African Journal of Engineering Research and Development, Volume 2, Number 1, 2009

DESIGN, FABRICATION AND PERFORMANCE EVALUATION OF A SPRINKLER SYSTEM

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ABSTRACT

Keeping lawns and gardens green in the dry season is very difficult. In many establishments, irrigation has been carried out manually. The objective of this project is to design and produce a sprinkler system to irrigate as required. A sprinkler system with an output capacity of 1.42 litres/sec, was designed, fabricated from aluminium and tested. A one horse power pump was selected to accommodate more heads. The sprinkler radius of throw (r) and wetted diameter of coverage (D) were 7m and 14m respectively. The wetted area covered by the sprinkler system was approximately 150m^2. The optimum performance of the sprinkler system was at the trajectory angles of 18^0 to 24^0. During testing, an average uniformity coefficient of 85 and percentage distribution uniformity of 90% were attained.

Keywords: Sprinkler, Riser, Irrigation,

INTRODUCTION

Irrigation generally is defined as the application of water to the soil for the purpose of supplying the moisture essential for plant growth (Michael, 1986). A sprinkler system is one of the irrigation methods in general application and it can be defined as a system which develops a spray by the flow of water under pressure in order to supply the essential moisture for plant growth. Sprinklers can be a good investment when properly designed, installed, and managed. The parts of all sprinkler systems are similar in most respects. They consist of the pump to provide the needed pressure, the main pipelines and laterals, risers and sprinkler heads (Vaughn, 1980). The sprinkler head is the most important component of sprinkler irrigation. Its operating characteristics under optimum water pressure and climatic conditions, determine the suitability and efficiency of the system. There are two major types of sprinkler heads: the rotary head and the spray head (ASAE, 2001). Rotary heads move in a circular manner and throw water longer distances than spray heads that throw water in a rectilinear manner. Spray heads may further be divided into two types: Impact Driving Heads which use the stream of water that throws the sprinkler patterns to bump a spray load arm which slowly turns the sprinkler heads and Gear Driven Heads in which water turns a series of gears in the sprinkler body causing the sprinkler head to rotate in a slow manner (Featherstone, 1985). Nozzles are used to determine a fluid's flow rate through a sprinkler. The ISA 1932 nozzle was developed in 1932 by the International Federation of the National Standardizing Association (later succeeded by the International Organization for Standardization or (ISO) (ASME, 1971).

Material Selection and Testing Procedure

Materials for the construction of the sprinkler head were selected based on availability of material, resistance to corrosion, lightness, low cost, good strength-to-weight ratio and castability. This is with a view of reducing the overall cost of production. Aluminium was used for the fabrication of the body, stem, driving nozzle, main nozzle and oscillating arm. Stainless steel was used for the oscillating arm shaft, oscillating arm spring and cotter pin. Brass was used for the cylindrical roller bearing and plastic was used for the wear washer.

Design Consideration

Selection of Pump

The discharge and power were evaluated to select the pump. Centrifugal pump was selected to operate the system. The pressure required to operate the pump was calculated using pressure formula.

$$P = h \ell g$$

Where

P	=	Pressure (N/m^2)
h	=	Pressure head (m)
ℓ	=	Density of water (kg/m^3)
g	=	acceleration due to gravity (m/s^2)

n Design

This is part of the sprinkler head coupled to the riser of the sprinkler system. It has the following :nsions: height of 0.04m, external diameter of 0.065m and central diameter of 0.045m.

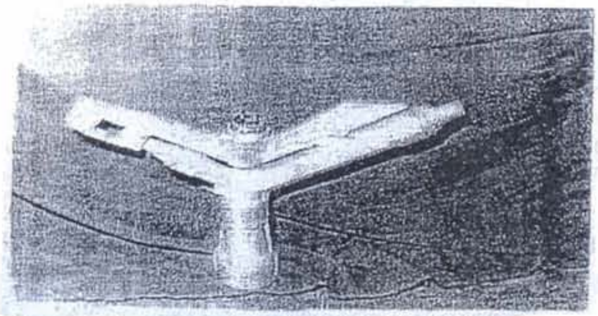

Plate 1: The Impact-type Sprinkler Head

ıg Selection

:aring was designed to permit the relative motion between the stem and the body of the sprinkler head. ıdrical roller bearing was selected from codes.

ıting Arm Shaft Design

ing that the load due to the weight of the oscillating arm is uniformly distributed along the section of ft, it was designed for bending, deflection and shear failure to obtain the diameter from the relation nd Akaaimo, 2004).

$$\frac{6}{Ss}\left[(K_b M_b)^2 + (K_t M_t)^2\right]^{1/2}$$

=	Shaft diameter
=	Allowable shear stress for shaft
=	Combined shock and fatigue factor applied to bending moment
=	Combined shock and fatigue factor applied to torsional moment
=	Bending moment
=	Torsional moment

Selection

lesign involves the relationship between force, torque, deflection and stress. The type of spring for the sprinkler head was helical spring.

Design

:le fabricated in this sprinkler system is a hollow cone type. Two types of nozzle were incorporated ırinkler head: the driving nozzle called the spreader and the main nozzle called the range. These ave different diameters (Phocaides, 2001).

abrication

of material and production has been carefully considered in the material and process selection. ve been made to produce at a reduced cost. Therefore, the total cost of production was ₦22,560.

ınce Evaluation

e conducted on the sprinkler system to ascertain its performance. According to American Society tural Engineers S526.a DEC 96, the purpose of system evaluation was to determine the following: e Distribution Uniformity (%DU), Coefficient of Uniformity (CU) and Precipitation Rate (PR).

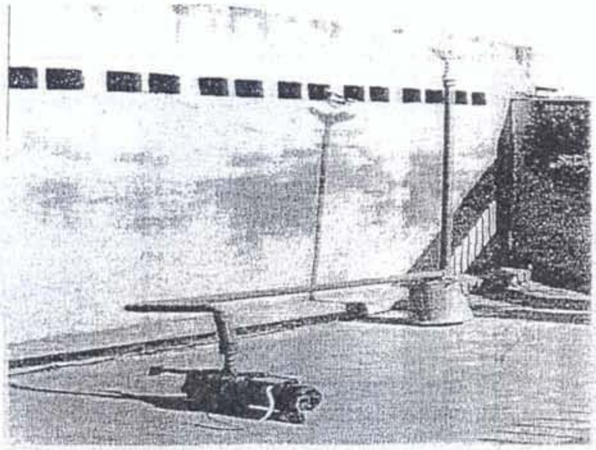

Plate2: The Sprinkler System

It was stated further that a value of %DU lower than 50% is not alright for the sprinkler system. It means that the jet of water coming out of the sprinkler nozzles is not uniformly distributed. Moreover, a coefficient of uniformity smaller than 70 may indicate worn, broken, or malfunctioning water application device.

Material Needed: Stop watch, collectors, thermometer, hygrometer, wind vane, measuring tape and water source.

Discussion

The experiment was conducted in the morning to prevent the evaporation of water from the collectors. The collectors were spaced at an interval of 0.5m to each other along the two sides of the lateral and each row of the collectors was 2.5m to the riser. The temperature, relative humidity and wind velocity was noted while performing the testing. According to ASAE Standard 2001, 15 minutes is required for the experiment on sprinkler system. Moreover, after the testing, the depth and volume of water in each collector was noted.

Experimental Data

Location of Test: Iwo in Osun State
Date: 20th October, 2006
Lateral length: 2.5m
Diameter of lateral: 5cm
Type of sprinkler package: Impact type of sprinkler system
Nominal height of nozzle above ground, m: 1.5m

Climatic conditions:

Mean wind speed: 3.4 m/s
Maximum wind speed: 3.7 m/s
Average temperature: 26^{0}C
Relative humidity: 80%
Collector line number: Two
Diameter of collector (Dc): 120mm
Area of collector opening ($Ac = 0.765 \times Dc^2$): 6955.81mm^2
Nominal spacing of collectors: 1m
The following formulas were used in computing the results in the table below.

1. A code of C# was used for the collectors
2. For lateral move systems distances was recorded from a designated end
3. The adjusted volume equals the volume caught in each collector plus the amount of water that evaporated from the control collectors while water was in specific collector.

   i.e. $V_{a1} = V_1 + E_1 + T_1$
4. The depth is the adjusted volume divided by the area of the collector opening.

i.e. $$D_1 = \frac{1000 x V_{a1}}{A_c}$$

rformance Evaluation Results

ector	Duration of experiment	Catch volume ml	Adjusted catch volume ml	Modulus of deviation volume	Depth applied m	Modulus deviation depth
	t_i (min)	V_I	V_{ai}	$/V_i - V/$	D_I	$/D_i - D/$
	15	99.5	99.5	0.82	14.28	0.11
	15	100.0	100.0	1.32	14.36	0.19
	15	99.0	99.0	0.32	14.21	0.04
	15	99.0	99.0	0.32	14.21	0.04
	15	98.5	98.5	0.18	14.14	0.03
	15	98.0	98.0	0.68	14.07	0.10
	15	99.0	99.0	0.32	14.21	0.04
	15	98.5	98.5	0.18	14.14	0.03
	15	98.5	98.5	0.18	14.14	0.03
	15	100.0	100.0	1.32	14.36	0.19
	15	99.0	99.0	0.32	14.21	0.04
	15	97.0	97.0	1.68	13.93	0.24
	15	96.0	96.0	2.68	13.78	0.39
	15	97.5	97.5	1.18	14.00	0.17
	15	98.0	98.0	0.68	14.07	0.10
	15	99.0	99.0	0.32	14.21	0.04
	15	99.5	99.5	0.82	14.28	0.11
	15	99.0	99.0	0.32	14.21	0.04
	15	98.0	98.0	0.68	14.07	0.10
	15	100.0	100.0	1.82	14.43	0.26
		1973.5	1973.5	16.14	283.31	2.29

A ANALYSIS

Determination of percentage Distribution Uniformity (%DU) its formula is:

$$\text{ntage DU} = \frac{\text{Average catch in the lower quartile} \times 100\%}{\text{Average catch overall}}$$

ige catch overall can be computed from this formula

$$\frac{\sum_{i=1}^{n} V_1}{n}$$

$$\frac{973.5}{20}$$

8.68

atch volume below this average value is in the lower quartile range

rage catch in the lower quartile

$$\frac{5 + 98.0 + 98.5 + 98.5 + 97.0 + 96.0 + 97.5 + 98 + 98}{9}$$

/8

antage of this method of determining %DU is that it treats under-watering as the critical element but ot tell us how big or severe the dry spot is.

Determination of Coefficient of Uniformity (CU)

in be calculated using the Christiansen formula.

$$= 100\left[\frac{1 - \sum_{i=1}^{n} / V_1 - \bar{V} /}{\sum_{i=1}^{n} V_1}\right]$$

CU_C = Christiansen Uniformity Coefficient
n = Number of collectors used in data analysis
V_i = Volume of water collected in the ith collector
$\bar{V}$ = Arithmetic average caught by all collectors

$$CU_c = 100\left[\frac{1-16.14}{1973.5}\right]$$

$$\therefore CU_c = 99.18$$

OR

CU can be determined by the formula written in ASAE Standard, March 2001

$$CU_c = 100\left[\frac{1-\sum_{i=1}^{n} / D_i - \bar{D} /}{n\bar{D}}\right]$$

$$\bar{D} = \frac{\sum_{i=1}^{n} D}{D}$$

$$\bar{D} = 14.1655$$

$$CU = 100\left[\frac{1-2.29}{20x14.1655}\right]$$

$$CU = 83$$

One limitation that CU has is that it treats under-watering and over-watering the same.

(c) Determination of Precipitation Rate

Its formula is

Precipitation Rate (inches/hr) = Average can reading (ml) x 3.66 / Test time (min) x entrance area to catch can (in.^{2})

$$PR = \frac{98.68x3.66}{15x18.0864}$$

$$PR = 1.33\ inches/hr$$

$$PR = 1.33 x 2.5$$

$$PR = 3.325\ ^{cm}/_{hr}$$

CONCLUSION

We conclude that the precipitation intensity of this sprinkler system was 3.325cm/hr compared to the existing one that has a precipitation intensity of 2.50cm/hr. The area covered by the sprinkler system was about 150m^2 and this favourably compared with existing ones. The aluminium used for this head made it lighter and cheaper than the existing one that was either made from stainless steel or brass. The average uniformity of 85 and percentage distribution uniformity of 90%, compared favourably with existing sprinkler systems.

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