | 2.25 |
| 40 | 992.2 | 0.653 | 0.658 | 9.730 | 0.0696 | 7.38 | 2.28 |
| 50 | 988.0 | 0.547 | 0.554 | 9.689 | 0.0679 | 12.33 | 2.29 |

Produced by Simon (1997)

| Pipe surface | Equivalent sand grain roughness |
|---|---|
| Wrought iron steel | $0.46 \times 10^{-4}$ |
| Galvanized iron | $1.52 \times 10^{-4}$ |
| Cat iron | $2.60 \times 10^{-4}$ |
| Riveted steel | $9.90 \times 10^{-4}$ |

Produced by Simon 1997

# APPENDIX B

According to S. Chand (2000) whenever a fluid is in motion, its innumerable particles move along certain lines depending upon the conditions of flows. This could be express as below;

I. Path line shows the direction of particle as it moves ahead, in general this is the curve in three dimensional space.

II. Streamline is an imaginary line within the flow so that the tangent at any point on it indicates the velocity at that point. Equation of a streamline n the three dimensional flow is given as

$$\frac{dy}{v} = \frac{dx}{u} = \frac{dz}{w}$$

**Continuity Equation**

The continuity equation is based in the principle of conservation of mass. It states as follows if no fluid is added or removed from the pipe in any length than the mass passing across different sections shall be same

$$\rho_1 A_1 v_1 = \rho_2 A_2 v_2$$

**Pressure**

The intensity of pressure of a liquid may be expressed in the following two ways as a force per unit area (Pa) and as an equivalent static head (meters)

**Absolute and Gauge Pressure**

Gauge pressure is the pressure measured with the help of pressure measuring instrument in which the atmospheric pressure is taken as datum. Mathematically;

$$\text{Absolute pressure} = P_{atm} + P_{gauge}$$

Atmospheric pressure is 101.3m of water, 760 of mercury

**Atmospheric Pressure**

The atmospheric air exerts a normal pressure upon all surfaces which it is in contact with and it is know as the atmospheric pressure

# APPENDIX C

Estimation of the pressure and velocity along the pipe work connection at different points.

Applying Bernoulli equation between points (0) and (1) where (0) is the level in the reservoir and (1) the height of the tap from ground.

$$\frac{Po}{\rho g} + \frac{Vo}{2g} + Z_0 = \frac{P1}{\rho g} + \frac{V1}{2g} + Z_1 \text{ ---------(1)}$$

Where $Z_0 = 5.38$m

$V_0 = 0$

$P_0 = 0$ (at atmospheric pressure)

$P_1 = ?\text{N/m}^2$

$V_1 = 2.29$m/s

$Z_1 = 0.8$m

'rom equation (1)

$$5.38 = \frac{P1}{\rho g} + \frac{(2.29)^2}{2 \times 9.81} + 0.8$$

$$P_1 = 9.81 \times 10^3\{5.38 - (\frac{5.2441}{19.62}) - 0.8\}$$

$$P_1 = 9.81 \times 10^3(4.313)$$

$$P_1 = 42.7 \text{ kN/m}^2$$

t (1); $V_1 = 2.29$m/s

$D_1 = 11.65mm$

$P_1 = 42.7\ kN/m^2$

.t point 2 $V_2 = ?m/s$

$D_2 = 18mm$

pplying continuity equation between points 1 and 2

$= A_1V_1 = A_2V_2$ ---------------(2)

$_2 = \frac{A_1V_1}{A_2}$

here $A = \frac{\pi}{4}D^2$

$_2 = \frac{(D_1)^2\ V_1}{(D_1)^2}$

$_2 = \frac{0.01165^2\ X\ 2.29}{0.018^2}$

$= 0.95m/s$

point 3; $V_3 = ?m$

$D_3 = 16mm$

m equation (2) above,

$V_2 = A_3V_3$

$= \frac{A_2V_2}{A}$

$= \frac{(D_2)^2V_2}{(D_3)^2}$

$V_3 = \frac{0.018^2 \times 0.95}{0.016^2}$

$V_3 = 1.22m/s$

At point 4 $D_4 = 16mm$

$V_4 = V_3 = 1.22m/s$

It is necessary here to consider the separate head water loss between points 1 and 2

$h_{12}$ = separation loss = $\frac{(V_1 - V_2)^2}{2g}$

$h_{12} = \frac{(2.29 \times 0.95)^2}{2 \times}$

$h_{12} = 0.092m$

At point 3 $h_3$ = sharp entry loss (at elbow)

$h_3 = \frac{K}{2g} V_3$ -----------------(4)

K = co-efficient of friction from dynamic viscosity table = 0.5

$h_3 = \frac{0.5 \times 1.22}{2 \times 9.81}$

$h_3 = 0.03m$

At point 4 head loss at elbow heading

$h_4 = \frac{K_p}{2g} V_4$

$K_p = 0.9$

$h_4 = \frac{0.9 X 1.22}{2 \times 9.81}$

$h_4 = 0.056m$

Applying the energy equation between points 1 and 5

$$E_1 - L_{15} = E_5 \text{ ---------------(5)}$$

Where $E_1 = \frac{P_1}{\rho g} + \frac{V_1^2}{2g} + Z_1$

$$E_5 = \frac{P_5}{\rho g} + \frac{V_5}{2g} + Z_5$$

$L_{15} = h_{12} + h_3 + h_4$ (losses in the system due to friction)

$$\frac{42.7 X 10^3}{9.81} + \frac{2.27^2}{9.81 X 2} + 1.013 - (0.092 + 0.03 + 0.056) = \frac{P_5}{\rho g} + \frac{1.22^2}{2 X} + 0.8$$

$$5.63 - 0.178 = \frac{P_5}{9.81 X 10^3} + 0.875$$

$P_5 = (9.81 X 4.577)10^3 - 0.875$

$P_5 = 44.9kN/m^2$

At points 6 and 7 $D_6 = D_7 = 16mm$

$$V_6 = V_7$$

Applying continuity equation between points 5, 6 and 7

$Q = A_5V_5 = A_6V_6 + A_7V_7$

$V_5 = 2V_7$ since $A_5 = A_6 = A_7$

$V_7 = \frac{1.22}{2}$

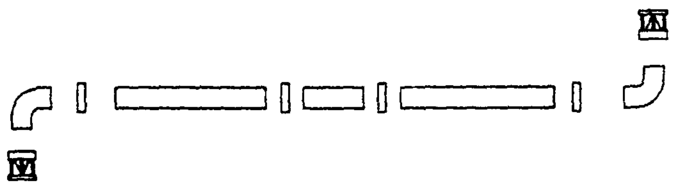
$V_7 = 0.61 m/s$

At point 8 (Nozzle exit); $D_8 = 8mm$

$A_6V_6 = A_8V_8$

$V_8 = \frac{0.016^2 \times 0.61}{0.008^2}$

$V_8 = 2.44 m/s$



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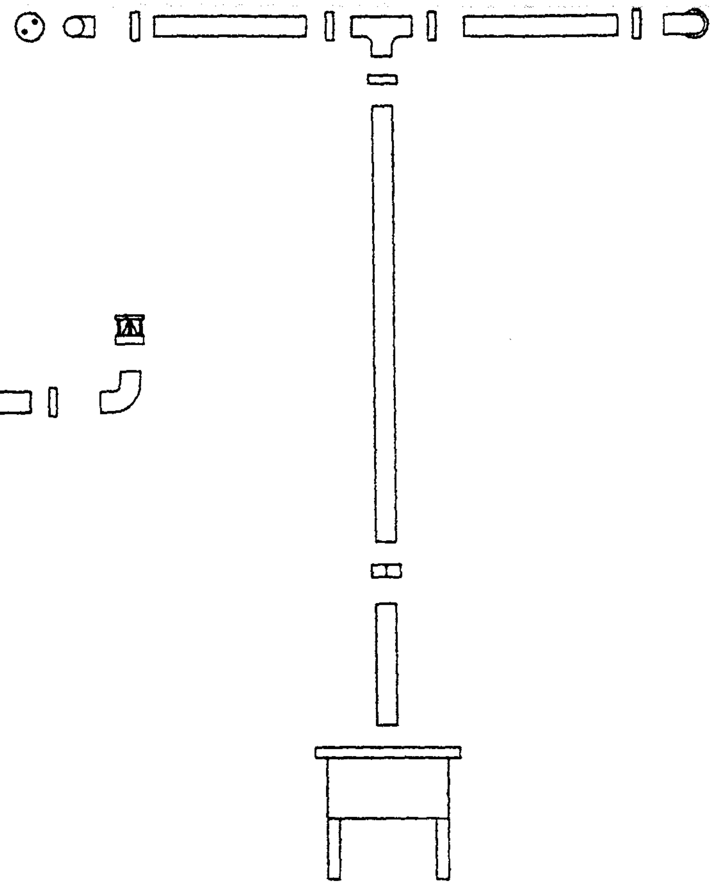
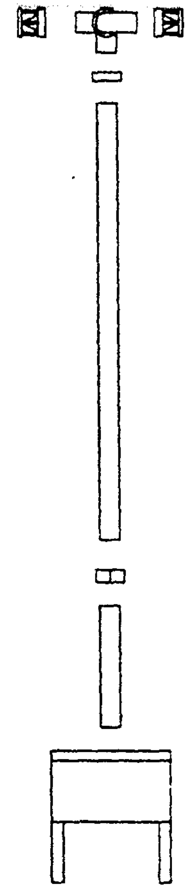


FRONT ELEVATION



SIDE ELEVATION

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| MATRIC NUMBER; 2003 / 14769EA |
| DEPARTMENT; AGRIC AND BIORESOURCES |
| LECTURER; MR. P ADEOYE |
| APPROVED BY; DO |
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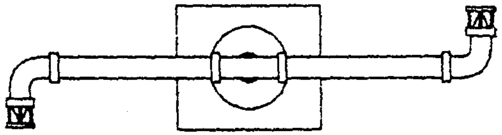

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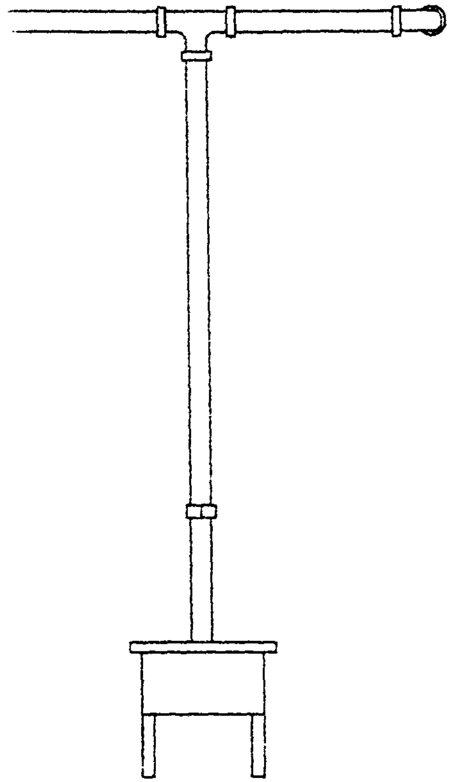

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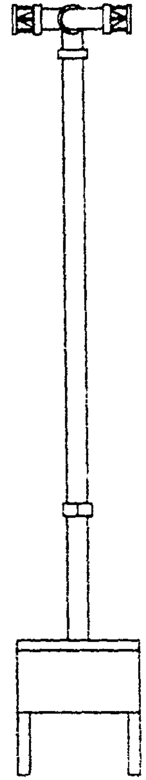

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