MODIFICATION AND EVALUATION OF MASTER CONTROL UNIT FOR DIFFERENT IRRIGATION SYSTEMS

By

UDAYAKUMAR K. S.

PROJECT REPORT

Submitted in partial fulfilment of the requirement for the degree of

Bachelor of Technology in Agricultural Engineering

Faculty of Agricultural Engineering & Technology
Kerala Agricultural University

Department of Land & Water Resources & Conservation Engineering
Kelappaji College of Agricultural Engineering and Technology
Tavanur - 679 573
Malappuram

1994

DECLARATION

I hereby declare that this project report **"MODIFICATION AND EVALUATION OF MASTER CONTROL UNIT FOR DIFFERENT IRRIGATION SYSTEMS"** is a bonafide record of project work done by me during the course of project and that this report has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title of any other University or Society.

UDAYAKUMAR K.S

CERTIFICATE

Certified that this project report, entitled **"MODIFICATION AND EVALUATION OF A MASTER CONTROL UNIT FOR DIFFERENT IRRIGATION SYSTEMS"** is a record of project work done by **Sri. Udayakumar K.S.** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to him.

Xavier.
13-1-95

Tavanur,
13-1-95

Er. Xavier K. Jacob
Assistant Professor
Department of LWRCE

ACKNOWLEDGEMENT

I express with gratitude my sincere thanks to my respected guide, Er. Xavier K. Jacob, Assistant Professor, Department of Land and Water Resources and Conservation Engineering, for his professional guidance, encouragement and valuable advice which enabled the successful completion of my project work.

I am greatly indebted to Prof. Dr. K. John Thomas, Dean i/c, K.C.A.E.T., Tavanur for his invaluable help and encouragement. The help and co-operation rendered by Prof. T.P.George, former Dean i/c, K.C.A.E.T., Tavanur is also remembered with gratitude, on this occasion.

I sincerely acknowledge the help rendered by Mr. Rajendran P, Farm officer i/c, Assistant Professor, K.C.A.E.T. Tavanur, in giving instructions and guidance regarding the preparation of the turf and installation of the irrigation system.

I also remember, with indebtedness, the help rendered by Er. E.K. Kurien, Assistant Professor, K.C.A.E.T., Tavanur in providing the facilities for conducting the field work.

I consider it as a pleasure to extend my heartfelt thanks to Mr. Sunish Isaac, for all his valuable help. I also thank Mr.V.V. Ray, Jr. Programmer, K.C.A.E.T., Tavanur, who helped me to submit this report in time.

I remember, at this stage, the co-operation and help rendered by Mr. Sujith George, Mr. Jayarajan. R, Mr. Abdul Wahab V.S., Mr. Vinod Kumar P.R., and Mr. Sabu Paul, in the different stages of my work.

I would like to extend my sincere thanks to all the staff members and friends for their enthusiastic support, which helped in the completion of this work.

Thanks are due to M/s Peagles, Mannuthy, for their error-free typing and prompt service.

Words cannot express my deep sense of indebtedness to my father and mother for their unfailing support and encouragement, which enabled me to successfully complete the work.

On this occasion, I remember with respect and gratitude, the blessings of all my teachers, whose invaluable guidance and support have enabled me to have everything at my reach, all my life.

And, last but not the least, I humbly acknowledge the grace and blessings of the all pervading Supreme Power which enlightened my path throughout.

UDAYAKUMAR K.S.

CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

SYMBOLS AND ABBREVIATIONS USED

A	-	Ampere
Agril.	-	Agricultural
ASAE	-	American Society of Agricultural Engineers
cm	-	centimetre(s)
Co	-	Company
dc	-	direct current
Dept.	-	Department
ELBS	-	English Language Book Society
Engng.	-	Engineering
ET	-	Evapotranspiration
et al.	-	and others
F	-	Farad
Fig.	-	Figure
FP	-	Full circle pop-up sprinkler
HDPE	-	High Density Poly Ethylene
HP	-	Half circle pop-up sprinkler
hp	-	horse power
hr	-	hour(s)
IBH	-	Indian Book House
IC	-	Integrated Circuit
ICID	-	International Congress on Irrigation and Drainage
Inc.	-	Incorporated
Irrgn.	-	Irrigation

IS	-	Indian Standards
K	-	Kilo
KCAET	-	Kelappaji College of Agricultural Engineering and Technology
kg	-	kilogram(s)
kpr	-	kilo pascal
LED	-	Light Emitting Diode
lit	-	litres
lph	-	litres per hour
Ltd.	-	Limited
M	-	mega
m	-	metre(s)
ma	-	milli Ampere
mm	-	millimetre(s)
mm/hr	-	millimetre per hour
No.	-	number
pp	-	pages
psi	-	pounds per square inch
PVC	-	Poly Vinyl Chloride
Pvt.	-	Private
QP	-	Quarter circle pop-up sprinkler
s	-	seconds
Tech.	-	Technology
TP	-	Three-quarter circle pop-up sprinkler
Univ.	-	University

V	Voltage
Vol.	Volume
°	Degree
'	minutes
"	inch(es)
	ohms
	micro
%	percentage

INTRODUCTION

Water is one of the most abundant widely distributed and essential substance on earth. It occur in nature in the solid, liquid and gaseous state. Water is a scarce resource and it is a critical input in agricultural production. Rain being the primary source of water in Indian agriculture, is concentrated in only about four months of monsoon period, the remaining months being dry. In the past with scarce population the natural soil moisture from rain was more than sufficient for agricultural production to satisfy the basic human needs of food, fabric and fat. But the growing population created more pressing demands for food and agricultural production and this demand combined with the uncertainty in rainfall, forced man to supplement the natural moisture by artificial means, and thus come the need for irrigation.

Irrigation is basically the application of water to soil to assist the production of crops, Application of irrigation water being an extensive input its use efficiency and managment are critical factors in determining the cost of production and the quantity of agricultural yield.

Irrigation is carried out in many ways. The most common being the traditional surface, irrigation methods such as Basin, furrow and sub surface irrigation methods. But these methods require high cost of field preparation, involve much water lost by seepage, run off, evaporation and can be employed only in areas with abundant water supply. But with growing scarcity of water, and agriculture being taken up to water-scarce areas, modern irrigation techniques like drip, micro, and pop up irrigation are found to be more eficient. But even with these modern techniques significant water losses such as percolation, seepage and evapo-transpiration are inevitable. Unless otherwise provided with means of applying just the right amount of water and at proper time intervals. The amount of water applied and the scheduling of irrigation are important factors deciding growth of a crop.

The application of sub optimal quantity of water naturally reduces the yield of a crop in many ways. On the other hand excess water can be more hazardous. First and foremost excess water can lead to sub optimal aeration of the soil. Secondly it reduces the microbial activity of the soil and decaying of plant roots.

All these and many more have necessitated automation which helps in delivering just the required amount of water, neither more nor less at precise intervals. The values of these parameters are determined based on studies regarding the infiltration rate, evapo-transpiration, root penetration, wind etc.

Irrigation with low application rate is desirable for optimal plant-soil-water relationships in regard to plant response to soil moisture regime and water movement in soil profile. To obtain low application rates from any water emitter, the principle of pulsed water application was developed.

Use of drippers, micro and pop-up sprinklers in the irrigation of lawns do not in any way alter their aesthetic and artistic values and automation of the same greatly enhances its appeal, besides increasing the use of efficiency of water.

Main objective of this study are:

1. To determine discharge flow rate, wetted radius and application depth for pop-up sprinkler.

2. To modify the master control unit for automation of the motor operated pop-up, drip and micro sprinkler by solinoid valve from direct supply line and to evaluate its performance.

3. Control of irrigation ON/OFF time based on type of soil and type of crop.

REVIEW OF LITERATURE

In many parts of the world amount and timing of rain fall are not adequate to meet the moisture requirement of crops throughout the growth period, and irrigation has become an inevitable part of agriculture. The ever increasing food demand of the growing population is causing rapid expansion of irrigation and its methods. To attain maximum productivity with minimum water and minimum ecological disturbance, scientific irrigation practices such as micro irrigation are adopted.

2.1 Micro irrigation

Micro irrigation is defined as an irrigation method that applies water to less than 100% of crop area. It includes drip, micro jet, pop-up and micro sprinkler irrigation systems. The very first experiments in micro irrigation was started in Germany in 1860 using clay pipes as a combination of irrigation and drainage systems. Later porous pipe, canvas etc. where used for irrigation and in the late 19 0s plastic pipes micro irrigation systems where used to irrigate green houses in UK. Plastic pipes micro irrigation system where extensively used to irrigate green house plants in the US by early 1960s. Modern day surface trickle irrigation technology has its origin in the 1960s when Simca Blass, an engineer developed and used this technology in 1963 in Israel. Micro sprinkler irrigation system developed at the beginning of 1980s has been designed as an improvement over trickle irrigation systems.

Micro irrigation is becoming a popular irrigation method for vine and tree crops in many areas of UK (Brain.J.Boman, 1989). In situations where the root system develops according to the natural rain fall, such as in the banana plantation in northern Australia, Central America and many Asian countries, only the micro sprinkler is capable of supplying the required quality of water and nutrients accurately and efficiently to already developed root system.

Pop-up sprinkler irrigation is called landscape micro irrigation and is extensively used for landscaping and turf irrigation.

2.2 Advantages

2.2.1 water conservation

Micro sprinkler irrigation system can effect considerable saving in water. Micro sprinklers wet only about 40-80% of this soil surface in a mature or hard soil. The area wetted can be varied according to the development of root system. The direct evaporation from this spray itself under normal pressure and wind conditions does not exceed 2% (Christeinsen, 1942). Dev Nir (1982) reported that in green houses, sprinkler irrigation not only provides water, but also regulates air humidity, temperature etc.

In conventional sprinklers large droplets with greater kinetic energy disrupt soil surface by crusting, causing reduced infiltration rate (Diado and Wallender, 1985). This is avoided in micro sprayer emitters due to their small droplet size.

Micro sprayer emitters have a low precipitation rate which is less than 3mm/hour. Thus by applying the right amount of water at the correct irrigation rate there will be no seepage beyond the root zone, no problems of aeration in the root zone, caused by water logging (Chaya and Hills, 1991).

Geuerguiev <u>et</u> <u>al</u>. (1988) made a study on sprinkler irrigation for rice for 3 years in Bulgaria. This sprinkler system achieved a 67% saving in water applied for the cost of a 10% drop in yield.

The shape of the wetted surface can be changed from full circle (small for young trees and progressively larger as the trees developed) to a half circle or strips. Hence water needed to wet unwanted portions of the field is saved.

The Haryana irrigation department (Sivanappan, 1987) has reported that saving of water by a sprinkler compared to surface irrigation averaged to 57% in the case of Bajra, Jowar, Wheat,Barley and Gram and 24% for cotton. The Punjab Agricultural University has reported a water saving of 42.7% for wheat and 47.5% for maize. The University of Agricultural sciences, Bangalore has found that the net irrigated area and cropping intensity were higher when sprinkler irrigation was introduced in the university farm (Sivanappan, 1987).

2.2.2 Irrigation efficiency

In tests done by the Israeli Agricultural extension service, the irrigation efficiency of micro sprinklers 94%-97% was found to be higher than that of any other irrigation method tested, this being attributed to the uniform wetting of the irrigation area and to the correct amount of the water applied. Because of the high irrigation efficiency, less time is required to supply the required quantity of water, thus saving in energy.

Coefficient of uniformity of sprinklers is higher in sprinklers operating on high pressure and producing finer sprays than in those operating on lower pressers and producing large droplets. Irrigation efficiencies of 65%-85.5% were obtained (Keller, 1992).

With Microsprinklers, the amount of water required by the plants is applied to a given volume of soil and this enables the root system to develop evenly and to spread densely throughout the soil, thus ensuring the supply of water and nutrients of the tree. With low irrigation rates, there are no run-off problems or water ponding. The irrigation rate can be easily matched to the soil and the climatic condition. The uniform wetting of the whole soil volume makes it easy to use all types of soil moisture monitoring devices. All these lead to a higher irrigation efficiency of micro sprinklers.

2.2.3 Agro technical advantage

Micro sprinklers are connected to the lateral by a flexible tube, enabling underground installation of the distribution pipes. This helps in preventing damage caused by birds and rodents. A large mesh filter screen used in micro irrigation allows for longer operating time between cleanings. Micro sprinkling can also be used to introduce fertilizers in to the irrigation process. Although micro sprinkling is used primarily for the application of water to crops, it is a multipurpose system with a wide range of uses such as fertilizer and herbicide application, frost protection, and cooling of green houses.

2.2.4 Labour saving

Most mechanised and automated sprinkler systems require very little labour and are simple to manage. Being fixed sprinkler system, pop-up sprinklers etc can eliminate field labour during the irrigation season and be fully automated to simplify management.

2.2.5 Cost and yield

Compared to other sprinkler systems the micro sprinkler system are economical to install and have low discharge rates. The efficient hydraulic design of the micro sprinkler coupled with the correct use of flow regulators, accounts for the diminishing price difference between drip irrigation and micro sprinkler systems.

Micro sprinkler irrigation is capable of improving the physical condition of the soil, and thus will enhance the yield to a great extent. In the Arava deserts of Israel (1991) about 24 million tonnes of tomato/hectare could be produced by micro irrigation. When tried on an apple orchard in Israel micro sprinklers caused an increase in yield of 15-30% than with drip irrigation.

2.2.6 Other advantages

The pop-up sprinklers are connected to the distribution pipes installed underground. The pop-up heads are placed flush with the turf. This feature is very important in landscaping operations as it does not interfere with the design of the turf.

The subsurface pop-up sprinkler system could be particularly useful where strict environmental and water management controls are desired. Several unique recreational and horticultural application are also possible. In the case of water sensitive crops, where wetting of the upper portion of the plant is undesirable, under-the-canopy irrigation using pop-up sprinklers can be done.

It is well known that root distribution pattern is related to water distribution in the soil. In a field trial comparing micro sprinkling with drip irrigation in 7 year old apple orchard located in Israel, root patterns were significantly different under the two irrigation systems. The micro irrigated roots were evenly distributed in the wetted soil volume and the number of roots/tree were much greater. Roots of drip irrigated trees where concentrated in shallow small volume of soil under the dripper where us under micro irrigation, a large number of roots penetrated to a depth of

70-80cms. The canopy per active root relationship was also much better under micro irrigation.

Sprinklers are connected to the laterals by flexible tubes enabling underground installation of the distribution pipes. Visual inspection of micro sprinklers is simple and fast. Less time is required for the inspection of a micro sprinkler than it is for the inspection of the several emitters per tree in drip irrigation system. Micro sprinkler was demonstrated in a trial on a shallow land in Israel (Agri business world wide, January/February, 1992). The yield of 7 year old apple orchard using micro sprinklers was 15-30% higher and of better grade than that of drip irrigated plot.

2.3 Performance characteristics of the system

Spray emitters usually have slotted caps or deflector plates which typically distributed water in distinct streams. The extend on the wetted zone in micro irrigation is determined by the spacing of the sprinkler heads and is a function of the soil type (Keller, 1975). Johnston (1981) reported on the flow rates and the wetted diameter of seven spray emitters and two spinner emitters. He determined that the actual coverage pattern for several emitter models varied considerably from the manufactures specifications.

Greater emphasis should be placed on improving crop production in humid climates, where water use efficiency is inherently greater that in other regions (Sindair et al., 1984). Furnishing a suitable moisture regime for superior plant performances is contingent on knowing the appropriate micro heads spacing.

Brian J. Roman (1989) studies the distribution pattern of micro irrigation spinner and spray emitters at the University of Florida's Agricultural Research and Education Center, using the ASAE standard 330. This standard recommends the sprinklers to be 0.6 m above the catch containers. He designated a new term which appropriately described the wetted area. This was accomplished by defining the term "effective radius" to be the average distance from the most distant 5% of the containers which received water.

2.3.1 Designer considerations

Spray systems are zoned and operated in sections or circuit sized to fit the existing water supply. The number of heads/circuit is dependent on the flow requirements of each, and the capacity and pressure of the water supply. Thus the smaller water supply with require more zones or circuits and increased length of the watering cycle. Therefore, for full realisation of the utility of the system, an adequate water supply must be provided in proportion to the property size.

2.3.2 Water distribution and uniformity

The degree of uniformity of water application decides the irrigation efficiency of micro sprinklers. The water spray distribution characteristic of the emitters and the spacing will regulate the uniformity of the water application. This spray distribution characteristic of sprinkler head are typical and change with nozzle and operating pressure.

Christiansen (1942) was probably the first to point out the significance of distribution pattern in assessing performance. The distribution pattern for a sprinkler gives water application rate as a function of radial distance from the sprinkler.

Keller and Karmeli (1974) introduced the coefficient of manufacturing variation (CV) as a statistical measure of manufacturing variation in irrigation emitters. Unlike impact sprinkler, micro irrigation emitters generally are located in this field with non overlapping pattern on widely spaced plants. Merriam Keller (1978) defined the distribution characteristic (DC) as the standard method for evaluation of non overlapping sprinklers. The DC is defined as the ratio of the area which receives more than half of the average application to the total wetted area, expressed as a percentage. They suggested that DC values greater than 50% are satisfactory and DCs above 66.5% are the best.

Solomon (1979) presented the manufacturing variation for various single and multiple orifice type emitters used for micro irrigation. These emitter types had a CV range of 0.02-0.07 for nine micro sprinklers and micro spray emitter models used for irrigation of treecrops.

Post et al. (1986) examined six micro irrigation emitters at a pressure of 172kpa. They concluded that application uniformity was much lower for the known overlapping micro irrigation emitter than for overlapped sprinklers. All 6 of the emitters produced poor ratings when standard concept of uniformity coefficient used for sprinkler irrigation were applied.

2.3.3 Droplet size

The water droplet size is an important consideration in the design of sprinkler irrigation systems. Small droplets are easily lost due to wind drift and evaporation (Kohl and De Bohr, 1984). Drop size can effect the spray pattern which inturn affects both uniformity of coverage and irrigation efficiency.

Droplet diameter is affected by various parameters. Kohl (1974) determined that higher pressure for a fixed nozzle size promoted smaller droplets over the entire application profile.

Kohl and Boer (1984) observed that for low pressure spray type sprinklers, the geometry of the spray plates surface, rather than the nozzle size and operating pressure, was the dominant parameter that influences drop size distribution.

Diado and Wallender (1985) observed that volume weighted mean droplet diameter increased for non circular nozzles compared to circular nozzles and that droplet diameter increased with nozzle size.

2.3.4 Pressure effects

Kensworthy et al. (1972) reported that the pressure distribution along a lateral line can be determined and uniform irrigation can be achieved by adjusting the length and size of micro tubes used, by adjusting the size of emitters or the spacing between the emitters

Bender et al. (1985) conducted tests on field evaluation of 40 and 100 kpa spray and 170 and 345 kpa impact sprinklers. Application rate and surface run-off were inversely related to sprinkler operational pressure and wetted diameter.

Hills et al. (1986) reported that pressure oscillation on level terrain on two types of spinner and spray emitters, did not improve the distribution efficiency.

Uniformity of application depends on matching operating pressure with the selected sprinkler diameter, wind effects and sprinkler spacing. Too low pressures cause dough nut shaped application pattern, were as too high pressures result in excessively small drop lets which are not carried to the extend of the desired wetted diameter (Richard H.Cuenca, 1989)

2.3.5 Effects of wind

Wind distorts sprinkle pattern and causes uneven distribution of water. This effect is less for micro sprinklers due to the shielding by the canopy and lesser wind velocity near the ground.

A number of sprinkler studies have been conducted by Herman and Kohl (1983) relating wind to uniformity. The direction and speed of wind, height of risers, nozzle size and pressure turbulence in the stream of water entering and leaving the nozzle and jet angle were found to have an effect on sprinkler pattern distortion.

Von Berneth (1988) observed that wind drift was affected by drop size distribution, water jet trajectory angle and wind velocity.

Prevailing wind condition have a significant effect on the application pattern of a sprinkler system consistent. High velocity winds can rule out the effective use of sprinkler irrigation or limit operation to times of relatively low winds such as night (Cuenca, 1989).

2.4 Components

The system consist of pump unit, control head, filter,main line, submain, laterals, micro sprinklers pop-up sprinklers and drip emitters.

2.4.1 Pump unit

The pressure required to force water through the entire system is developed by the pumping unit. The most common type of pump used in sprinkler irrigation is the centrifugal pump (Michael, 1978; Sivanappan, 1987). Jayakumar et al. (1988) recommended the a pump with 1.5HP to 2HP will be sufficient for an area of 1ha or less, irrespective of the crop being irrigated.

The factors with effect the size of the pump are the size and shape of the irrigated area, topography, system discharges, cost of equipment, number of pumping hours/season, prices of electricity and efficiency of the pumping unit.

2.4.2 Control head

The central control and operation point of the system consists of valves, discharge and pressure meters (means for control and regulation of discharge and pressures including non return valves) and automation equipment and control. Each control head serves and controls an irrigation unit, with a common irrigation pattern. The unit size may vary and if the field is not too large, it can be operated from one control head as one unit, otherwise it may be divided into smaller units, each with separate control heads.

2.4.3 Filters

The filter is an important part of the control head and requires the greatest amount of care and maintenance. It should be efficient, easily washable, involving a minimum head loss. ASAE (1980) reports that filter units used to prevent emitter clogging where widely recognised as the key to successful operation of the micro irrigation systems. Centrifugal filters, sand separators, vertical cyclones, gravel filters and screen filters are the generally used efficient filters.

2.4.4 Main and submain

The main line is a pipe which delivers water from the pump to the submains. It may be either be permanent or portable. The mains and submains are designed keeping in view both capacity-which means that the unit size should be large enough to deliver the required amounts of water needed to irrigate the field - and uniformity - which means that the unit design should maintain an allowable pressure variation so that flow into all lateral lines will have little variation.

Jayakumar et al. (1988) suggested that HDPE main pipes of diameter 40 and 50 mm and wall thickness of 2.5-3mm and pressure withstanding capacity of 4 kg/cm^2 can be used for big gardens.

2.4.5 Laterals

The laterals supply water from the submains to the sprinkler head. Commonly used laterals are flexible poly ethylene or PVC pipes. Wu and Girthin (1973) developed procedure for drip irrigation system for determining the lateral pipe size.

2.4.6 Emitters: Pop-up, Micro and Drip

The versatility of spray system accounts for their extensive use for all type of properties. Spray heads for installation in lawns are pop-up type and micro sprinklers. The pop-up heads are installed flush with turf and a nozzle pops up to deliver this spray during operation and recedes within the body when inoperative. Orifices of nozzles are sized to provide a specified radius of coverage and flow at a specified pressure.

2.5 Automation equipments

The term automation is defined as a procedure or method used to regulate a water system by mechanical or electronic equipment that replaces human observation, effort and decision, the condition of being automatically controlled. Automatic micro irrigation ensures saving of work, time and precise application of water without the risk of forgetfulness. Automatic irrigation control along with automated scheduling helps to achieve very high application efficiency and higher yield since water stress on soil never exceeds the present limit.

Early application of electronics to agriculture were faced with difficulties from fragile vacuum tubes in a hostile environment. The development of transistors and later integrated circuits devices brought new levels of capability and reliability to electronic equipment now used in agricultural application.

Naol (1975) developed an automatic irrigation system for mulberry fields. Evapotranspiration from mulberry or chard is found equal to 1 to 1.5 times the evaporation from a free surface.

Maticic (1975) described about a tensio meter control apparatus which consisted of mercury tube tensio meters and automatic relays and conducts. This was used to control stationeries sprinkler irrigation system according to soil water deficit.

Nosenko and Koyangin (1975) reported about anew apparatus for continuous micro irrigation according to water requirement through out their vegetative period. Average rate of sprinkling was limited to .01 to .002 mm/m in order to satisfy the water requirement.

Thomas et al. (1989) developed an electronic percentage timer for center pivot irrigation system. The timer provides greater timing accuracy than electro mechanical timers presently used.

An automated facility for measuring the performance of individual irrigation sprinklers was developed by Hodges et al. (1990). The system was a programmed to operate unattended at night and during week ends whenever the wind speed exceeded 2.2 m/sec. In the vertical columns, using intermittent water application, the advents of wetting front, the cumulative infiltration and the infiltration rate were degreased and behaved as if the time average water application rate were being applied continuously. This decrease was also found with horizontal columns, but to a smaller extent. In effect the decrease would change the shape of the wetted soil volume in favour of the lateral direction when using point source irrigation. The decrease in vertical water movement can also have favorable implication with respect to losses of water and neutrons beneath a root zone. By making use of intermittent water application, it is also possible to use high-discharge emitters while still obtaining low rates of water (Levin and Van Rooyen, 1977).

Numerous workers have reported that hoigher yield and improved plant growth can be obtained by reducing the time intervals between irrigation and but maintaining low soil moisture stress condition (Hagan 1957; Statyer, 1957; Rauritz, 1967; Rawitz and Hellel, 1969; Asaaf, Levin and Bravdq, 1975).

Rawlins and Raats (1975) reported that uniform frequent irrigation optimises root environment while drastically reducing water use

Levin and Van Rooyen (1977) found that water movement in the vertical direction is at a faster rate than in the horizontal to vertical water advance. Such change in ratio implies change in the shape of the wetted volume of soil beneath the point source in favour of lateral direction when the water is applied in pulses. This effect is especially large in sandy loam and can be expected to increase even more towards heavier textured soils.

A mathematical model for more accurate application according to demand in horticultural crops was developed satisfactorily by Graaf (1990). Heinmann et al. (1992) made an evaluation of an automated irrigation system for frost protection. The automated irrigation system used a micro computer to monitor environmental conditions external to the crop canopy and determined when and how much water to apply and control the irrigation system in order to adequately protect the crop. Result show that the system was effective for both protecting the crop from cold whether drainage and reducing the quantity of water used when compared to conventional approaches.

MATERIALS AND METHODS

The materials used and the methodology adopted for this study are discussed in this chapter.

3.1 Performance evaluation of pop-up sprinkler heads

3.1.1 Location

The performance evaluation of the pop-up sprinkler heads were conducted at the KCAET premises, Tavanur in Malappuram District of Kerala. The place is situated at 10° 53' 33" N latitude and 76° E longitude.

3.1.2 Experimental set up

The performance evaluation of two pop-up heads namely Full circle and Quarter Circle were carried out in two stages. In the first stage, a 0.5 hp centrifugal pump operated by an electric motor was used to conduct the study inside the laboratory. The second stage of the experiment was conducted using a 1.0 hp centrifugal pump in an open field located in the campus.

The pumps were used to lift water from the tank and to generate the required pressures. PVC pipe 32 mm diameter formed the discharge line to which a gate valve was attached to regulate the flow. The operating pressures were adjusted using the gate valve, which were indicated by the pressure gauge connected to the discharge pipe. The pop-up heads were threaded onto the end of the discharge pipe. The height of the pop-up heads above the surface of the catch cans was maintained at 50 cm.

The operating pressures used in this study were 0.5 kg/cm^2, 1.0 kg/cm^2, 1.5 kg/cm^2 and 2 kg/cm^2 and the duration of operation for each set of experiments was one hour.

The experimental set up is shown in Fig.1. The experiment was conducted using the catch can method. Catch cans of size 100 mm diameter and 120 mm height were laid out in a grid pattern. The cans were placed at the centre of each square, 1 m apart, assuming that the volume of water collected in each can represents the precipitation falling on it. The grid covered the entire area of the pop-up sprinkler head. The pattern in which the collectors are placed is shown in Fig.2.

Care was taken to keep the operating pressure constant during the test period. At the end of the operating period, the amount of water collected in each of the cans were noted. The discharge rate of different pop-up sprinklers at each pressure was also determined.

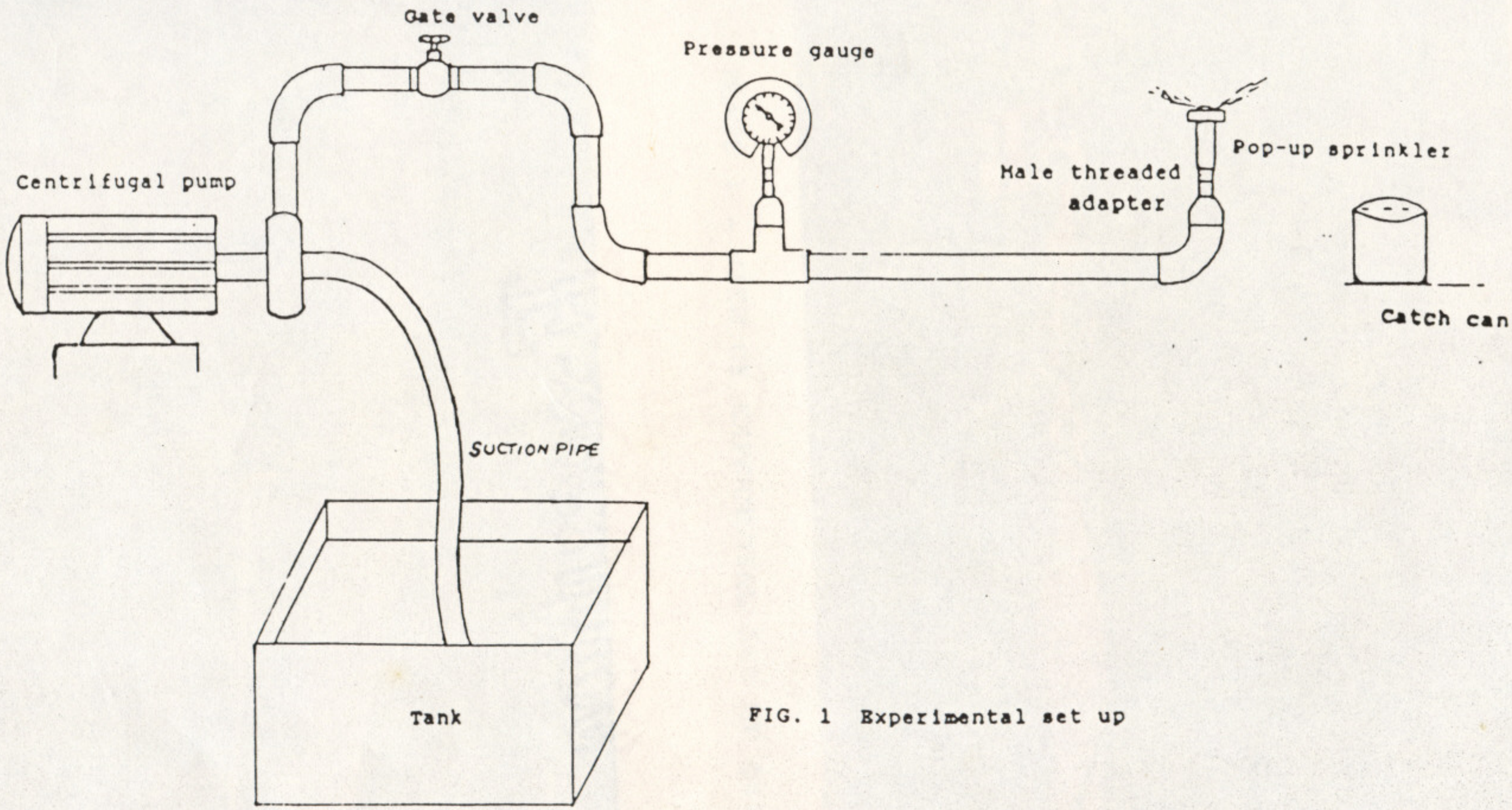


FIG. 1 Experimental set up

PLATE 1 - VIEW OF EXPERMENTAL SET UP (a)

PLATE 2 - VIEW OF EXPERMENTAL SET UP (b)

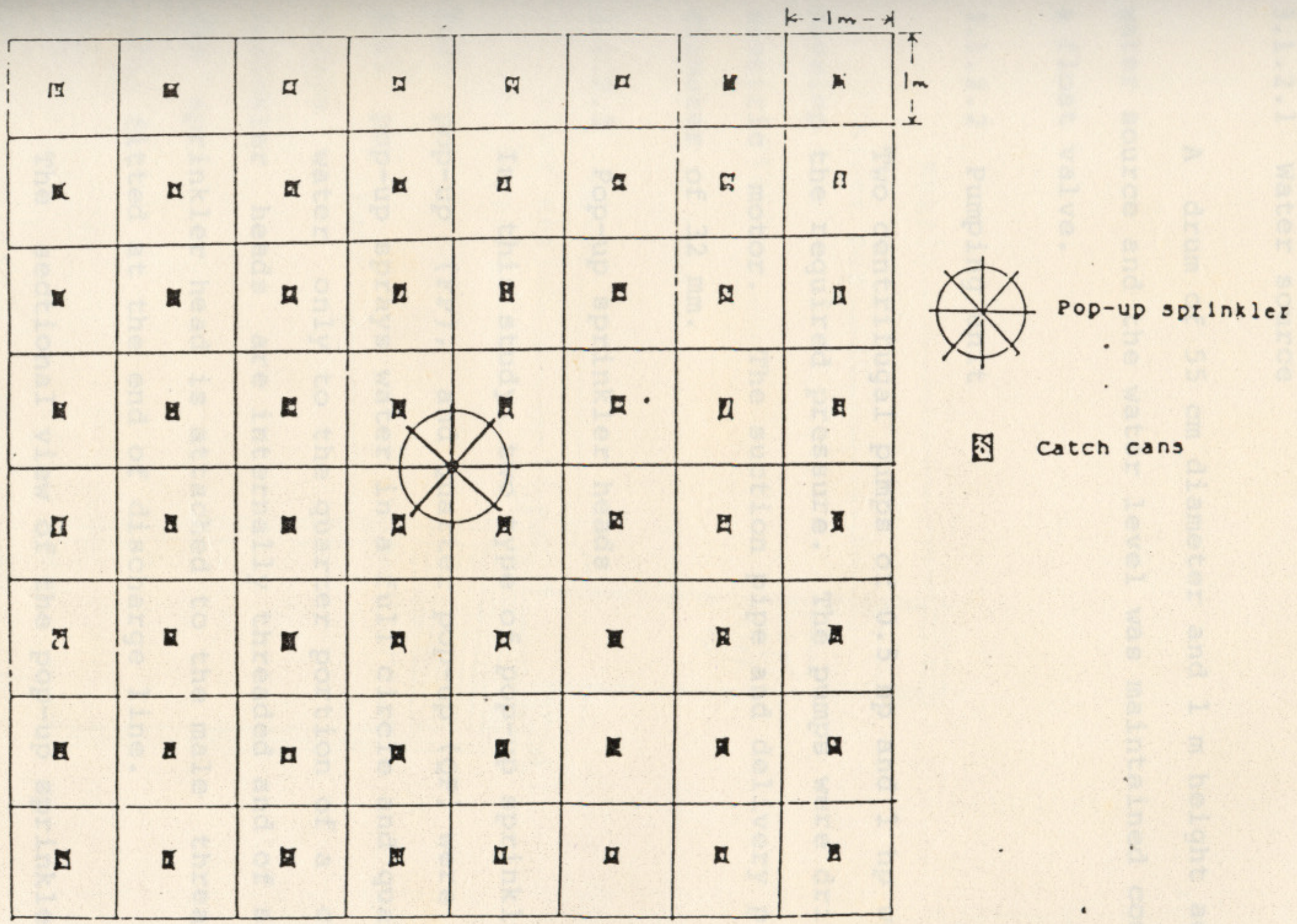


Fig 2 COLLECTOR PLACEMENT PATTERN

3.1.2.1 Water source

A drum of 55 cm diameter and 1 m height acted as the water source and the water level was maintained constant using a float valve.

3.1.2.2 Pumping unit

Two centrifugal pumps of 0.5 hp and 1 hp were used to develop the required pressure. The pumps were driven by 230 V electric motor. The suction pipe and delivery pipe have a diameter of 32 mm.

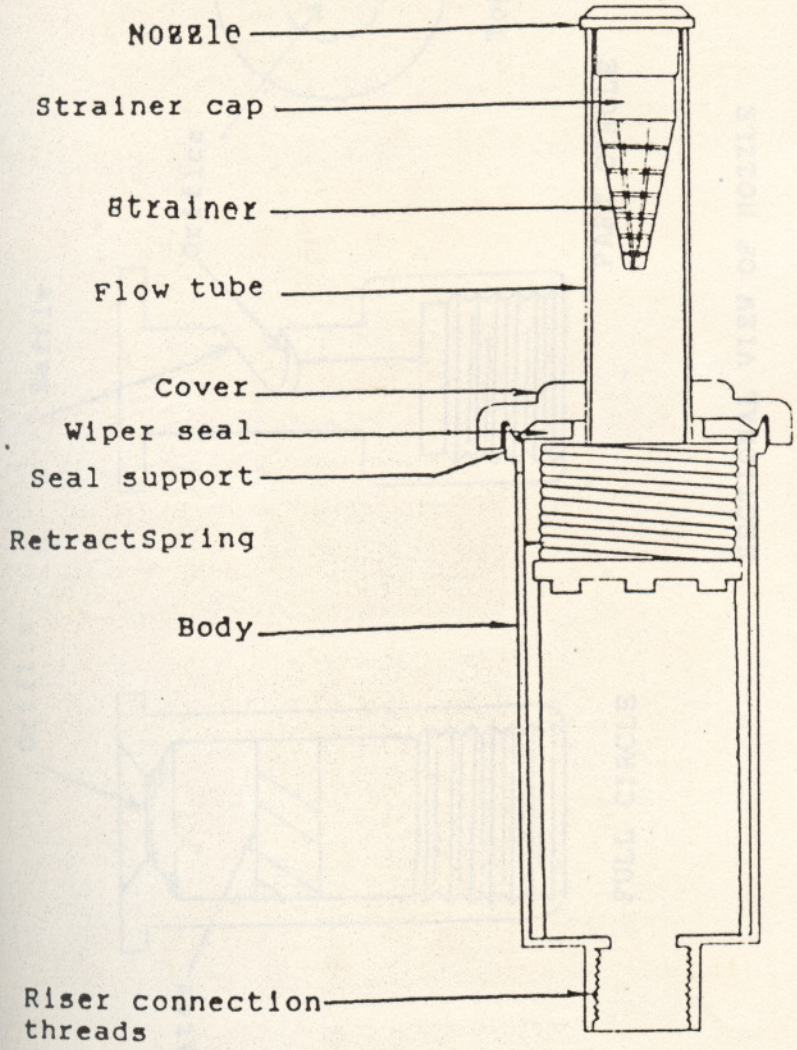
3.1.2.3 Pop-up sprinkler heads

In this study, two type of pop-up sprinkler heads - Full pop-up (FP), and Quarter pop-up (QP) were used. The full pop-up sprays water in a full circle and quarter pop-up sprays water only to the quarter portion of a circle. The sprinkler heads are internally threaded and of size 32 mm. The sprinkler head is attached to the male threaded adapter (MTA) fitted at the end of discharge line.

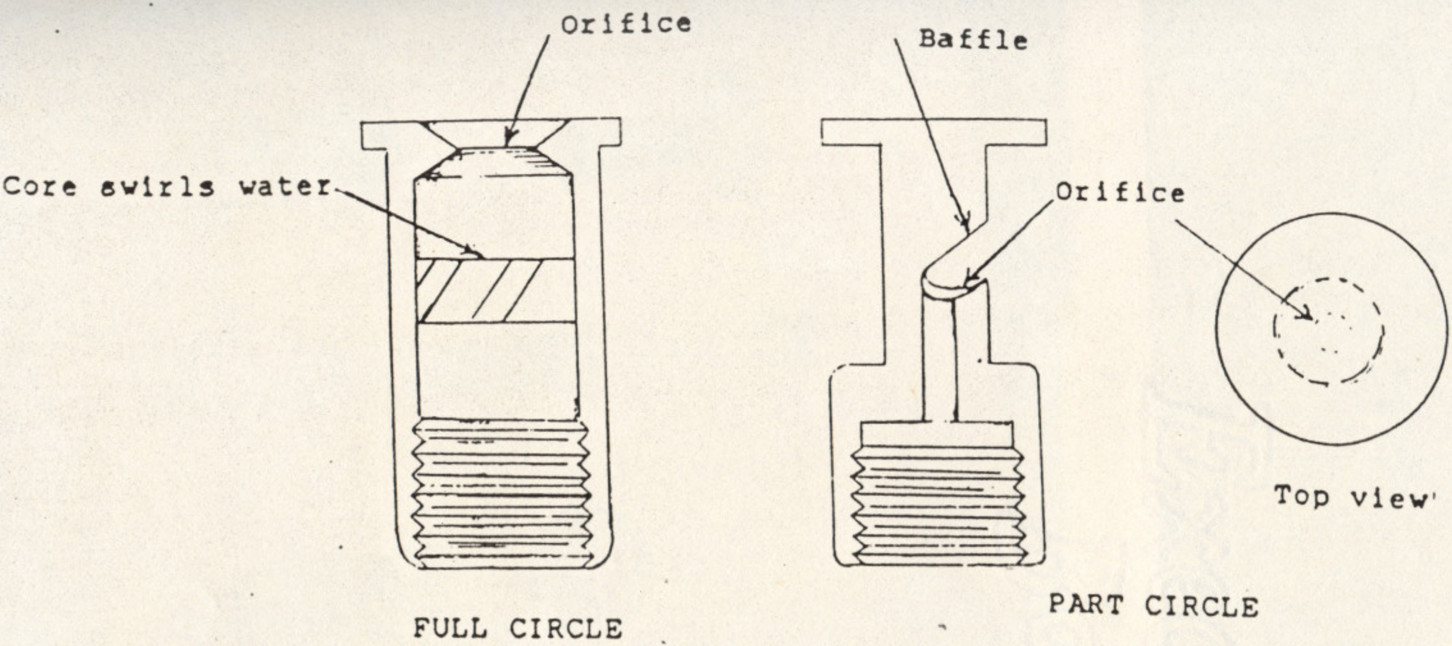
The sectional view of the pop-up sprinkler head and the nozzle are shown in Fig.3 and 4, respectively.

3.1.3 Determination of distribution pattern

The volume of water collected in each can was measured



SECTIONAL VIEW OF POP-UP SPRINKLER



SECTIONAL VIEW OF NOZZLE

FIG. 4

PLATE 3 - POP-UP SPRINKLER IN OPERATION

PLATE 4- POP-UP SPRINKLER EXPLODED VIEW

after operating the pop-up sprinkler for one hour. The cross-sectional area of each can was known and hence the depth of application of each grid was calculated by dividing the volume collected in each can by the same. The pattern was drawn which represents the percentage of average application of different distances from the sprinkler heads.

3.1.4 Determination of wetted radius

The effective radius (Re) is defined to be the average distance from the sprinkler head to the most distant 5 per cent of containers which receive water. The effective area (Ae) of application by the sprinkler head was then calculated as the circular area within a distance of the effective radius from the sprinkler head.

3.1.5 Determination of application depth

The absolute maximum application depth (DXa) was defined as the greatest depth caught in any of the containers for a particular sprinkler head. The effective maximum application depth (DXe) was defined to be the average depth caught in the 5 per cent of the containers that had greatest catch depth. The mean application depth (Da) was calculated as the average depth of water caught in the containers located within a distance of effective radius from the sprinkler head.

3.1.6 Determination of distribution characteristics

The average depth of application of all points within the effective radius of throw was calculated. The area receiving more than half of the average application depth was found. Merriam and Keller's distribution characteristic (DC) is defined as the ratio of the area which receives more than half of the average application to the wetted area, expressed as a percentage.

Distribution characteristic, DC

$$= \frac{\text{Area receiving more than half of the application depth, } m^2}{\text{Total wetted area, } m^2}$$

3.1.7 Determination of coefficient of variation

The coefficient of variation (CV) of catch can depth for a particular sprinkler head was calculated by dividing the standard deviation of the depths used to calculate the mean by the mean application depth, Da. The coefficient of variation is expressed as a percentage.

$$\text{Coefficient of variation, CV} = \frac{\text{Standard deviation of depth}}{\text{Mean deviation depth}}$$

$$\begin{array}{l}\text{Standard deviation of depths} \\ \text{used to calculate the mean}\end{array} = \frac{(Di - Da)^2}{N}$$

where,

Di is the individual application depth

Da is the mean application depth

N is the total number of application depths used to calculate the mean

3.1.8 Determination of discharge

For the evaluation of discharge, the pop-up sprinkler head was connected to the end of the discharge pipe. A 100 mm diameter can was placed over the sprinkler head to direct the discharge into a 30 litre vessel. The discharge was collected for a specified time in the vessel. The required pressure was maintained in the discharge line and was monitored by a pressure gauge. The time was noted using a stop watch. The volume collected in the vessel was measured using a measuring jar. The same procedure was repeated for different operating pressures and different sprinkler heads. The discharge in litre per hour was obtained as

$$\text{Discharge in lph} = \frac{\text{Volume collected in litres}}{\text{Time interval in hours}}$$

3.2 Development of the master control unit for the three irrigation systems

3.2.1 Location

The master control unit and the three irrigation

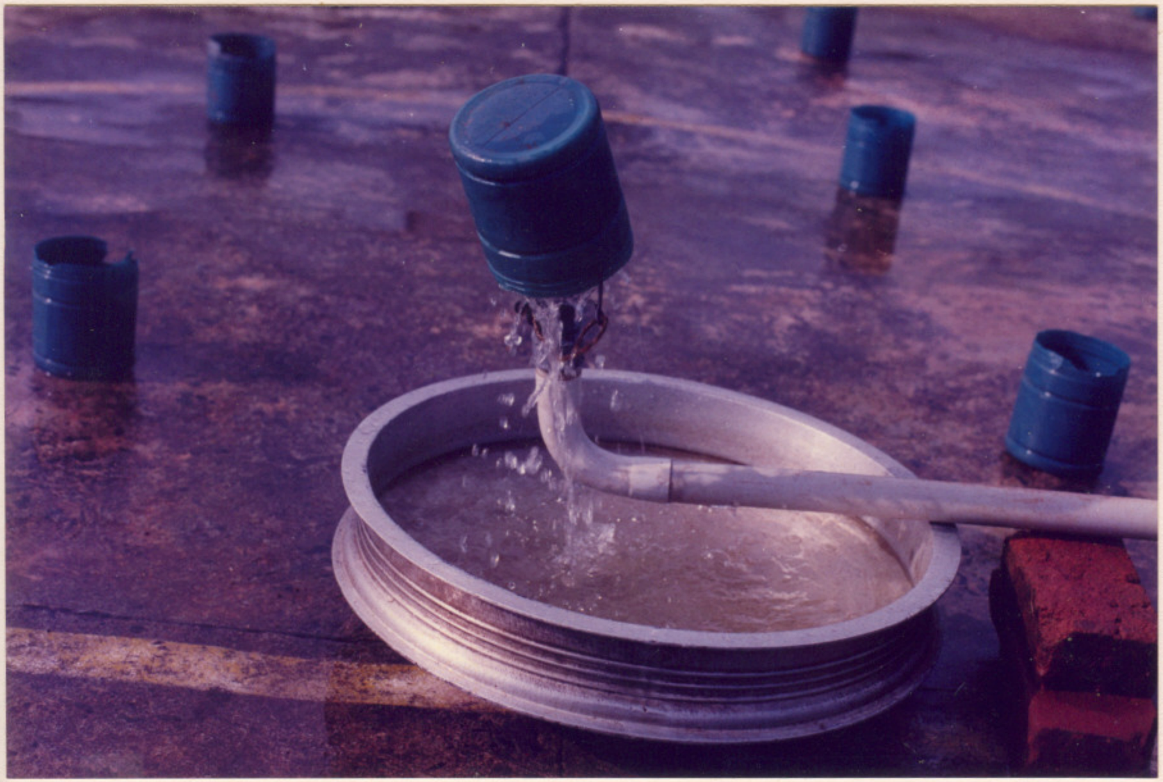


PLATE 5 - MEASUREMENT OF DISCHARGE

systems were installed in the garden in front of the library of KCAET.

3.2.1 Site preparation

The selected plots - four in numbers and lying near to each other were of sizes 9 m x 6 m, 9 m x 7 m and 7 m x 4 m were cleared of all grasses. The soil was manipulated and farmyard manure was applied. A well graded mixture of sand, soil and manure was filled and the plots wre approximately levelled. The plots were the planted with lawn grass plots of flowering plants were placed on the ridges in between and around the plots.

3.2.3 Components of the irrigation system

The master control unit was installed to control the three irrigation systems and to operate them simultaneously and side-by-side without manual control. The system consists of (i) storage tank, (ii) solenoid valves and pump, (iii) filter, (iv) main line, (v) submain and (vi) sprinkler heads.

3.2.3.1 Storage tank

The overhead tank located inside the KCAET premises acted as the main water source. The water supply was branched off in two directions. The pressure head required for the operation of the micro springlers in plot IV and the drip system was obtained directly from the head of water stored in the tank. The other branch of the water supply was fed to a storage tank to supply water to the pop-up springlers and the other micro springlers. A claypot having a capacity of 60 litres served the purposeof the storage tank. The water level in the tank was maintained using a float valve.

3.2.3.2 Solenoid valve and pump

The flow of water from the tank to the drip and micro springler system is controlled using solenoid valves. Both systems have two seperate solinoid valves. The solenoid or coil forms one of the basic parts of solenoid valve. Passage of small current through the control solenoid can be made to open or close a valve or valves and the flow of fluid can be controlled. The solenoid valve can be of ON/OFF type or can be constructed such that the amount of opening is a function of control current, there by having a characteristic in which the rate of fluid flow is a function of solenoid current. A 24V DC operated closed solenoid valve working at a pressure hange of 0 to 4 kg/cm^2 and made of brass was used for the drip system and the other solinoid valve was a 230V AC operated plastic solinoid valve.

A centrifugal pump of 1 hp operated by a 230 V AC electric motor was used to deliver water to the irrigation system. The suction and delivery pipe diameters were 32mm each.

3.2.3.3 Filter

A 40 mesh wire filter was used to filter the water entering into the system. By filtration, the entry of bigger suspended inorganic impurities is removed. The filter consists of a GI enclosure, 40 mesh were screen and appurtenance. The filter was washed and cleaned every week.

3.2.3.4 Main line

A PVC pipe having a diameter of 40 mm was used as the main supply pipe. The operating pressure was controlled using a gate valve connected to the main supply line. The pipe line was buried in trenches and trenches were re-filled.

3.2.3.5 Sub mains

PVC pipes of diameter 32 mm were used as submain. They were also laid in trenches made in the fields and after laying of the pipes, the trenches were refilled with soil. The submains were connected to the main line using reducing Tee joint. The pop-up sprinkler heads were attached to the ends of submains.

3.2.3.6 Sprinkler heads

The sprinkler heads were attached to the male threaded adapter (MTA) fitted at the end of each submain. The sprinkler head with the sub-main is completely covered by the soil and when the system operates, the nozzle rises up due to pressure and water is sprayed like natural precipitation. The drip emitters and micro springlers were comnected to the submains using HDPE (High Density Poly Ethylene) pipes and micro tubes.

3.3 Automatic control

An Automatic control unit to control the three irrigation systems - drip, micro-sprinkler and pop-up sprinkler systems was developed. The on and off periods of the three systems can be individually controlled. The application rates can be adjusted to suit the infiltration rate of the soil and the crop-water requirement.

The unit consists of an electronic timer with on and off delay adjustments for the three systems. The on and off delay periods are as follows:

Drip system	On time	1.1 s - 40 min
	Off time	20 min - 50 min

PLATE 6 - MASTER CONTROL UNIT - FRONT VIEW

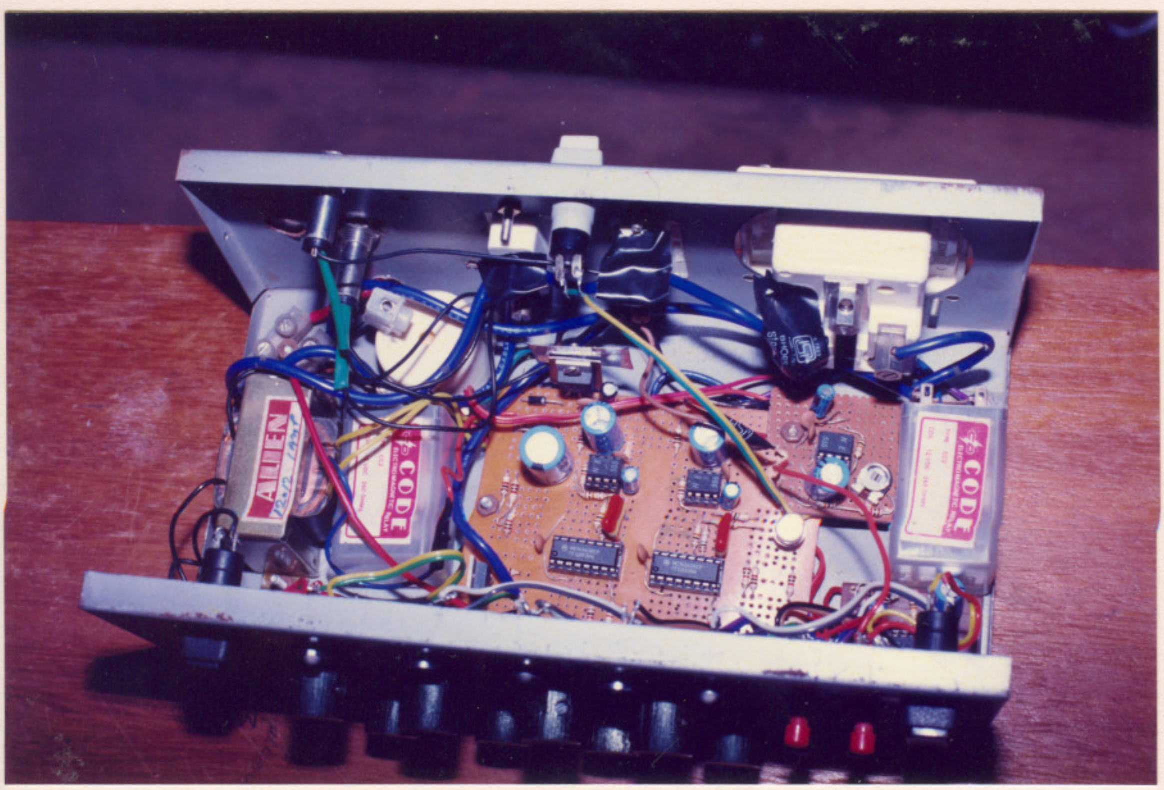


PLATE 7- MASTER CONTROL UNIT - INSIDE VIEW

Micro sprinkler system	On time	1.1 s - 5 min
	Off time	35 min - 1 hr
Pop-up sprinkler system	On time	1.1 s - 28 min
	Off time	35 min - 1 hr

With slight modifications in the circuit, the on and off timings can be adjusted as per requirement. Indicators are provided for the visual indication of the working of the on and off timers. Musical indication for the working of sprinklers is provided by the musical buzzer.

The off-timer circuit is based on CD 4060 B CMOS chip and on-timer circuit on IC 555. The circuit diagram of the timer is shown in Fig.5.

3.3.1 Working

The 12-0-12 V step down transformer provides an AC voltage which is rectified and filtered by a filter circuit. The unregulated DC, indicated by a red LED, provides the supply to the relays. In order to provide a regulated power supply to the sensitive off-timer IC 7808 is used which gives a regulated output of 8 V.

3.3.1.1 Off timer

The off-timer circuit is based on CD 4060 B CMOS

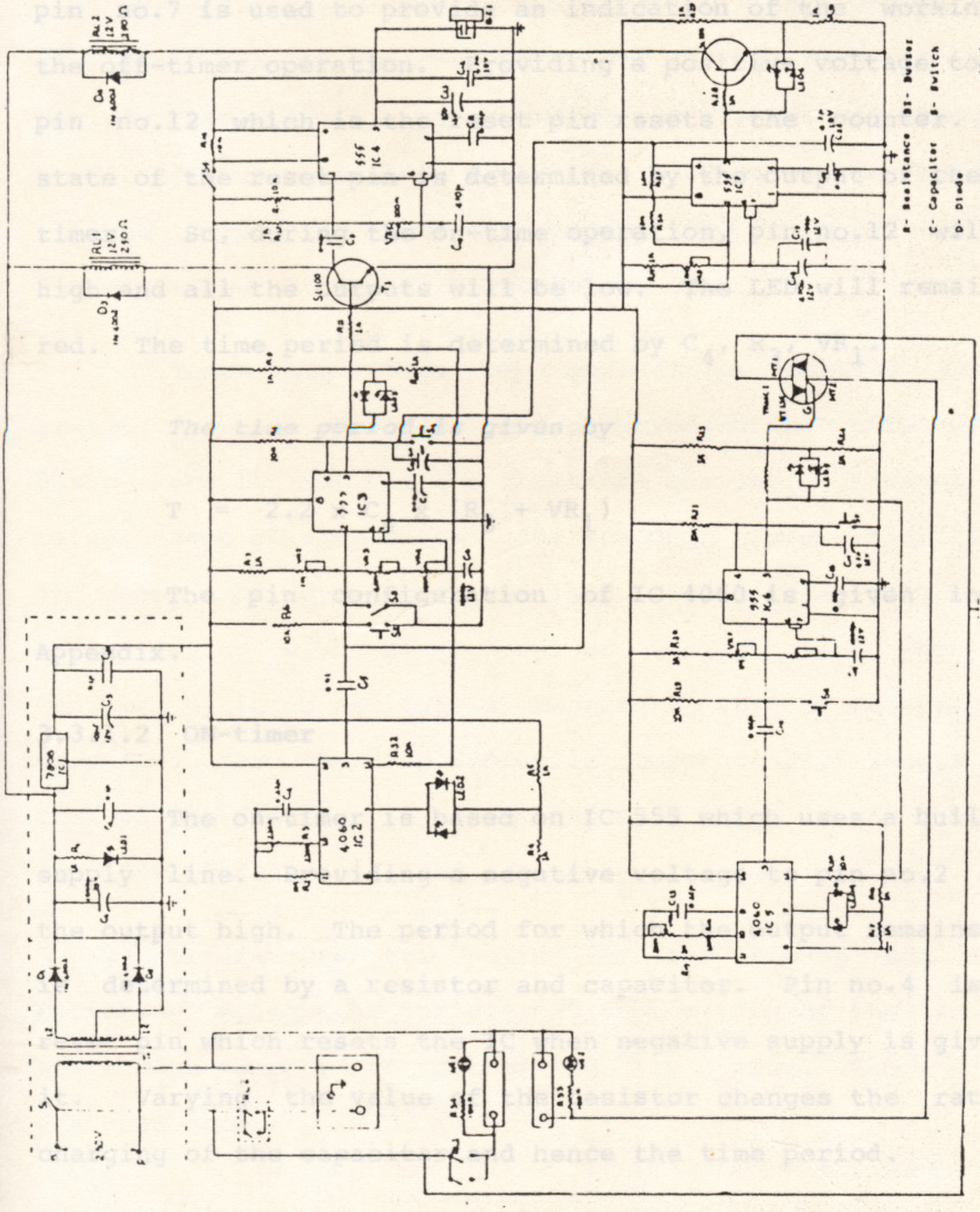


FIG. 5 Circuit Diagram of the Timer

oscillator cum 14 stage frequency divider. The regulated power supply is given to pin No.16. The output available at pin no.7 is used to provide an indication of the working of the off-timer operation. Providing a positive voltage to the pin no.12 which is the reset pin resets the counter. The state of the reset pin is determined by the output of the on-timer. So, during the on-time operation, pin no.12 will be *high and all the outputs will be low. The LED will remain lit* red. The time period is determined by C_4, R_3, VR_1.

The time period is given by

$$T = 2.2 \times C_4 \times (R_3 + VR_1)$$

The pin configuration of IC 4060 is given in the Appendix.

3.3.1.2 ON-timer

The on-timer is based on IC 555 which uses a built in supply line. Providing a negative voltage to pin no.2 makes the output high. The period for which the output remains high is determined by a resistor and capacitor. Pin no.4 is the reset pin which resets the IC when negative supply is given to it. Varying the value of the resistor changes the rate of charging of the capacitor and hence the time period.

The trigger pin of IC 555 is connected to the output of IC 4060 through a capacitor. As the output of IC 555 is low, the off-timers dividing operation will take place. Also the load can be switched on or off during the off or on periods respectively. by grounding the trigger and reset pin momentarily using push-on switches. A bi-colour is connected to the output to indicate if the load is on or off - red indicates the off position and green, on.

There are three on-timers in the control unit to control pop-up sprinkler, micro-sprinkler and drip system. Basic circuit for all the three are similar. However, the output stage of the on-timer for the drip system is different. It uses a triac to drive the load. Triac is a fully solid state device with no movement of contacts and the power consumed by it is negligible compared to that of relays. The on-period for the drip system is comparatively longer than that of sprinklers. If relays are used here, in the long run the life of relays will be adversely affected.

Triacs are not suited for the pop-up and micro-sprinkler systems as the current consumption of the load is quite high compared to that of the drip system. Hence relays are used here.

3.3.2 Controls of the drip system

The on-time of the drip system can be varied from 11 seconds to 40 minute, using two control knobs - the first one giving a time control 1.1 sec to 20 min and the second one from 20 min to 40 min. The indication of the on-time is provided by the LED. The drip can be switched on or off using two push on/off switches provided. The off period can be varied from 20 to 50 min. The output is available at the rear of the control unit.

3.3.3 Controls of the sprinkler system

Both the pop-up and micro-sprinklers have the same off-timer circuit and the off period can be varied from 35 min to 1 hr, using a control knob. The off-timing begins only after the pop-ups are switched off. Both the pop-ups and the micro-sprinkler are switched on simultaneously. the on-period for the micro sprinklers can be varied from 1.1 sec to 5 min using a control knob. The on-delay for the pop-ups varied from 1.1 sec to 28 min which are controlled using three knobs - the first to vary time from 1.1 sec to 2 min, the second from 2 to 8 min and the third from 8 to 28 min LED's are provided to indicate the working of both the on and off timers. A neon lamp indicates the working of the micro-sprinkler system.

An audible indication for the switching on of the sprinkler systems is given by a musical buzzer. A timer, using IC 555, is used to switch off the buzzer automatically. The time period for which the buzzer is on can be varied using a fixed variable resistor. If required, the buzzer can be permanently switched off using a push-on/off switch provided at the rear end of the control unit.

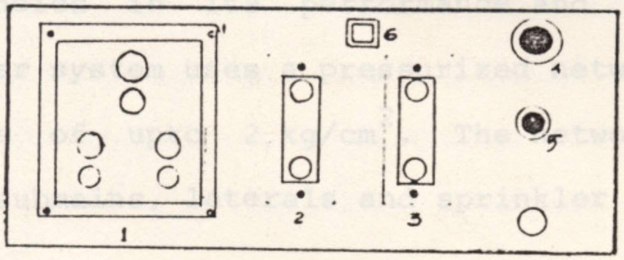
The front view and back view of the control unit are shown in Fig.6.

3.3.4 Construction

The complete timer circuit is assembled on a general purpose PCB. The construction has been started by soldering the resistor followed by the capacitors and the LED's, diodes and IC sockets. A suitable heat sink is provided for the triac. Heat-sink compound was applied while fixing the heat-sink. The circuit was housed in a small cabinet. When the circuit is working properly, the LED remain lit red.

3.4 Pop-up sprinkler design aspects

Effective performance of a proposed irrigation system depends on its efficient design, layout and management. An irrigation system, to suit the conditions of a particular site, is specially designed in order to achieve high



CONTROL PANEL- BACK VIEW

1. Power plug for the motor connection
2. Plug for drip solenoid valve
3. Plug for micro sprinkler system
4. Drip-on indicator
5. Micro sprinkler on indicator
6. Buzzer on/off switch

FIG. 6 (a)

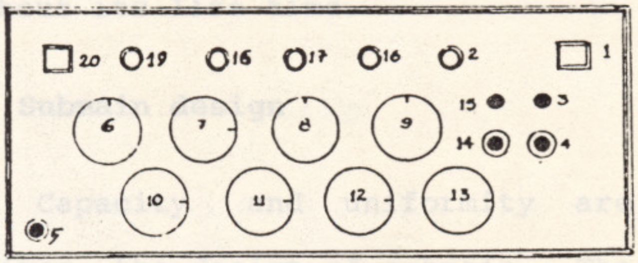


FIG. 6 (b) CONTROL PANEL-FRONT VIEW

1. Continuous on switch for pop-up and micro sprinklers
2. Micro sprinkler on/off indicator
3. Micro sprinkler and pop-up on switch
4. Micro sprinkler and pop-up off switch
5. Power indicator
6. Drip on time adjusting knob 1
7. Drip on time adjusting knob 2
8. Pop-up off time adjusting knob
9. Micro sprinkler on time adjusting knob
10. Drip off time adjusting knob
11. Pop-up on time adjusting knob 1
12. Pop-up on time adjusting knob 2
13. Pop-up on time adjusting knob 3
14. Drip off switch
15. Drip on switch
16. Pop-up off time indicator
17. Pop-up on/off indicator
18. Drip off time indicator
19. Drip on/off indicator
20. Power on/off switch

efficiencies in its performance and economy. The pop-up sprinkler system uses a pressurized network with an operating pressure of upto 2 kg/cm^2. The network consists of main lines, submains, laterals and sprinkler heads.

3.4.1 Main line design

Main line serves as a conveyance system for delivering the total amount of water at the required pressure to the irrigation system. It should be designed such that the total energy at any outlet along the main line is equal to or greater than the energy required for operating the entire system. The design approaches mainly to determine the allowable energy drop for the entire main line. The main pipe should be so selected that the operating cost is minimised throughout its life time.

3.4.2 Submain design

Capacity and uniformity are the criteria which determines the design of submain. The submain should have large enough capacity to deliver the required amount of water to irrigate the plots. Uniformity means that the submain should be sufficient to maintain an allowable pressure variation so that the flow into all the lateral lines will have little variation. Knowing the discharge requirements of a lateral and the number of laterals in a submain, the discharge requirements of a submain can be computed. The suitable size of the submain pipe is selected from design chart, once the values of discharge and slope are known. The friction loss can be computed using the Darcy Weisback's equation as

$$Hf = \frac{4flv^2}{2gd}$$

where,

Hf is the head loss in metres

f is the friction factor

l is the length of pipe in metres

v is the velocity of fluid in m/s

g is the acceleration due to gravity in m/s

d is the diameter of pipe in m

3.4.3 Lateral line design

In lateral line design, due consideration is given to discharge variations so that it is within acceptable limits. The sprinkler head and the sprinkler spacing are selected based on the shape of the plot, crop requirements and soil conditions. The total discharge at the inlet section for a given length under an operating pressure can be determined. Knowing the total length and operating head, L/H ratio is calculated. From the known, discharge, slope and L/H ratio, suitable size for lateral pipe can be obtained from design charts for both uniform and non-uniform slopes. Knowing the length and discharge, the friction loss can be computed using Darcy Weisback's equation as described above.

3.4.4 Sprinkler head selection

The selection of the various sprinkler heads depends on the shape of the area to be irrigated. Hence the positions of the Full and Quarter circle pop-up sprinkler heads were determined according to the nature of the plot. Sprinkler head had an external threading which enables it to be threaded on to the internally threaded coupling fixed on lateral line.

3.4.5 Pump selection

The selecting a suitable pump, it is necessary to determine the maximum total head against which the pump is working which may be

$$Ht = Hn + Hm + Hs + Hg$$

where,

Ht is the total design head against which the pump is working, in m

Hn is the maximum head required at the main to operate the sprinklers on the lateral at the required average pressure, in m

Hm is the maximum friction loss in the main and suction line, in m

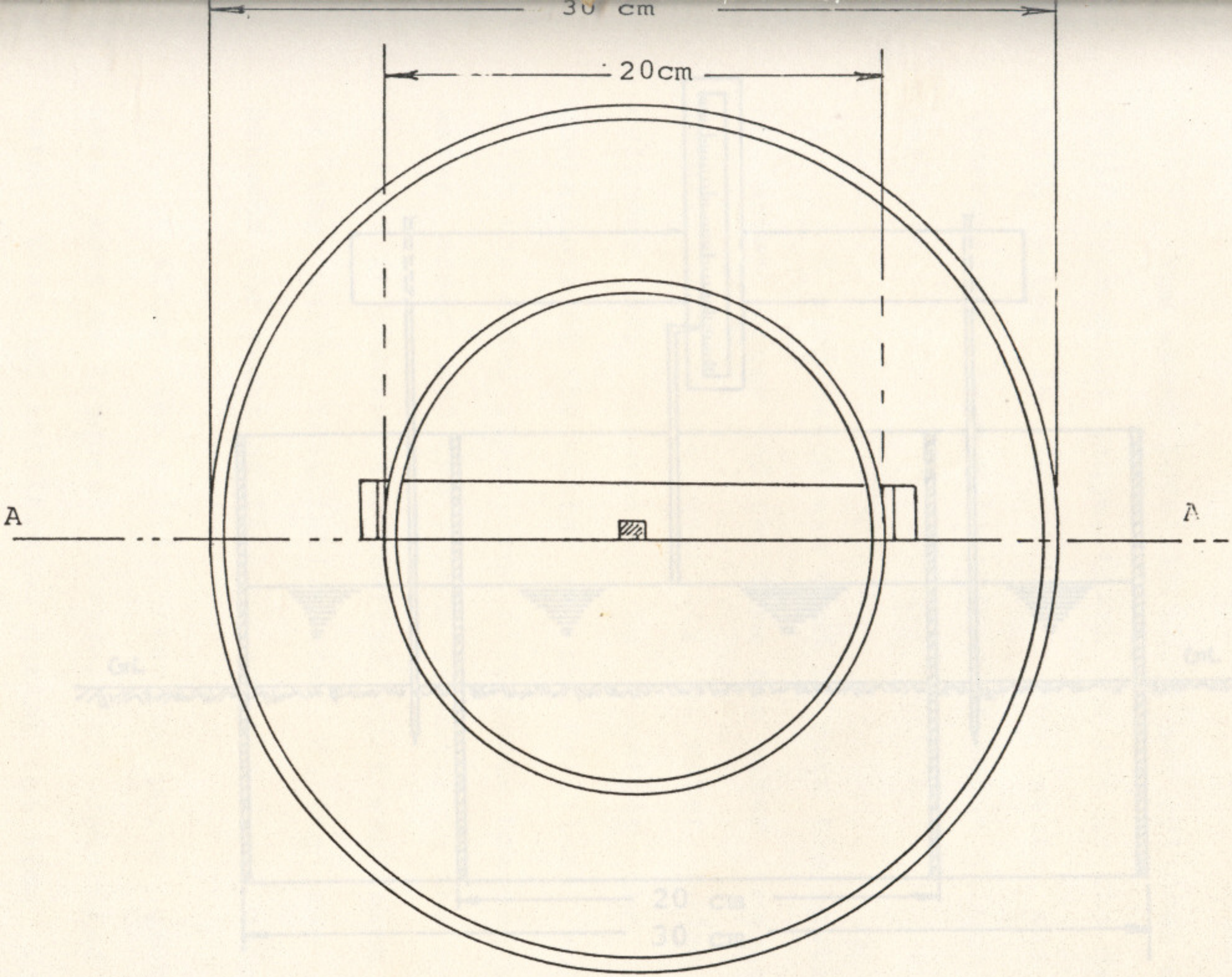
Hg is the elevation difference between the pump and the source of water after draw down, in m

The amount of water that is required is determined by multiplying the number of sprinklers by the capacity of each. When the total head and rate of pumping are known, the pump may be selected from rating curves available from the manufacturers.

The drip system and the micro-sprinkler system are also designed and laid out according to the design procedure and specifications involved.

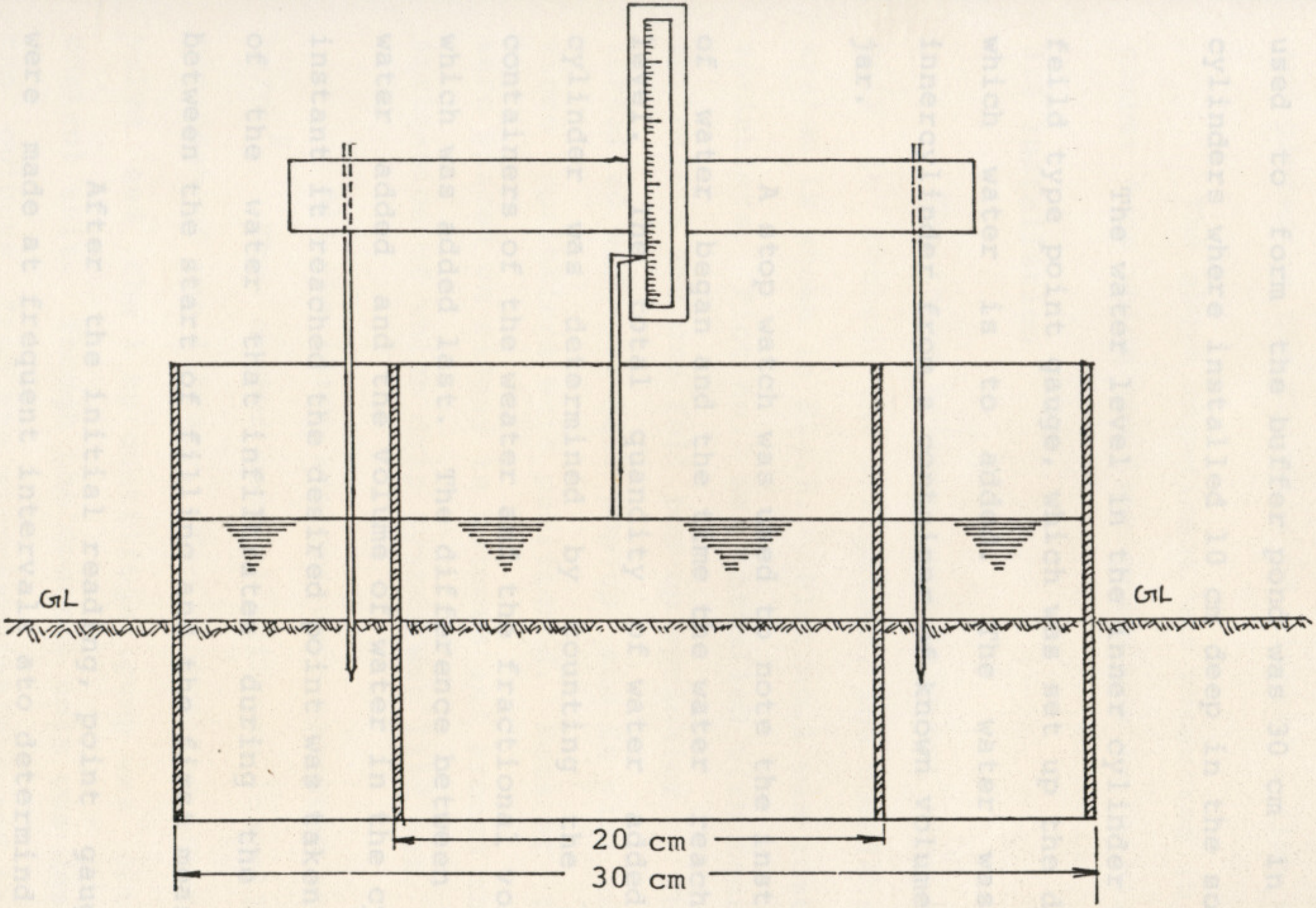
3.5 Estimation of the infiltration charactristic of the soil

The infiltration charachristic of the soil have a bearing on deciding the ON and OFF periods of the irrigation systems. The method adopted here was the use of cylinder infiltrometers. The principle used in this method is the ponding of the water in a metal cylinder installed on the feild surface and the observing the rate at which water level is lowered in the cylinde. The experimental set up used in the onfiltration measurements are illustratd in Fig 7 and 8. The inner cylinder, from which the infiltration measurement



PLAN

FIG.7 EXPERIMENTAL SET-UP FOR MEASURING INFILTRATION WITH A CONCENTRIC CYLINDER INFILTROMETER



SECTION A.A.

FIG.8 EXPERIMENTAL SET-UP FOR MEASURING INFILTRATION WITH A CONCENTRIC CYLINDER INFILTROMETER were taken, was off 20 cm diameter whereas the outer cilinder, used to form the buffer pond was 30 cm in diameter. The cylinders where installed 10 cm deep in the soil.

The water level in the inner cylinder was read with a feild type point gauge, which was set up the desired level to which water is to added. The water was added to the innercylinder from a container of known volume and a graduated jar.

A stop watch was used to note the instant the addition of water began and the time the water reached the desired level. The total quandity of water added to the inner cylinder was determined by counting the number of full containers of the weater and the fractional volume in the jar, which was added last. The difference between the quantity of water added and the volume of water in the cylinder at the instant it reached the desired point was taken as the quantity of the water that infiltrates during the time intervell between the start of filling and the first measurement.

After the initial reading, point gauge measurements were made at frequent intervals ato determind the amount of water that had infiltrated during the time interval. Water was added quickly after each measurement so that a constant average infiltration head was maintained. The average values of accumilated infiltration y and average infiltration rates are ploted as the function of elapsed a time t.

The above experiment was conducted in the soil of plot number 4 on which the lawn grass was to be planded.

3.6 Installation

The three systems were laid out with a master control unit to control the irrigation. The complete layout of the system is shown in Fig.9. Plot no.1 was installed with micro sprinklers. Plot no.2 was installed with four quarter pop-up sprinklers and one full pop-up sprinkler. The plot no.3 was installed with one half pop-up and in plot no.4 the remaining micro sprinklers were positioned. Pots of flowering plants were placed on ridges in between and around the plots, for the irrigation of which drip system was laid out.

All the three systems were operated at a pressure of 1 kg/cm^2. The master control unit was installed in southern verandah of the library. The controlled input to the solenoid valve and the 1 hp centrifugal pump was obtained from the control unit. Though the control unit was designed such that the outputs from the micro-sprinklers and the pop-ups draw their inputs separately, during the installation only one pump was available. Due to this, the time controls for both the

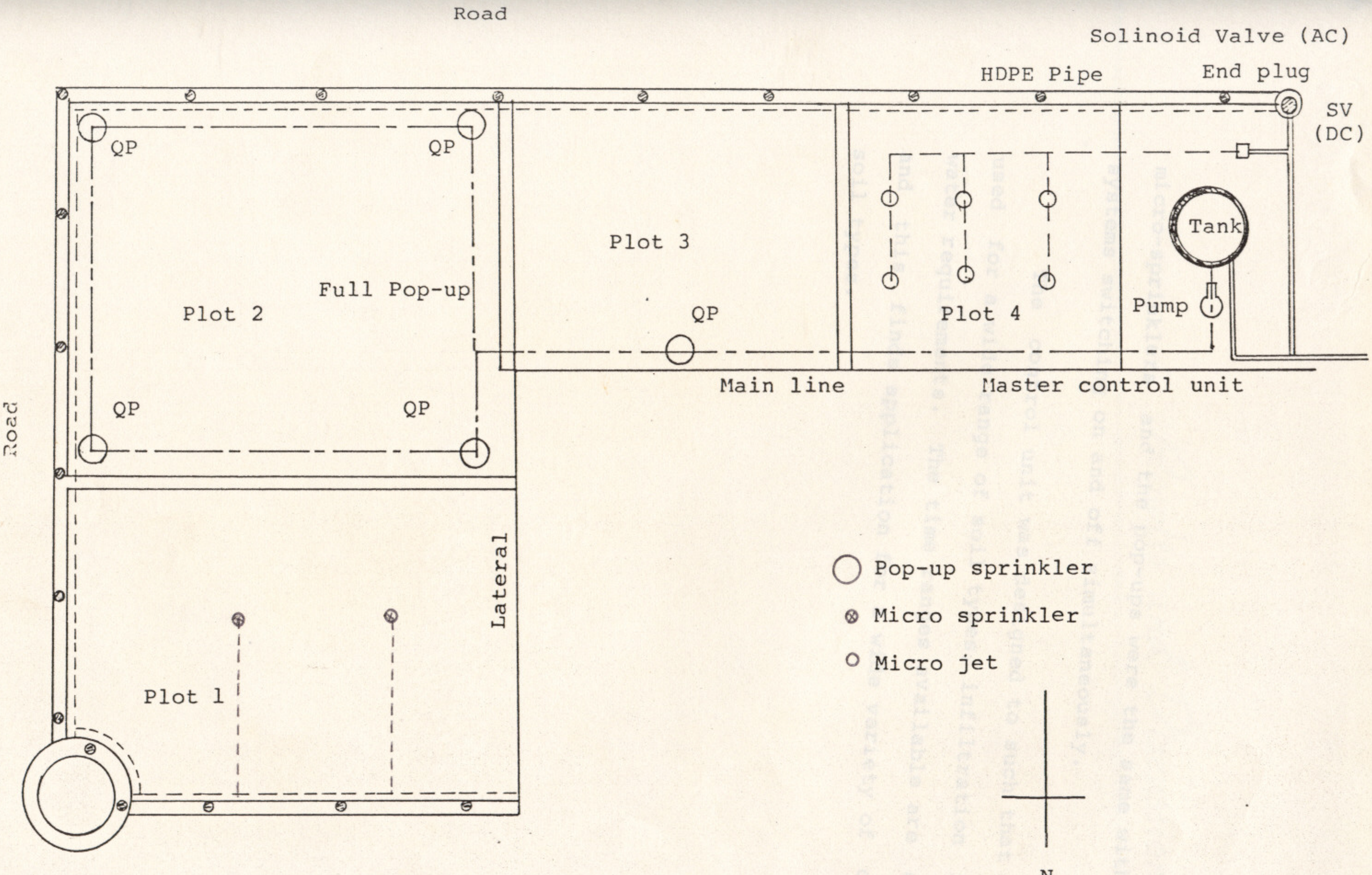


FIG.9 LAYOUT OF IRRIGATION SYSTEMS

micro-sprinklers and the pop-ups were the same with both the systems switching on and off simultaneously.

The control unit was designed to such that it can be used for a wide range of soil types, infiltration rates and water requirements. The time ranges available are quite-wide and this finds application for a wide variety of crops and soil types.

RESULTS AND DISCUSSION

This chapter discusses the results of the experiments conducted to evaluate the performance of the pop-up sprinkler heads and the development and installation of the master control unit.

4.1 Performance evaluation of pop-up sprinklers

The performance of two pop-up sprinkler heads were evaluated to determine their water distribution pattern, wetted radius, distribution characteristics and coefficient of variation at different operating pressures.

4.1.1 Radius of throw

Both the pop-up emitters were found to spray a small amount of the water well beyond the main area of water application. In order to properly describe the wetted area therefore the term effective radius (Re) was defined such that it is the average distance from the emitter to the most distant 5 per cent of the containers which received water. The effective area (Ae) of water application by the emitter was then calculated as the area at a radial distance equal to the effective radius from the sprinkler head. The ranges of the effective radii for the two pop-ups were:

Full pop-up - 2.5 m - 4.5 m

Quarter pop-up - 5.0 m - 5.5 m

The effective areas ranged from:

Full pop-up - 19.63 m^2 - 63.62 m^2

Quarter pop-up - 19.63 m^2 - 23.76 m^2

At lower pressure of 0.5 kg/cm^2, the wetted areas were almost equal for both the pop-up heads. At greater pressures, the full pop-up wetted greater areas than the quarter pop-ups.

4.1.2 Application depth

It was observed that there were a few containers in each test which received significantly more water than the other containers. Hence, to formulate a suitable definition for the application depth, two terms defined were - the absolute maximum depth (Dxa) as the greatest depth caught in any of the container for a particular sprinkler head and the effective maximum application depth (Dxe) was defined as the average depth caught in 5 per cent of the containers that had the greatest catch depths. The mean application depth (Da) was calculated as the average depth of water caught in the containers located within a distance of the effective radius from the sprinkler heads.

In case of the full pop-up, the mean application rate was found to decrease with the increase in pressure. The values ranged from, 19.77 mm/hr to 8.02 mm/hr. For quarter pop-up, the mean application rate increased with increase in pressure. The wetted radius and application depths for the two pop-ups are shown in Table 1.

The increase in wetted area with pressure was observed to be quite high in case of the full pop-up. The discharges, however, did not increase in a corresponding manner. This could be why the application depths decreased with increase in pressure. For the quarter pop-ups, the increase in discharge was much higher than the increase in effective radii with pressure, increasing application depths.

4.1.3 Distribution pattern

The moisture distribution pattern for the two pop-up heads was determined under different operating pressures. The percentages of average application depth collected in the cans within the effective radius from the sprinkler head were calculated. A graph, showing the percentages of average application depth at different distances from the emitter was plotted. In order to represent the different ranges of the percentages of average application depth, different symbols

Table 1. Performance of pop-up sprinklers

Pop-up sprinkler	Pressure kg/cm^2	Discharge lph	Wetted radius m	Mean application rate (Da) mm/hr	Dxe:Dia
	0.5	451.2	2.5	19.7	1.86
	1.0	638.8	3.5	19.69	1.33
FP	1.5	774.8	3.5	11.06	1.50
	2.0	902.1	4.5	8.02	2.20
	0.5	120.2	5.0	4.48	4.98
	1.0	177.2	5.5	5.08	5.61
QP	1.5	217.4	5.5	7.49	5.78
	2.0	274.0	5.5	8.19	6.22

were used. It was observed that most of the area received less than 150 per cent of the average application.

It was seen that both the pop-ups wetted more than 50 per cent of the total wetted area with more than half of the average application, and the percentage of area receiving less than 10% of the average application was about 19 per cent for both the sprinkler heads.

Figures 10, 11, 12 and 13 show the distribution patterns of full pop-up sprinkler heads. For all operating pressures, a minimum of 28 per cent of the total wetted area received water greater than the average application depth. An average of 42 per cent of the total wetted area received less than 50 per cent of the average application rate for all operating pressures. The wetted radius increased with pressure. All the distribution patterns were found to be uniform for all operating pressures. At a pressure of 1.5 kg/cm^2 most of the cans within a two metre radius from the sprinkler head received about 100-150 per cent of the average application. At 2 kg/cm^2, the area within two metre radius from the sprinkler head received about 150-250 per cent of the average application.

Figures 14, 15, 16 and 17 show the distribution pattern of quarter pop-up operating under the pressures of

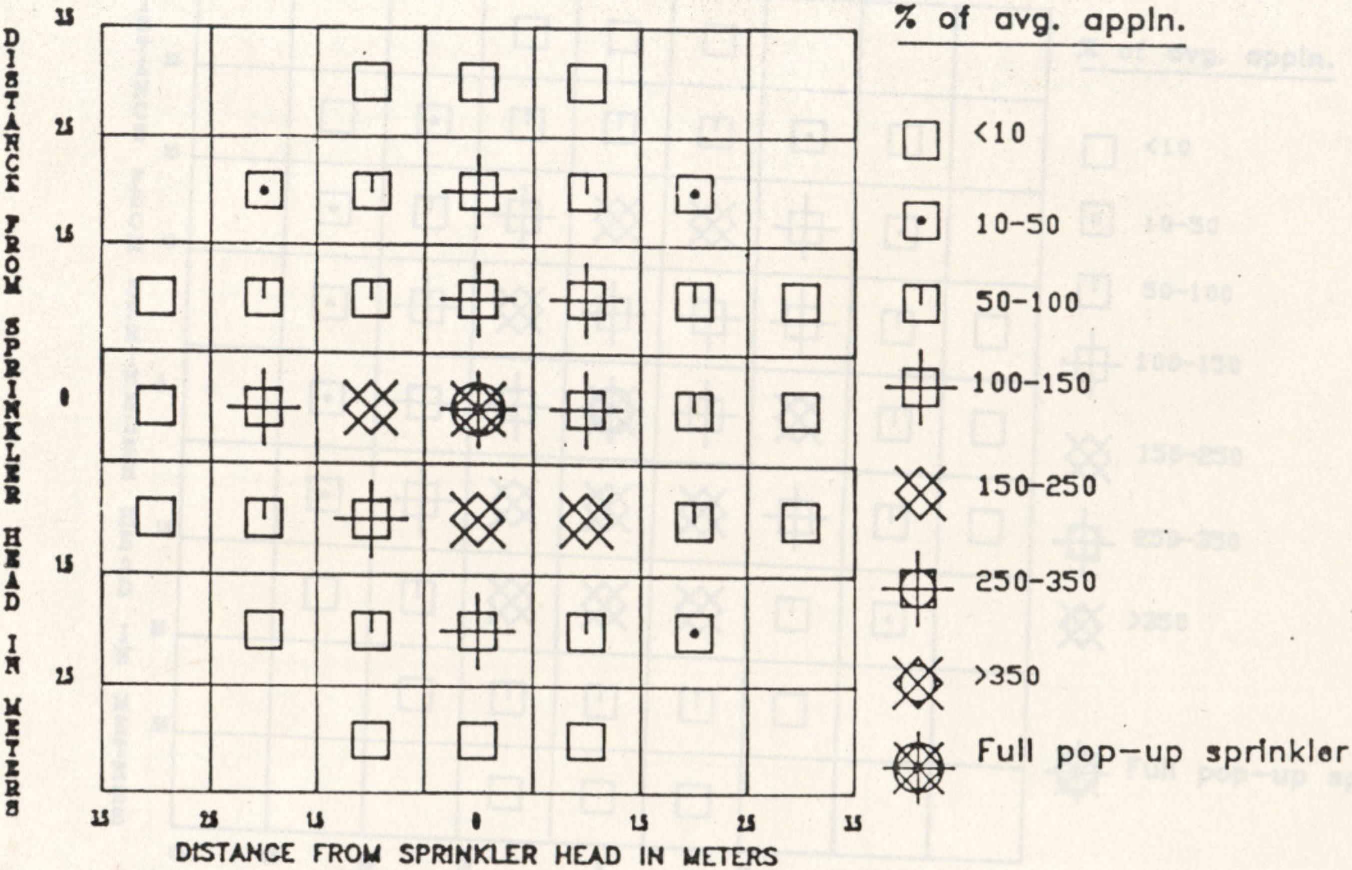


FIG.10 DISTRIBUTION PATTERN OF FP AT 0.5 kg/cm^2

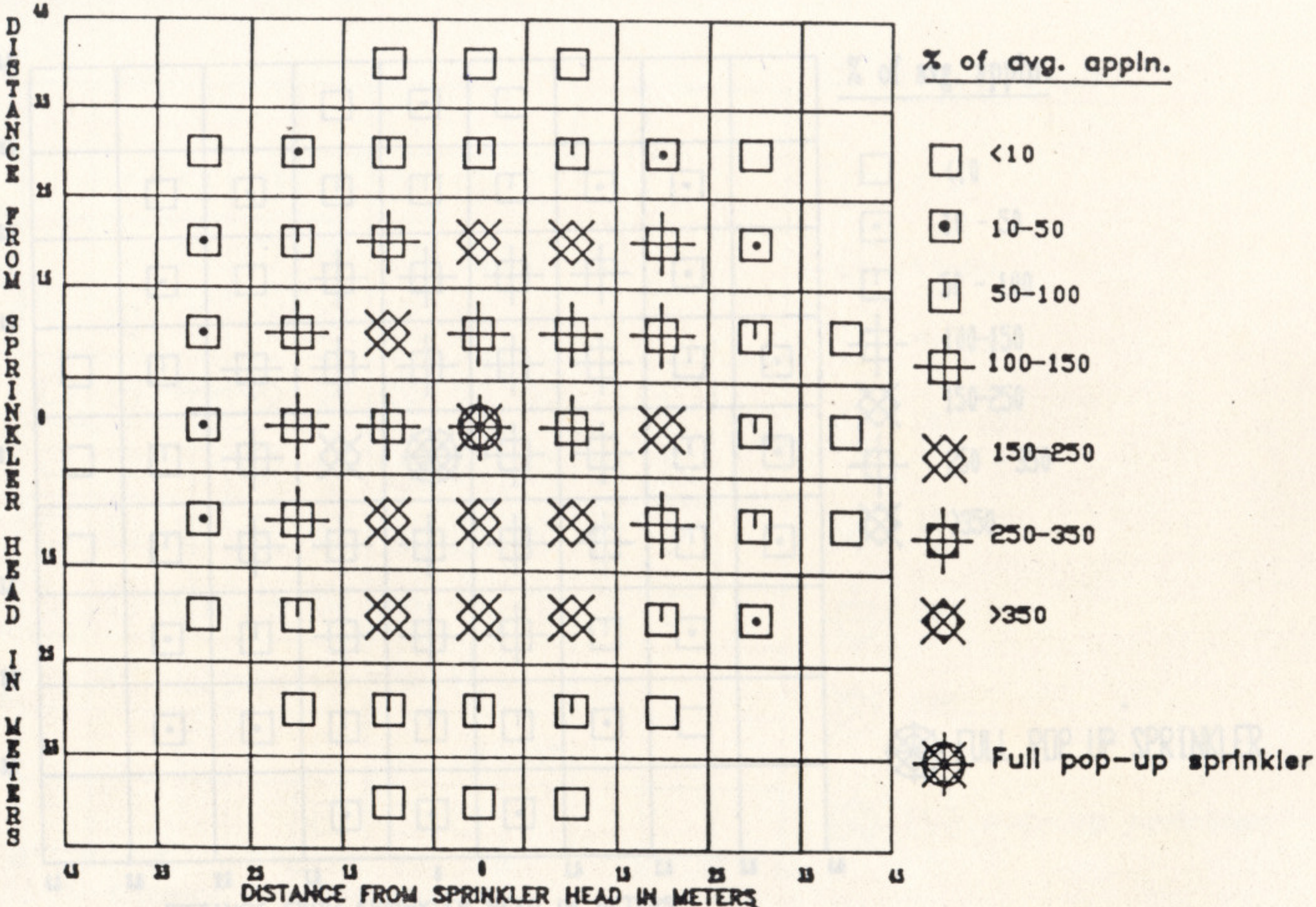


FIG.11 **DISTRIBUTION PATTERN OF FP AT 1 kg/cm^2**

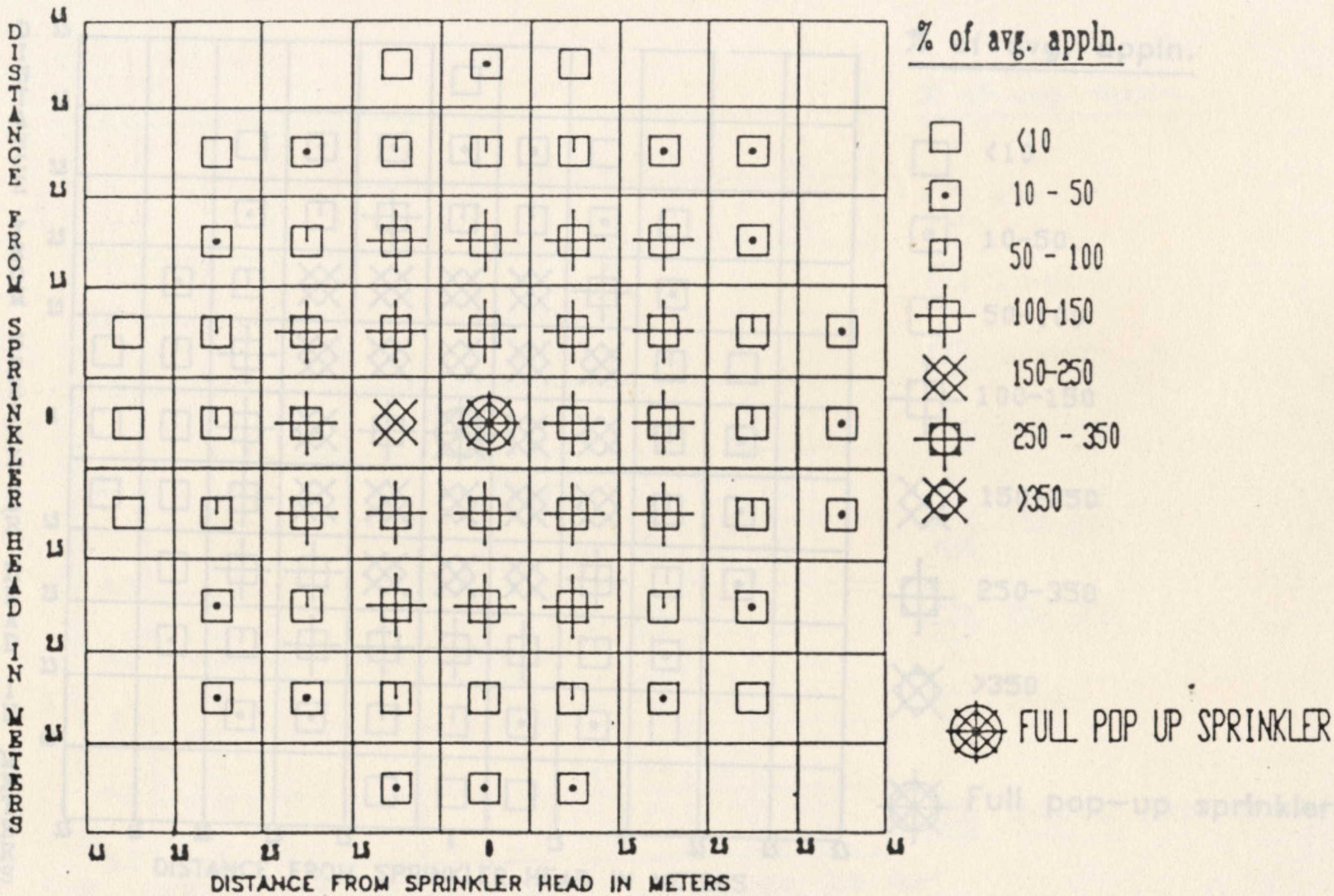


FIG.12 DISTRIBUTION PATTERN OF FP AT 1.5 kg/cm^2

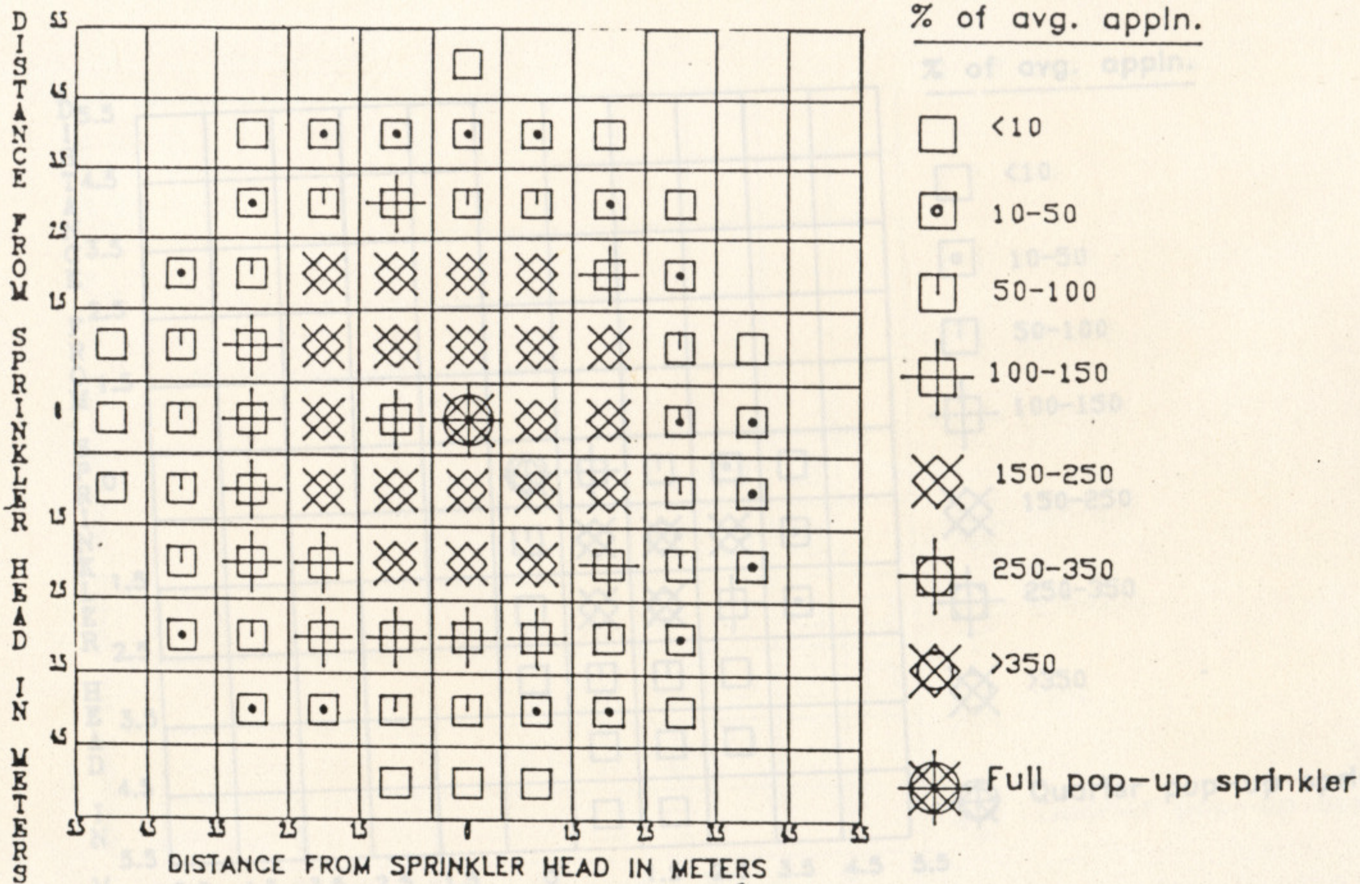


FIG.13 DISTRIBUTION PATTERN OF FP AT 2 kg/cm^2

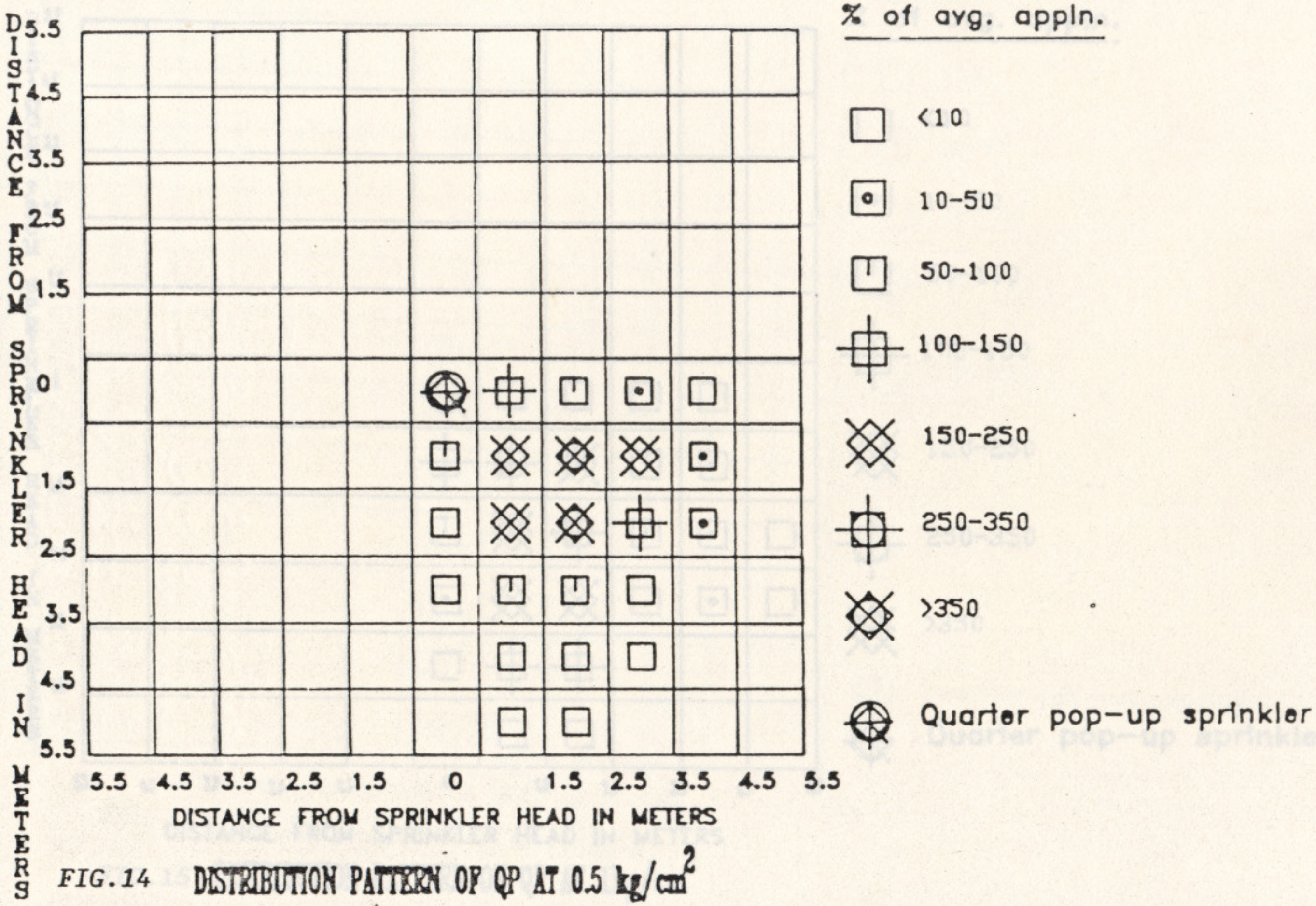


FIG.14 **DISTRIBUTION PATTERN OF QP AT 0.5 kg/cm^2**

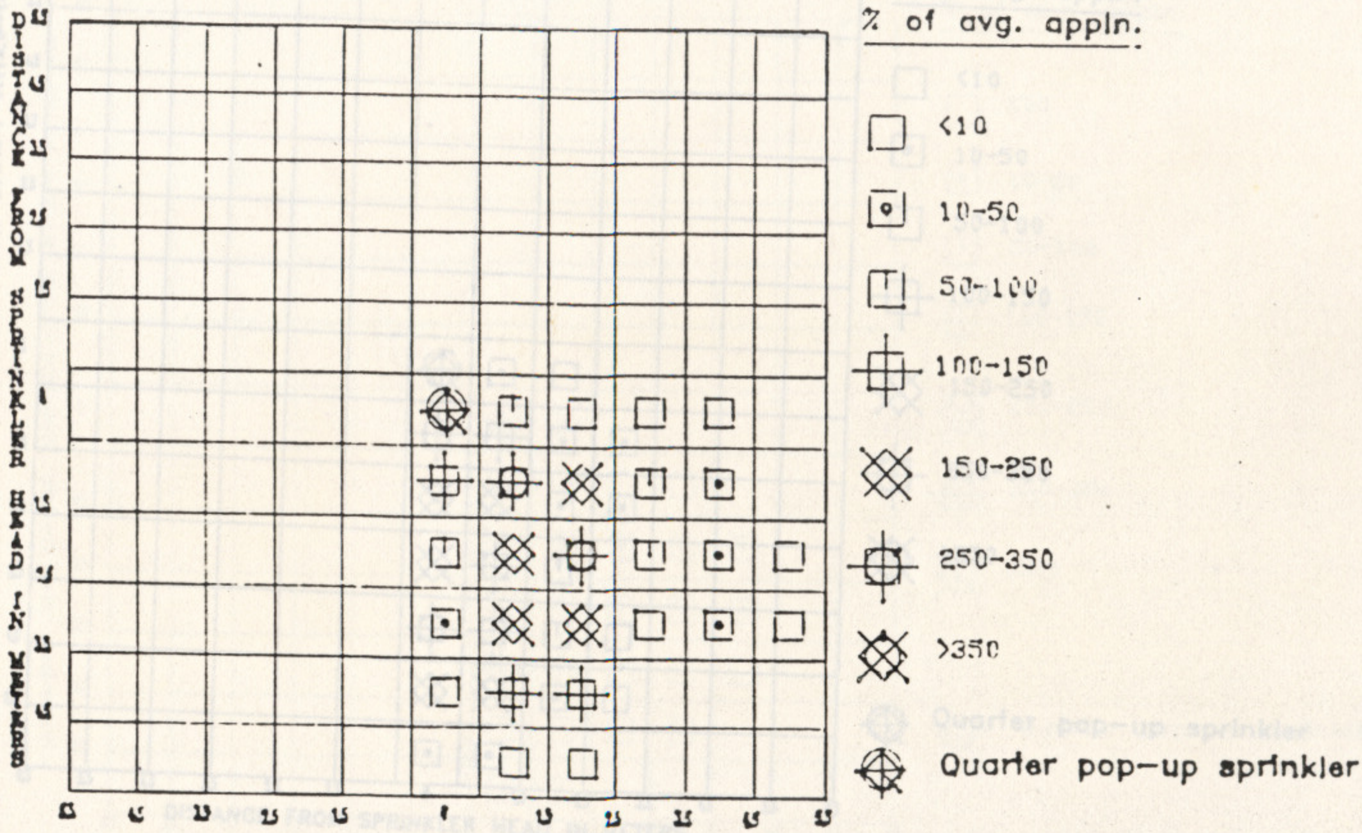


FIG.15 **DISTRIBUTION PATTERN OF QP AT 1kg/cm^2**

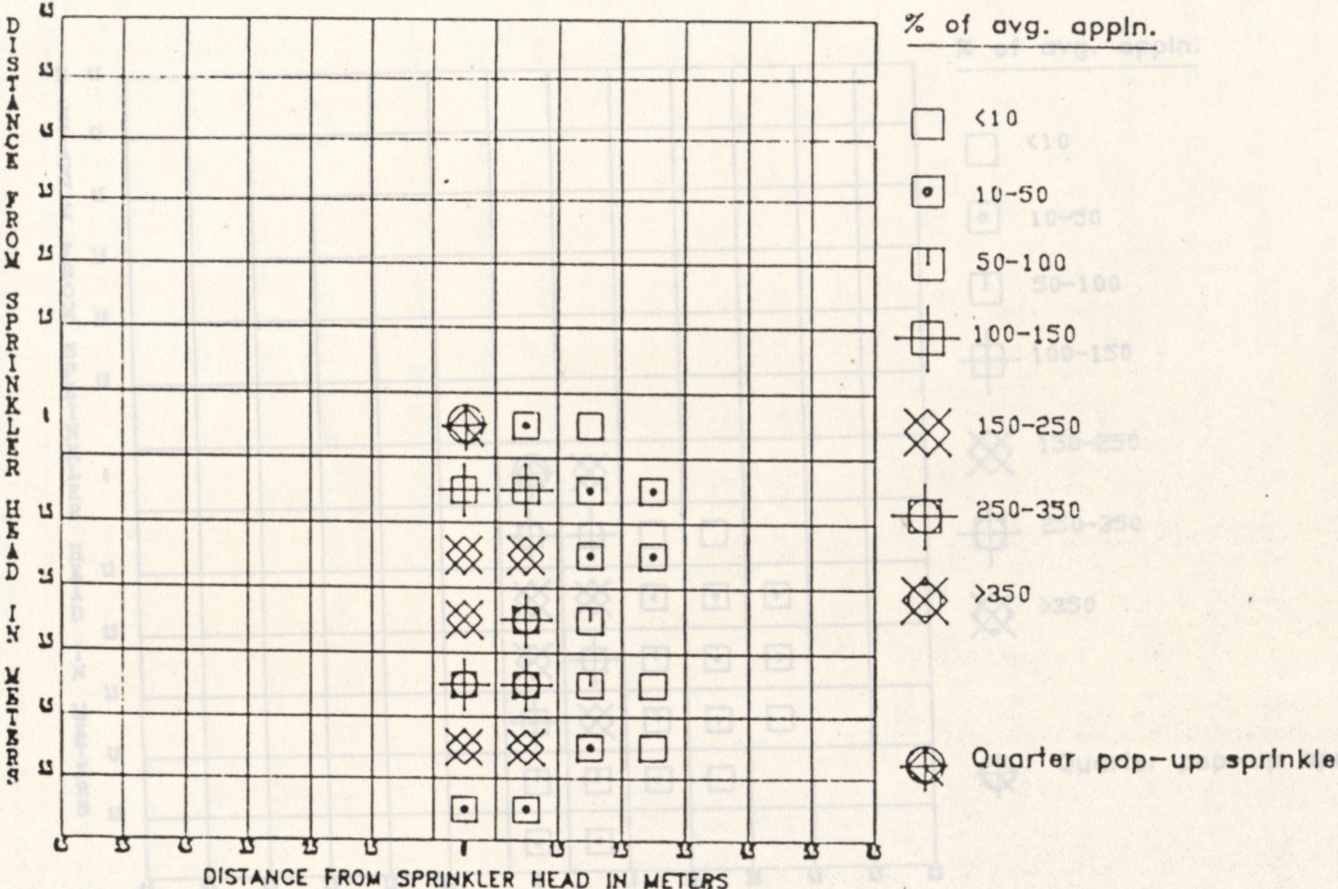


FIG. 16 DISTRIBUTION PATTERN OF QP AT 1.5 kg/cm^2

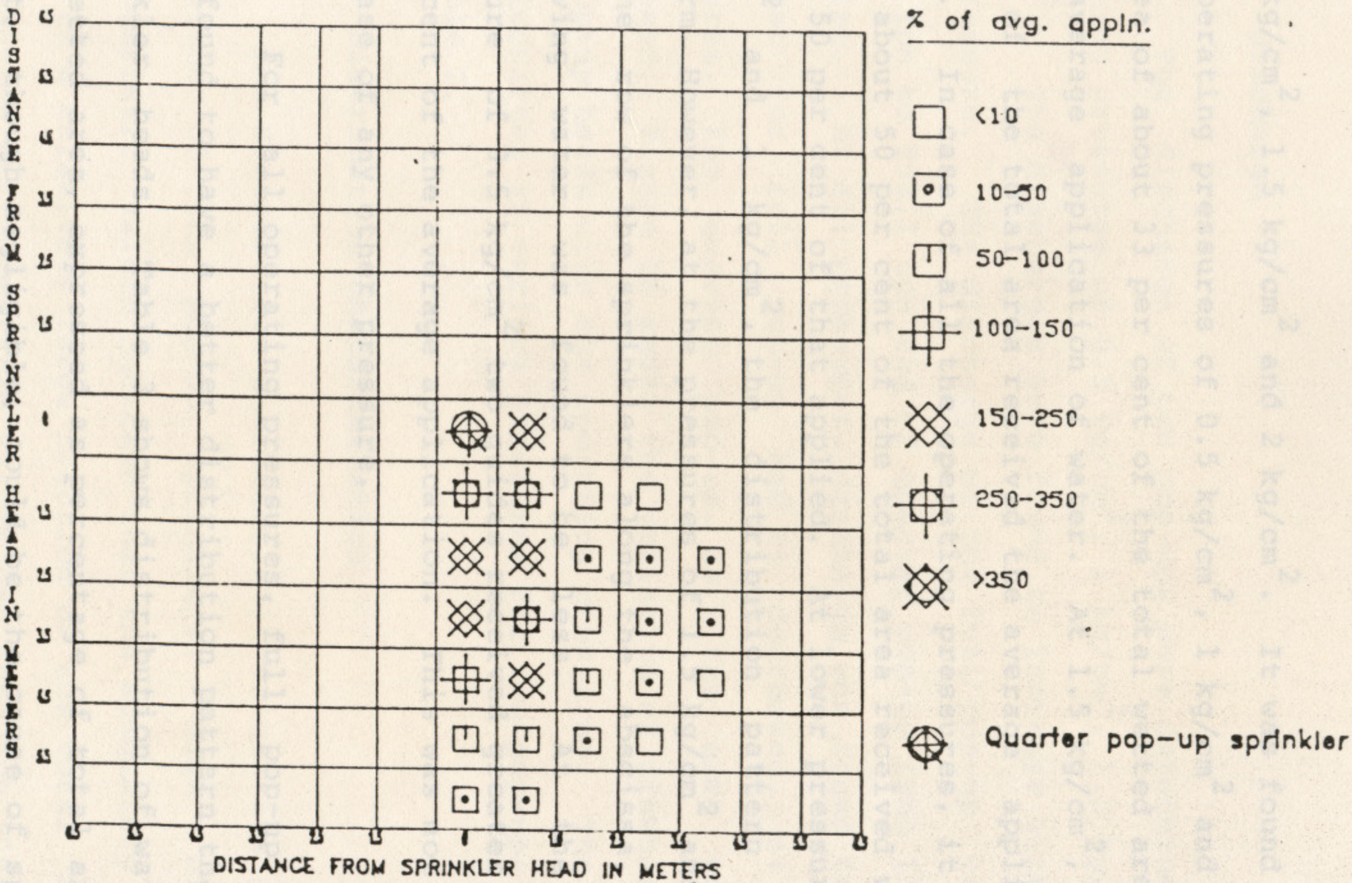


FIG. 17 **DISTRIBUTION PATTERN OF QP AT 2 kg/cm^2**

0.5 kg/cm^2, 1.5 kg/cm^2 and 2 kg/cm^2. It was found that for the operating pressures of 0.5 kg/cm^2, 1 kg/cm^2 and 2 kg/cm^2, an area of about 33 per cent of the total wetted area received the average application of water. At 1.5 kg/cm^2, 43.5 per cent of the total area received the average application of water. In case of all the operating pressures, it was seen that about 50 per cent of the total area received water less than 50 per cent of that applied. At lower pressures of 0.5 kg/cm^2 and 1 kg/cm^2, the distribution pattern was quite uniform. However, at the pressures of 1.5 kg/cm^2 and 2 kg/cm^2, in the row of the sprinklers along the abscissa, the area receiving water was found to be less. At the operating pressure of 0.5 kg/cm^2 two guides received greater than 350 per cent of the average application. This was not found in the case of any other pressure.

For all operating pressures, full pop-up sprinklers were found to have a better distribution pattern than quarter sprinkler heads. Table 3 shows distribution of water within the wetted area, expressed as percentage of total area. Wind effect, though negligible, could be the cause of spray drift in case of the higher operating pressures for quarter pop-up. The isolated change in pattern at 0.5 kg/cm^2 operating pressure was due to a defect in the manufacture of the sprinkler head.

4.1.4 Discharge

The discharge of two pop-ups were determined at the operating pressures of 0.5 kg/cm^2, 1 kg/cm^2, 1.5 kg/cm^2 and 2 kg/cm^2. The discharges were found to increase with increase in pressure. The discharge of the full pop-up varied from 451.2 lph to 902.1 lph and of quarter pop-up from 120.2 lph to 274 lph. At all pressures, discharge was found to be the greatest for full pop-up and it decreased, at the same pressures, for quarter pop-up, as the area of coverage decreased. Figure 18 shows the variation of discharge of the two pop-up heads with the operating pressures. The values for the discharges at various pressures for two pop-ups are given in Table 1.

4.1.5 Distribution characteristics

The distribution characteristic values are a means of evaluation of the pop-up sprinklers. High distribution characteristic values indicate that the adequately irrigated area is a relatively large fraction of the total area. The distribution characteristic values can approach 100 per cent. However, distribution characteristic values greater than 50 per cent are satisfactory and those above 66 per cent indicated very good patterns. Table 2 shows the distribution characteristic values for two pop-up heads.

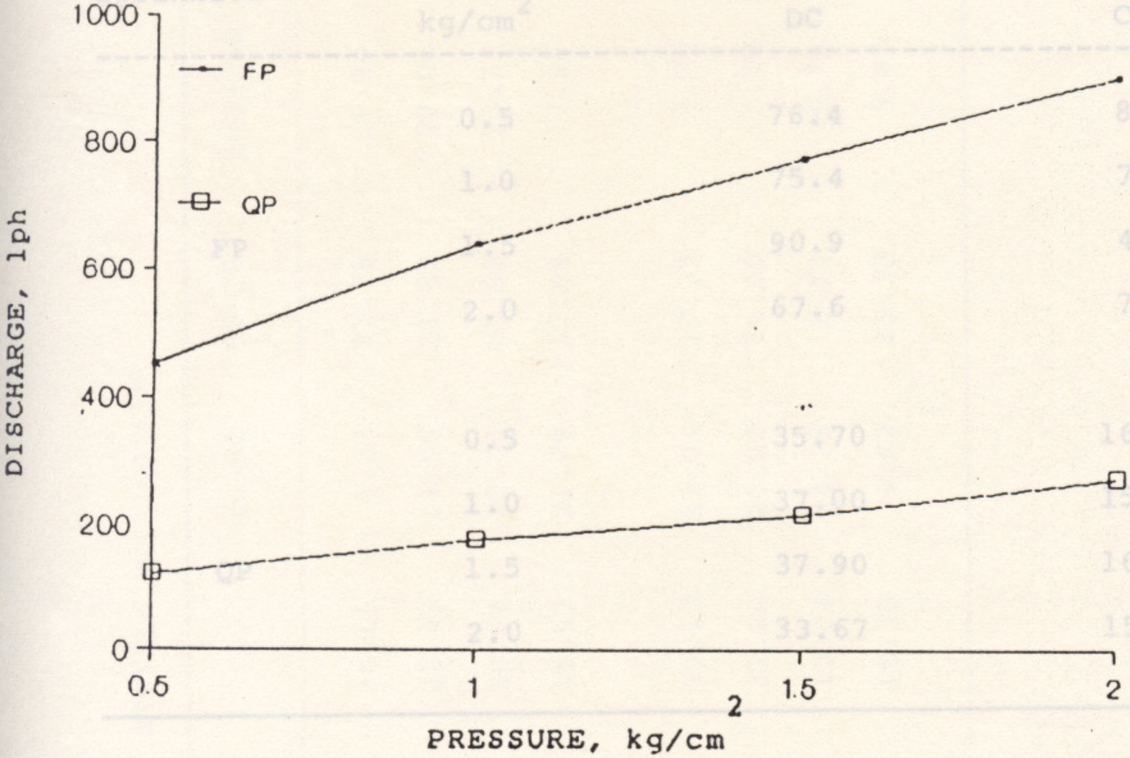


FIG. *18*

VARIATION OF DISCHARGE OF TWO POP-UP HEADS WITH OPERATING PRESSURES

Table 2. Uniformity parameter of pop-up sprinklers

Pop-up sprinkler	Pressure kg/cm^2	Distribution characteristic DC	Coefficient of variation CV %
	0.5	76.4	88.89
	1.0	75.4	75.18
FP	1.5	90.9	43.85
	2.0	67.6	70.14
	0.5	35.70	166.22
	1.0	37.00	153.49
QP	1.5	37.90	167.59
	2.0	33.67	159.58

Table 3. Percentage of average amplication

Pop-up sprinkler	Pressure	<10	10-50	50-100	100-150	150-250	250-350	>350
FP	0.5	36.11	8.33	27.78	19.45	8.33	0.00	0
	1.0	25.45	14.55	21.82	20.00	18.18	0.00	0
	1.5	10.00	30.00	25.00	33.33	7.67	0.00	0
	2.0	16.67	21.79	17.98	17.95	25.64	0.00	0
QP	0.5	39.13	13.04	17.39	8.70	13.04	8.7	0
	1.0	32.00	16.00	16.00	12.00	16.00	8.00	0
	1.5	13.04	34.78	8.70	8.70	21.47	13.04	0
	2.0	15.38	34.62	15.38	3.85	19.23	11.54	0

For full pop-up the distribution characteristic values at all the operating pressures were greater than 66 per cent. This indicated a very good wetting pattern. The distribution characteristic value for full pop-up operating at 1.5 kg/cm^2 was 90.9 per cent which distributed the applied water in an even manner and gave the best distribution pattern.

The distribution characteristic values of quarter pop-up at all operating pressures were found to be below 50 per cent indicating an unsatisfactory pattern.

4.1.6 Coefficient of variation

The coefficient of variation of catch depths for a particular sprinkler head was calculated by dividing the standard deviation of depths used to calculate the mean, by the mean application depth. The coefficient of variation is expressed as a percentage. The values less than 100 per cent can be considered good and those less than 200 per cent, satisfactory. The coefficient of variation values of the two sprinkler heads as shown in Table 2. Figure 19 shows the variation of the coefficient of variation with pressure for the different pop-up heads.

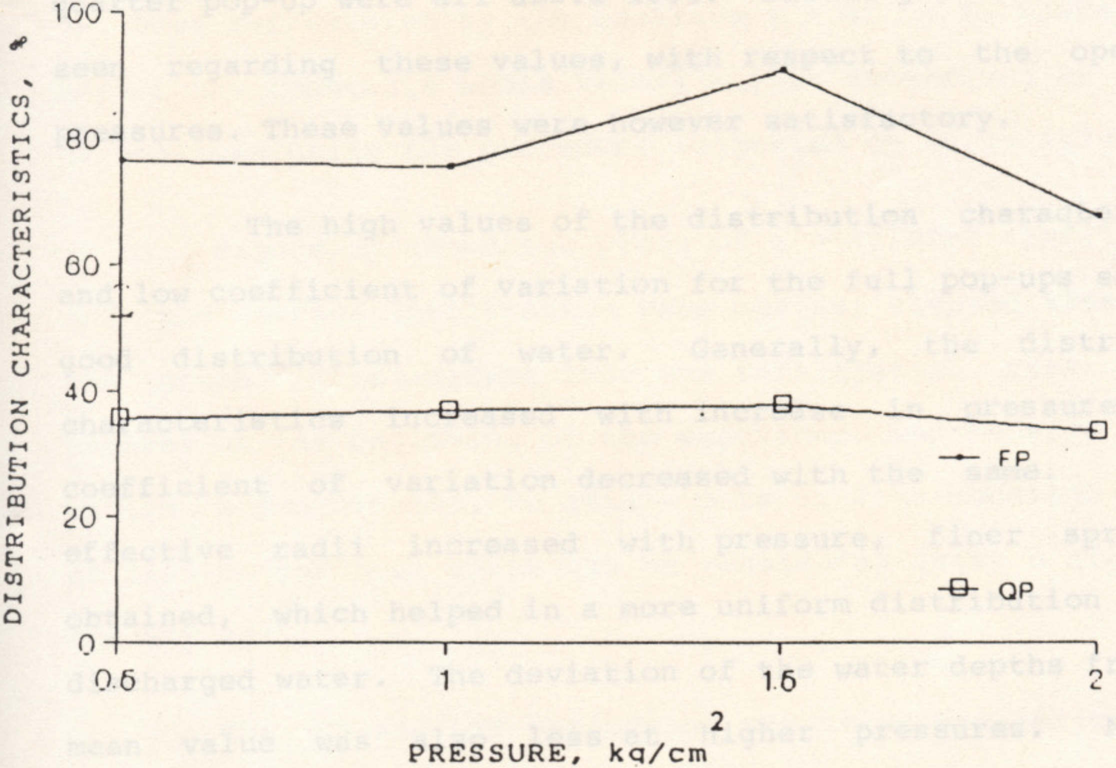


FIG.19

VARIATION OF COEFFICIENT OF VARIATION WITH PRESSURE FOR TWO POP-UP HEADS

The values of the coefficient of variation was found to decrease with increase in pressure for the full pop-up. But, the value at the operating pressure of 1.5 kg/cm^2 was a drastic reduction (43.9 per cent) while the other values were between 90 per cent and 70 per cent. At the values were less than 100 per cent.

The values of the coefficient of variation for the quarter pop-up were all above 150%. But no general trend was seen regarding these values, with respect to the operating pressures. These values were however satisfactory.

The high values of the distribution characteristics and low coefficient of variation for the full pop-ups showed a good distribution of water. Generally, the distribution characteristics increased with increase in pressure while coefficient of variation decreased with the same. As the effective radii increased with pressure, finer spray was obtained, which helped in a more uniform distribution of the discharged water. The deviation of the water depths from the mean value was also less at higher pressures. No such criteria were however applicable to the quarter pop-up sprinkler heads.

4.2 Determination of the infiltration rate of the soil.

An experiment was conducted to determine infiltration rate of the soil which was planted with lawn grass. The values of infiltration rate were a contributing factor for the setting of the ON and OFF periods of the pop-up and micro sprinkler systems.

The average values of accumulated infiltration "y" and average infiltration rates are plotted as the function of elapsed time "t". The functional relationship between y and t is best represented by the equation $y = at + b$, where a, , and b are constants whose values may be determined by method of averages using the procedure suggested by Davis (1943).

Figure 20 shows the plots of accumulated infiltration and the average infiltration rate against elapsed time. From the graph it is evident that the infiltration rate is the highest at the beginning of the experiment and recedes sharply within a few minutes, to attain more or less constant values of 51.6 cm per hour which can be considered quite a high value for any soil.

The ON and OFF periods of the timer were adjusted to suit these infiltration characteristics of the soil.

4.3 Modification of the master control unit and its installation

A master control unit was developed with the on and

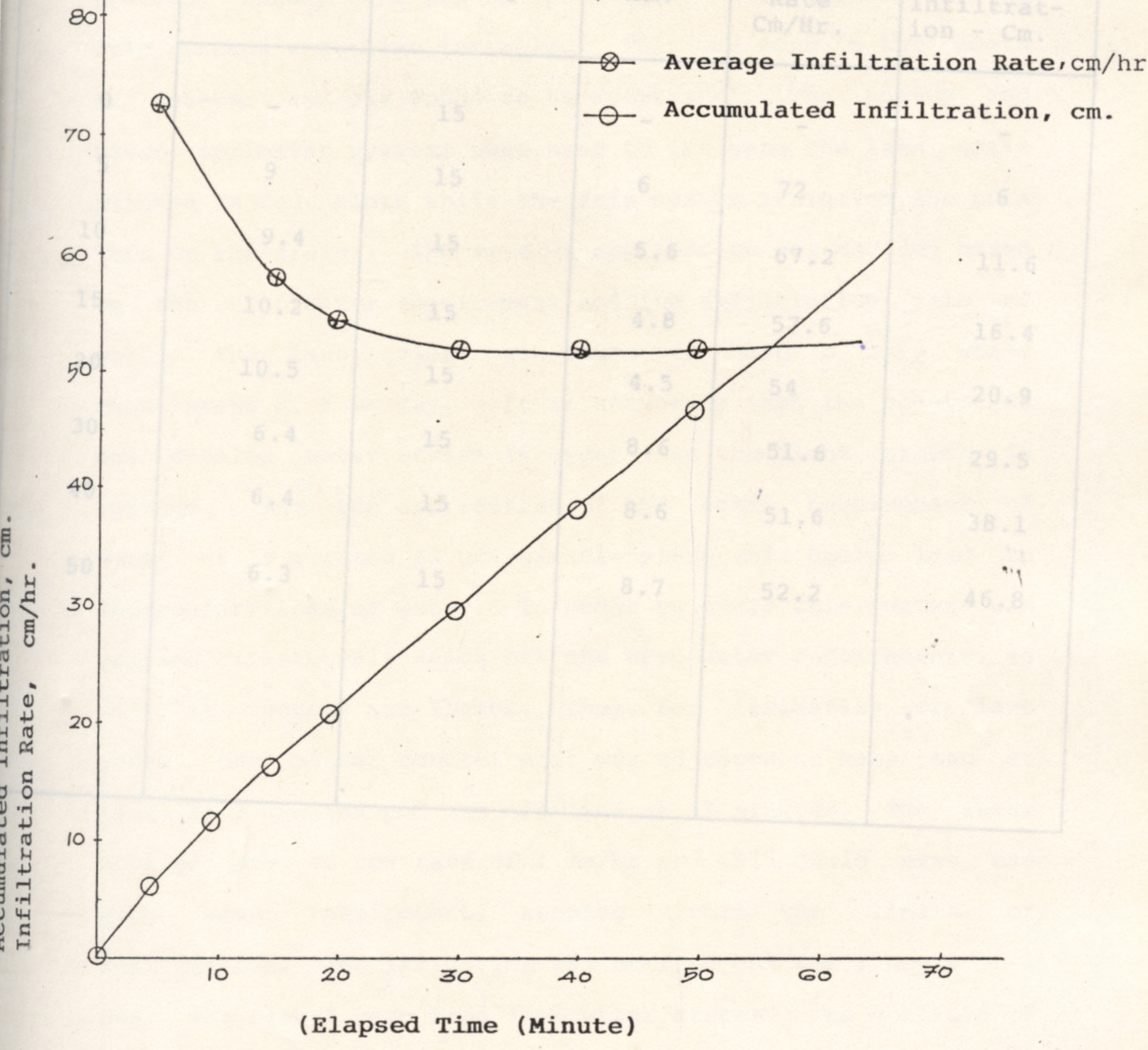


FIG.20 ACCUMULATED INFILTRATION AND AVERAGE INFILTRATION RATE AGAINSTS ELAPSED TIME

TABLE - SAMPLE DATA OF CYLINDER INFILTROMETER TESTS

Elapsed Time Minute	Distance from Water Surface from reference Point		Infiltration during period		
	Before filling	After filling	Depth Cm.	Average Rate Cm/Hr.	Accumulated Infiltration - Cm.
0	-	15	-	-	-
5	9	15	6	72	6
10	9.4	15	5.6	67.2	11.6
15	10.2	15	4.8	57.6	16.4
20	10.5	15	4.5	54	20.9
30	6.4	15	8.6	51.6	29.5
40	6.4	15	8.6	51.6	38.1
50	6.3	15	8.7	52.2	46.8

off time ranges as shown in Table 4. Three irrigation systems, namely the pop-up sprinklers, microsprinklers and drip systems were also installed. This was done in the month of October and was found to be successful. The pop-up and micro sprinkler systems were used to irrigate the lawn grass planted in four plots while the drip system irrigated the pots kept on the ridges. The rate of application was decided based on the crop water requirement and the infiltration rate of soil. The lawn grass was found to have a crop water requirement of 6 mm/day. It is necessary that the plants do not develop water stress in order that the plant growth is optimum. But the application of the total requirement of water at a stretch is undesirable since this could lead to unnecessary loss of water. In order to avoid this, water was applied at intervals which met the crop water requirements as well as reduced the losses. Thus, for irrigation of lawn grass, the master control unit was adjusted to keep the on time at 3 minutes and the off-line at 57 minutes. The water applied was at the rate of 1 mm/hr and this could meet the crop water requirement, keeping within the limits of infiltration. The irrigation was carried out for 6 hours in a day. The plants were free from water stress. The controls of the drip system were arranged to have an onperiod of 10 minutes and off period of 50 minutes.

Table 4. ON-OFF lime ranges

	ON			OFF
	Knobs			
	1	2	3	
Pop-up Sprinkler	1.1 sec-2 min	2-8 min	35 min-1 hr	35 min-1 hr
Micro Sprinkler	1.1 sec-5 min	--	--	35 min-1 hr
Drip System	1.1 sec-20 min	20-40 min	--	20-50 min

The plant response to irrigation was good which was indicated by the vigorous growth of grass and potted plants. The most satisfactory and successful part of the result was that the master control unit can be successfully used to automate irrigation systems, thus saving a lot on manual labour and reducing constant supervision. The control unit can be expanded to suit any crop and any number of irrigation systems.

SUMMARY AND CONCLUSION

An experimental study for the performance evaluation of two kinds of pop-up sprinkler heads under different operating pressures was conducted at K.C.A.E.T. campus, Tavanur. The experiment consisted of placing each of the sprinkler heads namely, full circle and quarter circle pop-up, at the centre of a collector grid and operating the sprinkler for a period of time, during which the operating pressure and the rate of discharge were observed and the measurment of catch in each collector at the end of the period of operation. From the measured values of the volume collected in the cans, the depths of application, wetted radius, distribution pattern, distribution characteristic and coefficient of variation for the two sprinkler heads at different operating pressures were determinerd.

The full pop-up sprinkler head was found to have good distribution characteristics generally. Distribution characteristics provided an indication of the percentage of adequately irrigated area in a field. High distribution characteristics indicated that a larger fraction of the total wetted area was adequately irrigated. The distribution characteristic values of the quarter pop-up were however unsatisfactry. The cofficient of variation is another performance indicator obtained by dividing the standard deviation of the depth used to calculate the mean by the mean application depth, expressed as percentage. The values of coefficient of variation less than 100% were considered good and those less than 200%, satisfactory. On the whole, the full pop-up showed a highly satisfactory peformance, with good distribution characteristics, good distribution pattern and good coefficient of variation.

The pop-ups, micro sprinklers and the drip irrigation systems were installed as required in the plots provided. The pop-up and micro sprinkler systems were used to irrigate lawn grass, whereas the drip system was laid out to irrigate potted plants. The three systems of irrigation were connected to the master control unit which controlled the irrigation automatically. The time periods for which each system was to be kept on was determined based on the crop water requirement and the infiltration rate of the soil. The lawn grass was found to have a crop water requirement of 6 mm/day. Therefore, the on periods for the pop-up and micro sprinkler systems was set to three minute and the off period to 57 minutes, which applied water at the rate of 1 mm/hr, the total time of irrigation being 6 hours per day. This rate of application suited the infiltration characteristics of the soil. The drip system was operated by a solenoid valve and the on and off periods for the potted plants were set to 10 minutes and 50 minutes respectively. The micro sprinkler irrigation system was found to be more efficient than the drip and pop-up systems, when applied to irrigation of small land holdings.

The master control unit can control time over a wide range and thus is suited to irrigation of any type of crop with any crop water requirement, and its time ranges can be changed further, with slight modifications. The master control unit is an effective means of reducing drudgery as the irrigations are automatically controlled and human supervision is limited to a minimum. The unit can be suitably expanded to automatically control any number of irrigation systems.

REFERENCES

Anonymous (1992). Micro-sprinklers for tree crops. Agribusiness World wide. pp. 11-14.

Berlin, H.M. (1965). 555 Timer Applications source book with Experiments. BPB Publications. New Delhi. pp. 7-18.

Beese, F., Hever, C. and Rodewald, W (1976) An apparatus for the springling of soil colums. Soils and Fertilisers Abstract 40 (4) : 198

Boman, Brian, J. (1989). Distribution pattern of micro-irrigation spinner and spray emitters. Applied Engineering in Agriculture **5** (1): 50-56.

Carvalho, J. Ramos, M.M., Bernordo, S. and Soares, A.A. (1993). Effect of nozzle pressure and diameter on size of drops distributed by an intermediate pressure sprinkler. ASAE. Vol.5 (18).

Chaya, L.A. and Hills, D.J. (1991). Droplet size and drift potential from microsprayer irrigation emitters. Transactions of the ASAE **34** (6): 2132-2421.

Chizikore, G.I., Bezrodnov, N.A. and Bathekov (1980). Determination of main parameters of intermittent irrigation. Soil Fertiliser **38**: 4360.

Cueca, Richard, H. (1989). Irrigation System Design - An Engineering Approach. Prentice Hall, Eagle wood Cliffs, New Jersy.

Finkel, Herman, J. (1982). CRC Hankbook of Irrigation TEchnology. Vol.I, CRC Press Inc. Boca Raton, Florida.

Frost, K.R. and Schwoles, H.C. (1956). Sprinkler Evaporation losses. Agricultural Engineering Vol.36 (8): 526-528.

Gueorguiev, G. Kostourski, N., Fourdjev, I., Perfanov, K. (1988). Study on the sprinkler irrigation of rice. Proceedings of XVICID European Regional Conference 2: 125-131.

Heinnemann, D.M., Morrow, C.T., Standbaush, T.S., Goulart, B.L. and Schegel, J. (1993). Evaluation of an automated irrigation system for frost protection. Applied Engineering in Agriculture 86 (6): 779-785.

Issacs, G.W. (1982). The elctronics ae in agriculture Agricultural Engineering, ASAE.

IS: 12232 (Part I) (187).

Karmeli, D. and Deri, G. (1974). Basic principles of Pulse irrigation. Journal of the Irrigation and Drainage Division, ASCE. Vol. 100 (IR3): 309-319.

Karmeli, David and Deri Gideon (1977). Pulse Irrigation - Design for operating sets. Journal of the Irrigation and Drainage Division, ASAE. Vol.103 (IR 1): 33-41.

Kay, Melvyn (1984). Sprinkler irrigation equipment and practice. ELBS and Batsford Academic and Educational, London.

Keller, J. (1992). Recent Advances in Drip and Sprinkler Irrigation - An overview. Training course on Drip and Sprinklers. Irrigation System Design and Layout. pp. 1-30.

Kohl, R.A. (1974). Drop size distributions from medium sized Agricultural spriknkers. Transactions of the ASAE. **17** (4): 690-693.

Kohl, R.A. and De Boer, D. (1984). Drop size distributions for a low pressure spray type agricultural sprinkler. Transactions of the ASAE. **27**(6): 1836-1840.

Levin, I. and Van Rooyen, F.C. (1946). Soil water flow and distribution in horizontal and vertical direction as infuenced by intermittent water application. Soil Science. **104** (6): 355-365.

Maiston, R.M. (1993). CMOS Circuit manual. B.P.B. Publications., New Delhi. pp. 11-125.

Merriam, J.L. and Keller, J. (1978). Farm irrigation system evolution. A guide for management. Utah State University. Logan.

Michael, A.M. (1992). Irrigation - Theory and Practice. Vikas Publishing House Pvt. Ltd. pp. 448-685.

Michael, A.M and Khepar, S.D. (1989) Water Well and Pump Engineering. Tata Mc Graw Hill Publishing Company Ltd, New Delhi.

Miller, W.W., Mahannoh, C.N. Shone, R.L., Jensen, E.H., and Finke, W.W. Jr. (1990). Evolution of a subsurface pop-up sprinkler. Applied Agricultural Research 5(1): 56-62.

Modi, P.N. and Seth, S.M. (1985). Hydarulics and fluid mechanics. Standard Book House, New Delhi.

Phene, C.J. and Berke, O.N. (1976). High frequency irrigation for violet nutrient management in humid regions. Soil Science Society of America Journal. 40

Rawlins, S.L. and Roots, P.A.C. (1975). Prospects for high frequency irrigation. Science **188** (4188): 609-610.

Ruzicka, M. and Kubot, T. (1990). Evolution of sprinkler irrigation sprinkling intensity. Zemedelska Technika **36** (2): 85-92.

Sharma, R.K. (1984). Text-book of Irrigation Engineering and Hydarulic Structures. Oxford and IBH Publishing Co., New Delhi, Bombay and Culcutta.

Sivanappan, R.K. (1987). Sprinkler Irrigation. Oxford and IBH Publishing Co. Pvt. Ltd. New Delhi, Bombay and Culcutta.

Tiwana, A.B. (1991). Versatile Electronic Circuits. B>P>B> Publications, New Delhi. pp. 45-52.

Zur, B. (1970). The pulsed irrigation principle for controlled soil wetting. Soil Science **122** (5): 282-291.

MODIFICATION AND EVALUATION OF MASTER CONTROL UNIT FOR DIFFERENT IRRIGATION SYSTEMS

By

UDAYAKUMAR K. S.

ABSTRACT OF THE PROJECT REPORT

Submitted in partial fulfilment of the
requirement for the degree of

**Bachelor of Technology
in
Agricultural Engineering**

Faculty of Agricultural Engineering & Technology
Kerala Agricultural University

Department of Land & Water Resources & Conservation Engineering
Kelappaji College of Agricultural Engineering and Technology
Tavanur - 679 573
Malappuram

1994

ABSTRACT

A study was conducted to evaluate the perfomance evaluation of two pop-up sprinkler heads : full circle pop-up and quarter circle pop-up. The wetted radius, application depth, discharge, distribution pattern, distribution characteristics and coefficient of variation for the two sprinkler heads were found out at different operating pressures of the two, the full pop-up sprinkler showed very good performance characteristics.

A master control was modified for the automatic controlling of irrigation by pop-up sprinklers, micro sprinklers and drip irrigation system. The unit had seperate controls for the on and off periods which could be adjusted as per requirement. The on periods were based on crop water requirement and infiltration rate of the soil. The micro sprinklers and pop-up sprinklers were used to irrigate lawn grass. The drip system was provided to irrigate potted plants. The ON and OFF periods for the pop-up sprinklers and the micro sprinklers were 3 minutes and 57 minutes respectively, and 10 minutes and 50 minutes respectively for drip systems. The master control unit provides for automation of any number of irrigation systems with suitable modifications. It is an effective means of reducing human supervision.