PERFORMANCE EVALUATION OF POP-UP SPRINKLERS AND DEVELOPMENT OF A MASTER CONTROL UNIT FOR IRRIGATION

By

INDU G. NAIR

MANOJ P. SAMUEL

SUMA NAIR

PROJECT REPORT

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DECLARATION

We hereby declare that this project report "PERFORMANCE EVALUATION OF POP-UP SPRINKLERS AND DEVELOPMENT OF A MASTER CONTROL UNIT FOR IRRIGATION" is a bonafide record of project work done by us during the course of project and that this report has not previously formed the basis for the award to us of any degree, diploma, associateship, fellowship or other similar title of any other University or Society.

INDU G. NAIR

MANOJ P. SAMUEL

SUMA NAIR

CERTIFICATE

Certified that this project report entitled **"PERFORMANCE EVALUATION OF POP-UP SPRINKLERS AND DEVELOPMENT OF A MASTER CONTROL UNIT FOR IRRIGATION"** is a record of project work done jointly by **Indu G. Nair, Manoj P. Samuel and Suma Nair** 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 them.

Tavanur,

30.11.1993.

Er. Xavier K. Jacob
Assistant Professor
Department of LWRCE

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INDU G. NAIR

MANOJ P. SAMUEL

SUMA NAIR

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SYMBOLS AND ABBREVIATIONS

A	Ampere
ac	Alternating current
Agric	Agriculture
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 other people
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

Tech.	Technology
TP	Three-quarter circle pop-up sprinkler
Univ.	University
V	Voltage
Vol.	Volume
°	Degree
'	Minutes
"	Seconds
Ω	Ohms
μ	Micro
%	Percentage

INTRODUCTION

Ever since the early stages of development of civilization, agriculture has formed an inseparable part of man's life style. To date, agriculture has remained the principal occupation of more than seventy per cent of India's population. Out of the total 328 million hectares of land, about 164 million hectares is under cultivation. Agriculture contributes more than 50 per cent of Gross National Product (GNP) also. But the present agricultural scenario has not developed to the extent of completely satisfying the basic human needs of food, fabric and fat (oil). This is primarily due to the uncertainty in the yields of food grain produced. Rain, being the primary source of water in Indian agriculture, is concentrated in about four months of the monsoon period, with the remaining eight months dry. In the past, one round of crops with the availability of natural soil moisture from rain was sufficient to meet the needs of the population at that time. As the population grew, it necessitated more agricultural production. This pressing demand for food and the great variation coupled with uncertainty in rainfall, prompted man to supplement the natural moisture by artificial supply. This was the beginning of irrigation.

There are references of the application of water for the growth of crops even in the oldest known scripture, the Rig Veda. Irrigation is basically an attempt by man to locally alter the hydrologic cycle and to promote increased agricultural productivity. It is the process of artificial application of water to crops for their growth. Irrigation water is an extensive input. Efficiency of water use therefore becomes a critical factor in determining the cost of production of various crops. Judicious use of water is essential since it is a very valuable resource, whose management has a very positive effect in agricultural yield.

Irrigation is carried out in many ways-the most prevalent one being the traditional surface irrigation methods such as basin, border and furrow irrigation. But these methods require precise grades, increasing the cost of field preparation. Also water is lost by seepage, run-off and evaporation and these methods create conditions of low aeration due to flooding. Use of saline water is not recommended in these methods. To overcome these problems and to manage efficiently the water input, new irrigation techniques like the drip and the sprinkler systems have been developed.

Trickle irrigation, also referred to as drip irrigation, differs from the surface irrigation methods in that the water is applied to a point or over a very limited fraction of the total surface area of the field. They supply water directly in the vicinity of root zone wetting a limited amount of root zone and depth of soil. In trickle irrigation systems, the close balance between applied water and crop ET reduces surface run-off and deep percolation to a minimum. The fact that limited portions of field surface are moist also tends to reduce weed growth which would otherwise consume irrigation water.

Sprinkler irrigation is a method of distributing water in pipes under pressure and spraying it into the air so that it breaks up into small water droplets and falls to the ground like natural rainfall. Sprinklers generally need less water and labour than surface irrigation and can be adopted to more sandy, erodible soils on undulating ground.

With micro-sprinklers, the amount of water required by the plants is applied to a given volume of soil achieving localised irrigation. This enables the root system to develop evenly and to spread densely throughout the volume of wetted soil, thus increasing supply of water and nutrients to plants.

Pop-up sprinkling, otherwise known as landscape micro-irrigation, is especially adapted to irrigation of lawns. The pop-up heads are installed flush with the turf. A nozzle pops up to deliver the spray during operation and recedes within the casing when not in operation. The pop-up height must be considered in relation to spray interference from the grass and should not be less than 2.5 cm. Otherwise the sprinkler would have no advantage over the stationary type sprinklers which provide no pop-up whatsoever. Five centimeter pop-up heads are more effective and perform better between mowings. Spray heads with an extra high pop-up of 7.5-10 cms are also available.

The sprinkler head is housed in a casing provided with a cover at the top. The top of the cover is kept almost at the land surface. The cover opens by means of a retract spring when the sprinkler is in operation and remains closed otherwise.

The normal area of coverage for pop-up spray nozzles varies from 4.8 to 9 m in diameter depending on the nozzle or orifice size. Spray nozzles are available in a wide assortments of part circle patterns. The usual assortment of arcs ranges from quarter circle to three-quarter circle. The sprinkler head spacings are a matter of choice.

Irrigation with low application rates 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 pop-up sprinklers in the irrigation of lawns does not interrupt the aesthetic value of the same and automation of the system greatly enhances its appeal.

This study was done under the broad objectives of the evaluation of the performance characteristics of the pop-up sprinklers using different spray nozzles and the development of a master control unit for automated irrigation by using the pop-up sprinklers, micro-sprinklers and the drip irrigation systems.

The specific objectives of this study are

1. To evaluate the distribution pattern of the selected pop-up heads at different operating pressures.

2. To determine the distribution characteristic and coefficient of variation of different pop-up sprinkler heads under different pressure heads.

3. To evaluate the discharge flow rate, wetted radius and application depths for different pop-up heads under different pressure heads.

4. To develop a master-control unit for automation of the pop-up sprinkler, drip and micro-sprinkler systems of irrigation and to install it.

REVIEW OF LITERATURE

Irrigation becomes an unavoidable part of agriculture if the rainfall in an area is not sufficient to meet the requirement of crops throughout their growth period. Agricultural production is to be accelerated to meet the ever increasing food demand of the growing population. This has led to rapid expansions in the field of irrigation. Irrigation is not the mere application of water to the land, but to supply water to the root zone of the plant according to its requirement. Scientific irrigation practices are adopted to obtain higher productivity with minimum ecological disturbance.

The primary objective of any irrigation method is to supply moisture which will be readily available for crop growth, at all times, without indiscriminately adding to the water table and avoiding the influence of soil salinity.

2.1 Requirements of an irrigation method

There are few basic requirements for any irrigation system. The application should be within desirable limits. The streamflow is adequate so that the quality of irrigation is such that the depth of wetting and hence the stand of crop are approximately uniform. It should afford a uniform water distribution and should enable salt leaching where such problems exist. It should allow the use of large concentrated water flows for reduction of conveyance losses, field channel network and labour cost. It should facilitate mechanised farming.

A suitable irrigation method shall ensure maximum yield at optimum water utilisation. The common irrigation methods in practice are surface methods, the sub-surface methods, drip irrigation and over head irrigation or the sprinkler irrigation. The surface irrigation methods include the traditional methods of border irrigation, check basin irrigation and furrow irrigation. Sub-surface irrigation is the application of water beneath the ground and creating and maintaining an artificial water table just below the ground surface.

Drip irrigation or trickle irrigation limits the water supplied for the consumptive use of the plants by maintaining a minimum soil moisture in the root zone thereby maximising water saving. A dripper discharges water directly into the area of the root system. It permits fine control of the application of moisture and nutrients at frequencies prescribed for individual plants. The basis for this potential water saving method is that frequent but just sufficient amounts of irrigation guard plants against water stress by maintaining the soil moisture level at field capacity.

Sprinkler irrigation is an improvement over conventional surface irrigation. It simulates the natural rainfall to bring down water in the form of rain just when needed and as much needed. It envisages application of water to the soil surface in the form of spray falling at a uniform pattern and at a rate less than the infiltration rate of the soil so as to avoid surface run off from irrigation. Sprinkler irrigation is suitable for all types of soils, more particularly coarse, sandy and gravelly soils and for almost all crops like wheat, jowar, cotton, potato, tobacco, groundnut, vegetables, ragi etc. particularly so for the production of high yielding crops or for having continuous and quick growth of valuable crops. It helps to conserve precious water upto 70 per cent. It is successful under the adverse conditions of poor quality water and soils of restricted capability.

Sprinkling as an important method of agricultural irrigation had its beginning in the early part of this century. The earliest agricultural sprinkling was limited to orchards, nurseries and intensive vegetable production. In 1930's the cost of the sprinkler systems was reduced by the development of the impact sprinklers and light weight steel pipe with quick couplers. With these improvements, sprinkle irrigation began to spread and to be used on a wide range of soils and field crops. By 1950's better sprinklers, aluminium pipes and more efficient pumping plants further reduced the cost and increased the usefulness of the system and accelerated the expansion of this method of irrigation. More recently, the self propelled centre-pivot, which gained popularity in the 1960's has provided a means for relatively low cost, high frequency automatic irrigation with a minimum of labour.

2.2 Micro irrigation

Micro-irrigation is a versatile means of applying water to less than 100 % of the required area. The very first experiment in micro-irrigation was started in Germany in 1860 using clay pipes as a combination of irrigation and drainage system. Later porous pipes and canvas were used for irrigation and in the late 1940's plastic pipe micro-irrigation system was used to irrigate green houses in UK. By early 1960's plastic pipe micro-irrigation systems were extensively used in the US to irrigate green house plants.

Modern day surface trickle irrigation technology dates back to 1960's when Simca Blass, an engineer developed and used this technology in 1963 in Israel. Micro-sprinkler irrigation system has been designed as an improvement over trickle irrigation system.

Mirco-irrigation is becoming a popular irrigation method for vine and tree crops in many areas of the country (Brian J. Boman, 1989). Pop-up sprinkler irrigation is called as "landscape micro-irrigation" and is extensively used for landscaping and turf irrigation.

2.3 Advantages

Sprinkle irrigation is an adaptable means of supplying all types of crops with frequent and uniform application of irrigation over a wide range of soil and topographic conditions. Pop-up sprinklers have special adaptability to turf irrigation. The system can be partly or fully automated to minimise labour cost and be designed to minimise water requirements.

2.3.1 Adaptability

Besides the adaptability over a wide range of soil, crop and topographic conditions, some other objectives that can be attained using pop-ups are:

(i) Effective use of small continuous streams of water, such as from springs and small tube or dug wells.

(ii) Proper irrigation of problem soils with intermixed textures and profiles or the irrigation of shallow soils that cannot be graded without detrimental results.

(iii) Irrigation of steep rolling topography without producing runoff or erosion

(iv) Effective light frequent waterings whenever needed.

2.3.2 Labour saving

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

Pop-up irrigation modifies weather extremes by increasing humidity, cooling crops and alleviating frost damage to buds and leaves by use of special systems design, using light, intermittent irrigation to supplement erratic or deficient rainfall or to start early grain of pasture so that other inputs can be planned with assurance of adequate water. Leaching of salts from saline soils is more efficient under the system of sprinkling than under the surface irrigation methods because the soil is less saturated, but it takes time.

2.3.3 Water saving

Christeinsen (1942) has estimated that direct evaporation from the spray itself when normal pressure is applied in a normal wind velocity condition, does not exceed two per cent. Dev Nir (1982) reported that in green houses, sprinkling irrigation not only provides water, but also regulates air humidity, temperature etc.

Providing too much water results in anaerobic conditions within the root zone while insufficient water inhibits root expansion and photosynthetic capacity (Wierenga and Sadiq, 1985). The amount of water applied can be well controlled using the pop-up sprinklers.

The Haryana Irrigation Department (Sivanappan, 1987) has reported that saving of water by a sprinkler as seen compared to surface irrigation averaged to 56 per cent in the case of bajra, jowar, wheat, barley and gram and 24 per cent in the case of cotton. The Punjab Agricultural University has reported (Sivanappan, 1987) a water saving of 42.7 per cent for wheat and 47.5 per cent 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).

Gueorguiev *et al*. (1988) made a study on sprinkler irrigation for rice for three years in Plovdiv and Ivalo, Bulgaria. The sprinkler systems used achieved a 67 per cent saving in water applied for the cost of a 10 per cent drop in yields.

The micro irrigation system results in considerable water saving and the area wetted can be adjusted according to the development of the root system. The shape of the wetted surface can be changed from full circle (small for young trees and progressively larger circles as the trees develop) to a half circle or strips. Hence water needed to wet unwanted portions of the field is saved (Anonymous, 1992).

2.3.4 Irrigation efficiency

In tests done by the Israeli Agricultural Extension Service, the irrigation efficiency of micro irrigation systems - 94 to 97 per cent - was found to be higher than that of any other irrigation method tested. This was attributed to the uniform wetting of the irrigated area and to the correct amounts of water applied. Because of 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 pressures and producing large droplets. Irrigation efficiencies of 65 per cent to 80 per cent were obtained (Keller, 1992).

Pop-up sprinkler, being a micro-irrigation system, supplies the right amount of water required by the plants to a given volume of soil. This helps the root system to develop evenly and spread densely through out the volume of the wetted soil, thus ensuring supply of water and nutrients. No run-off or water ponding problems arise due to the low irrigation rate, which can be easily matched to the soil and climatic conditions. The uniform wetting of the whole soil volume makes it easy to use all types of soil moisture monitoring device. All these are responsible for the higher irrigation efficiency of the system.

2.3.5 Other advantages

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

The sub-surface pop-up sprinkler system could be particularly useful where strict environmental and water management controls are desired. Several unique recreational and horticultural applications are also possible (Miller et al., 1990).

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.

The filter provided inside the pop-up head prevents entry of debris, into the nozzle. Due to higher operating pressures as compared to the drip systems and due to the greater nozzle size, clogging is considerably reduced. Although it is used primarily for the application of water to crops, it is a multi-purpose system with a wide range of users such as fertiliser and herbicide application, frost protection and cooling of green houses.

2.4 Performance characteristics

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

Brian (1989) studied the distribution pattern of micro-irrigation spray and spinner emitters at the University of Florida's Agricultural Research and Education Centre, Fort Pierce using the ASAE standards ASAE S330. The standard recommends the sprinkler 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 per cent of the containers which received water.

2.4.1 Design considerations

Spray systems are zoned and operated in sections or circuits sized to fit the existing water supply or a new, larger service, if required. The number of heads per circuit is dependent on the flow requirements of each, and the capacity and pressure of the water supply. Thus the smaller water supply will always necessitate more zones or circuits and increase the length of the watering cycle. Therefore, if full utility of the system is to be realised, an adequate water supply must be provided in proportion to the property size.

2.4.2 Water distribution and uniformity

The irrigation efficiency of micro-sprinklers will depend upon the degree of uniformity of water application. The water spray distribution characteristics of the emitters and their spacing will regulate the uniformity of water application. The spray distribution characteristics of sprinkler heads 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. The distribution pattern is affected by the nozzle combination and operating pressure as well as the sprinkler model itself.

Keller and Karmeli (1974) introduced the coefficient of variation as a statistical measure of manufacturing variation in irrigation emitters.

The commonly used terms may not adequately describe the manner in which water is distributed by the microirrigation systems. Hence the term distribution characteristic was introduced by Merriam and Keller (1978). The distribution characteristic 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 distribution characteristic values greater than 50 per cent are probably satisfactory and that very good patterns result with distribution characteristics greater than 66 per cent.

2.4.3 Droplet size

Different factors affect the droplet size. Carvalho made a study on the effect of nozzle pressure and diameter on the size of drops distributed by an intermediate pressure sprinkler. It was concluded that the average drop size was directly related to the nozzle diameter for a given pressure.

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 pressures spray type agricultural sprinklers, the geometry of the spray plate surface, rather than the nozzle size and operating pressure, was the dominant parameter that influenced drop size distribution.

2.4.4 Effect of pressure

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 by slightly adjusting 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 runoff were inversely related to sprinkler operational pressure and wetted diameter.

Uniformity of application depends on matching operating pressure with the selected sprinkler diameters, wind effects and sprinkler spacing. If the pressure is too low, the water stream is not adequately broken up and a doughnut shaped application pattern results. If the pressure is too high, the stream is broken up into extensively small droplets and does not carry water to the design wetted diameter.

2.4.5 Effect of wind

A number of sprinkler studies have been conducted by Herman and Kohl (1983) which relates 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 in sprinkler pattern distortion.

Spray from sprinklers is easily blown by wind and this can distort wetting patterns and upset irrigation uniformity. To reduce the effects of wind, the sprinklers can be brought close together. In the prevailing wind conditions, the laterals are positioned at right angles to the wind direction, reducing sprinklers along the lateral (Melvyn Kay, 1984).

Prevailing wind conditions have a tremendous effect on the application pattern of a sprinkler system. Consistent high velocity winds can rule out the effective use of sprinkler irrigation or limit operations to times of relatively low winds such as night (Cuenca, 1989).

However, when sprinklers are installed at a lesser height, the wind effect is considerably reduced due to shielding by the canopy and lesser wind velocities near to the ground.

2.5 System components

The system consists of pump unit, control head, mainline, sub main, laterals and pop-up sprinklers.

2.5.1 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). The capacity of the pump is dependent on the size and shape of the irrigated area, topography, system discharges, cost of equipment, number of pumping hours per season, prices of electricity and efficiency of the pumping unit.

2.5.2 Control head

The central control and operation point of the system consists of valves, discharge and pressure meters and automation equipments and control. Each control head serves and controls an irrigation unit having a unity of irrigation pattern and fertilizing regime.

2.5.3 Main and submain

The mainline is a pipe which delivers water from the pump to the submains. It may 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 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 with wall thickness of 2.5 to 3 mm and pressure withstanding capacity of 4 kg/cm^2 can be used for big gardens.

2.5.4 Laterals

Water reaches the laterals from the submains and it supplies the water to the sprinkler head. Commonly used laterals are flexible polyethylene or PVC pipes. Wu and Girthin (1973) developed a procedure for drip irrigation system for determining the lateral pipe size.

2.5.5 Sprinkler equipment

The versatility of spray systems accounts for their extensive use for all types of properties. Spray heads for installation in lawns are pop-up types, often referred to as lawn heads. These heads are installed flush with the turf. A nozzle pops up to deliver the spray during operation and recedes within the body when inoperative. Some models of spray heads have a greater pop-up than others. This factor must be considered in relation to spray interference from the grass. Orifices of nozzles are sized to provide a specified radius of coverage and flow at a specified pressure. The specified pressure must be provided by the system designer to obtain proper coverage.

2.6 Automation

The term automation is defined as "a procedure or method used to regulate a water system by mechanical or electronic equipment that takes the place of human observation, effort and decision, the condition of being automatically controlled".

Irrigation with low application rates has been found desirable for optimal plant-soil-water relationships, in regard to plant response to soil moisture regime and water movement in the soil profile.

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

Thomas _et al_. (1989) developed an electronic percentage timer for centre pivot irrigation systems. The timer provides greater timing accuracy than electromechanical timers presently used to vary water and chemical application amount to a given field.

An automated facility for measuring the performance of individual irrigation sprinklers was developed by Hodges _et al_. (1990). The system was programmed to operate unattended at night and during weekends whenever the wind speed exceeded 2.2 m/s.

In the vertical columns, using intermittent water application, the advance of wetting front, the cumulative infiltration and the infiltration rate were decreased and behaved as if the time averaged water application rate were being applied continuously. This decrease was also found with horizontal columns, but to a considerably 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 favourable implications with respect to losses of water and nutrients beneath the 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).

It has been found by numerous workers that higher yield and improved plant growth can be obtained by reducing the time intervals between irrigation and by maintaining low soil moisture stress condition (Hagan (1957), Slatyer (1957), Rauritz (1967), Rawitz and Hellel (1969) and Assaf, 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 a 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.

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 controlled the irrigation system in order to adequately protect the crop. Results show that the system was effective for both protecting the crop from cold weather drainage and reducing the quantity of water used when compared to conventional approaches.

MATERIALS AND METHODS

A study was conducted to evaluate the performance of different pop-up sprinkler heads and to develop a master control unit which simultaneously controls the three irrigation systems, namely, drip, micro sprinkler and pop-up sprinkler systems and to install it. This chapter describes the materials used for the study and the methods adopted for achieving the above objectives.

3.1 Performance evaluation of pop-up sprinkler heads

3.1.1 Location

The performance evaluation of different 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

Four types of pop-up sprinkler heads namely Full circle, Three quarter circle, Half circle and Quarter circle were used to conduct this study.

The performance evaluation of the pop-up heads were carried out in two stages. In the first stage, a 0.5 hp

Plate 1   View of experimental set-up (a)

Plate 2   View of experimental set-up (b)

Plate 3   Pop-up sprinkler in operation

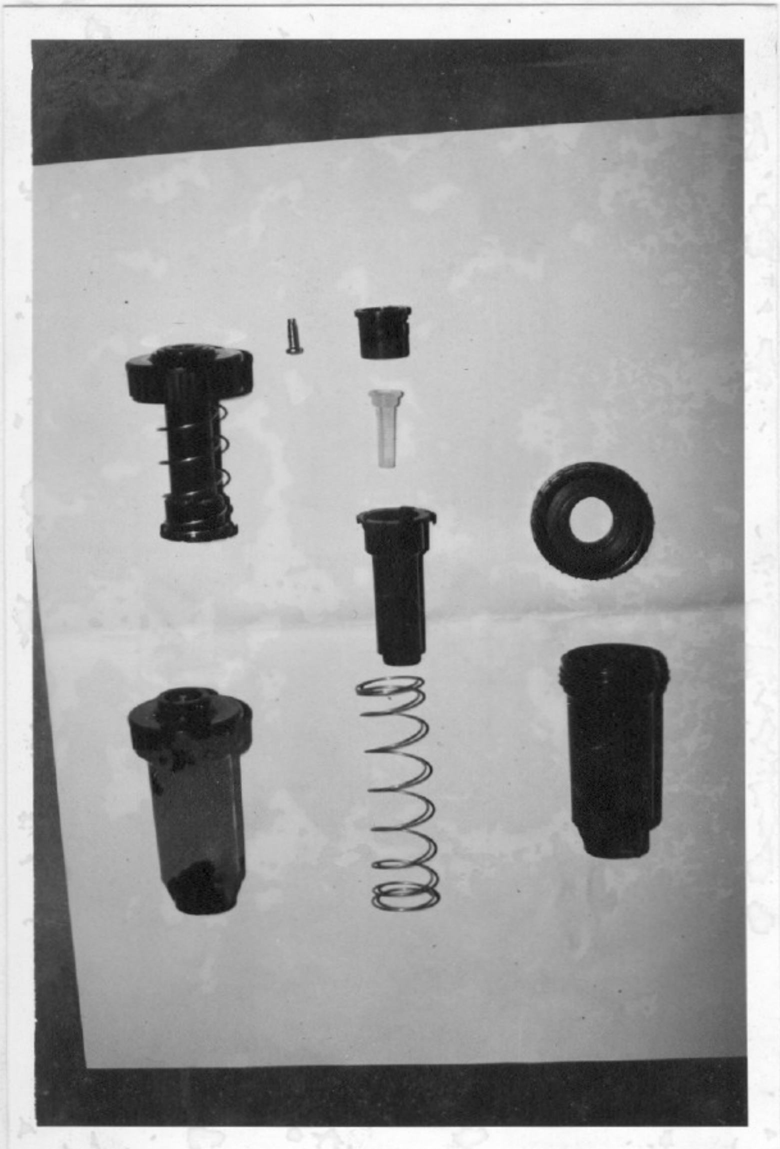


Plate 4   Pop-up sprinkler exploded view

Plate 5   Measurement of discharge

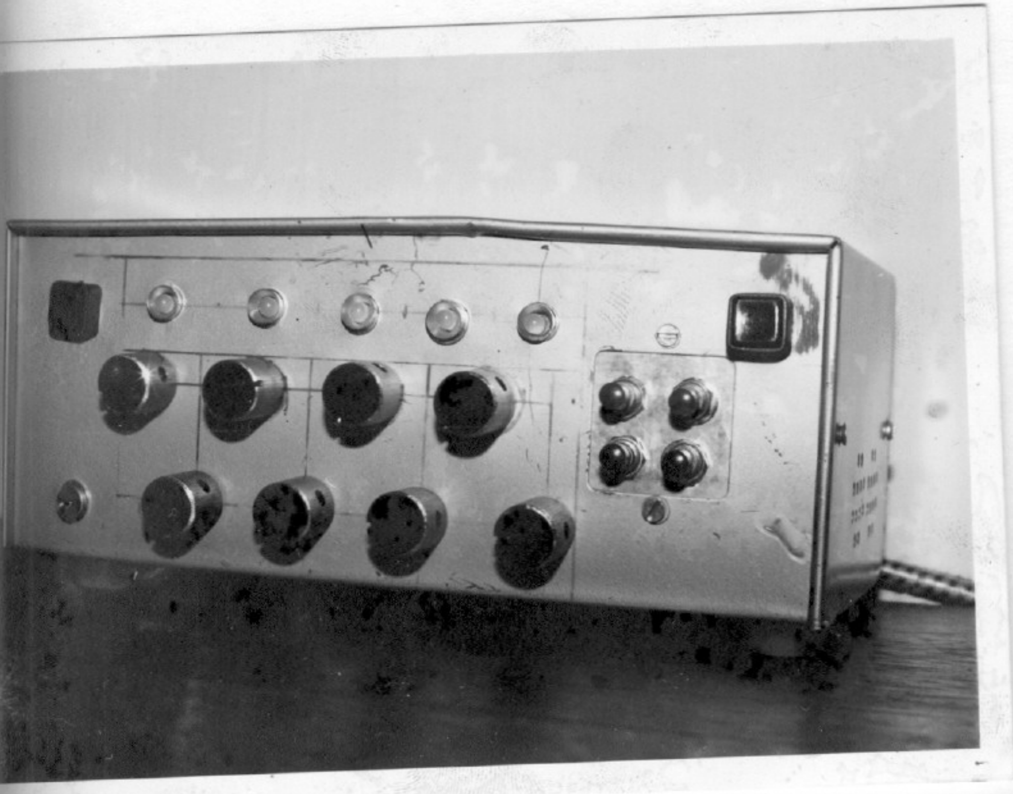


Plate 6   Master control unit - Front view

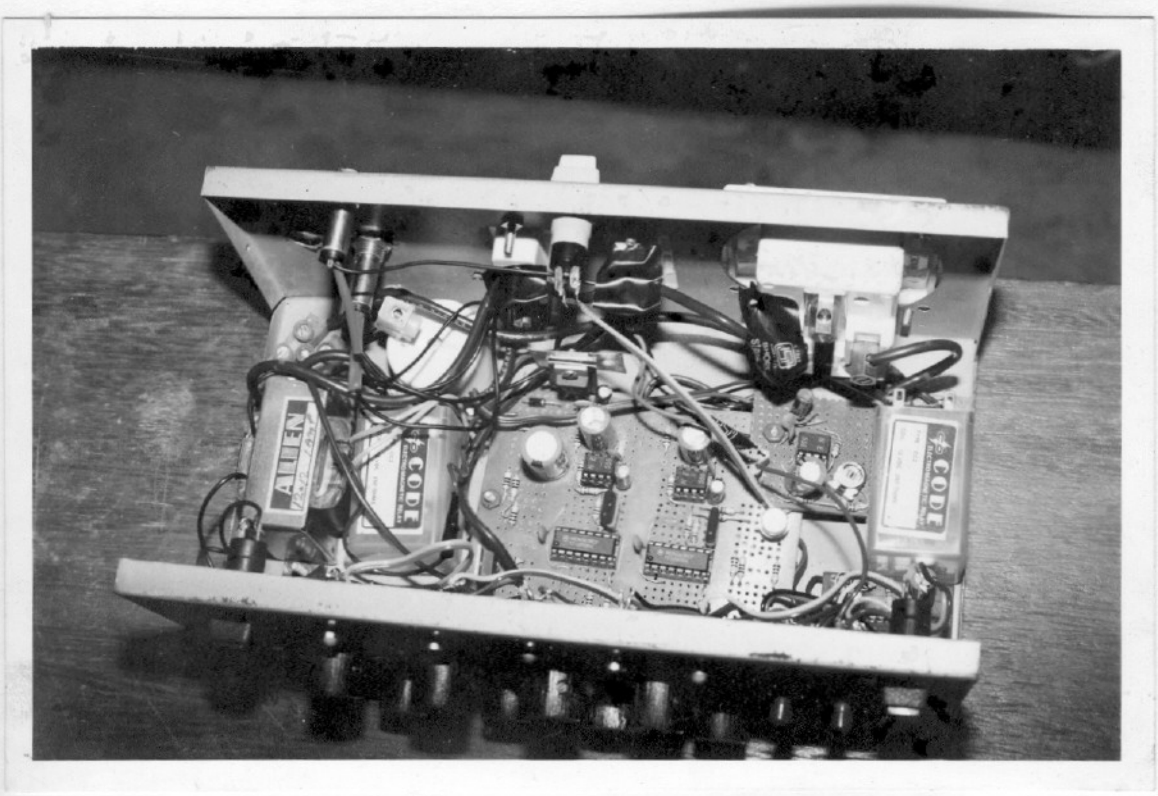


Plate 7   Master control unit - Inside view

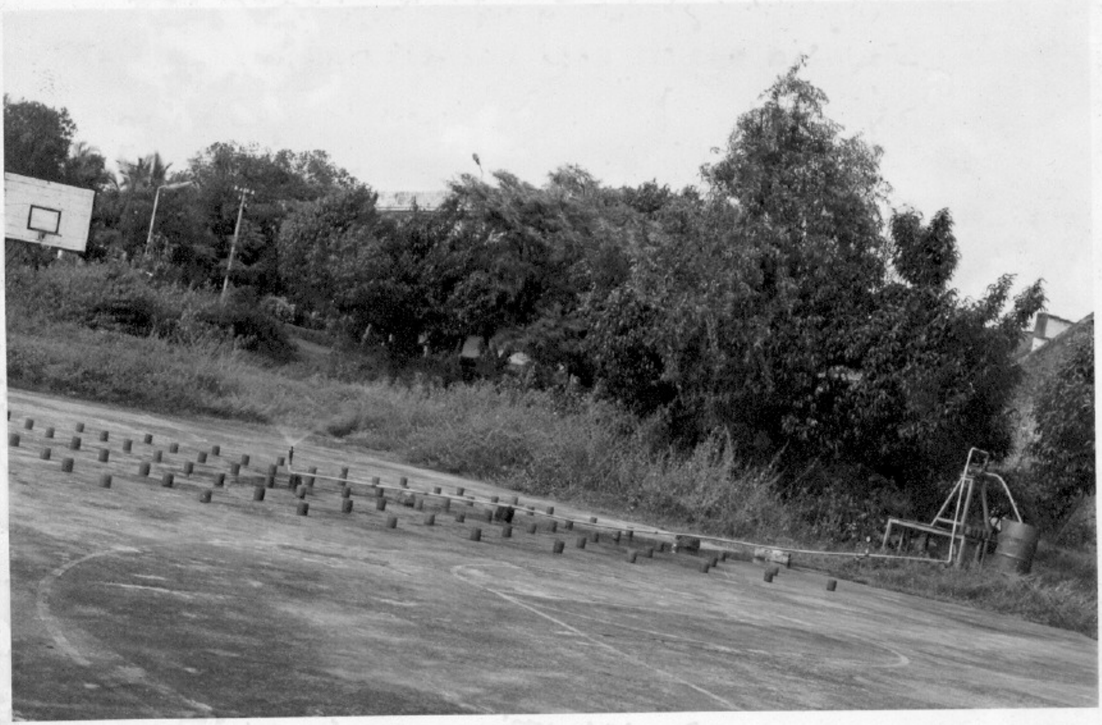


Plate 8 Testing of Pop-up sprinkler

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 represented the precipitation falling on it. The grid covered the entire area of the pop-up sprinkler head.

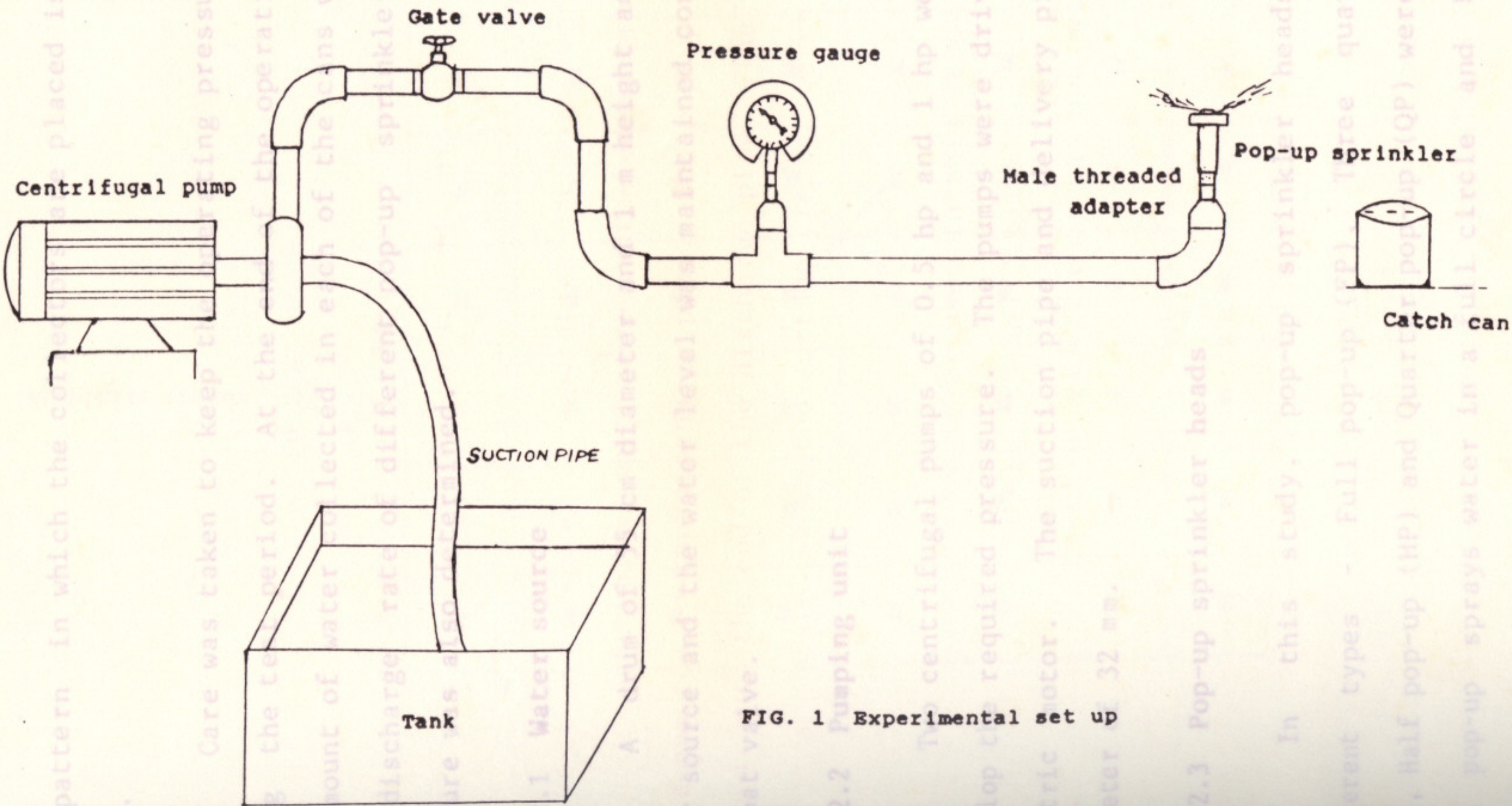


FIG. 1 Experimental set up

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.

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, pop-up sprinkler heads of four different types - Full pop-up (FP), Three quarter pop-up (TP), Half pop-up (HP) and Quarter pop-up (QP) were used. The full pop-up sprays water in a full circle and half pop-up

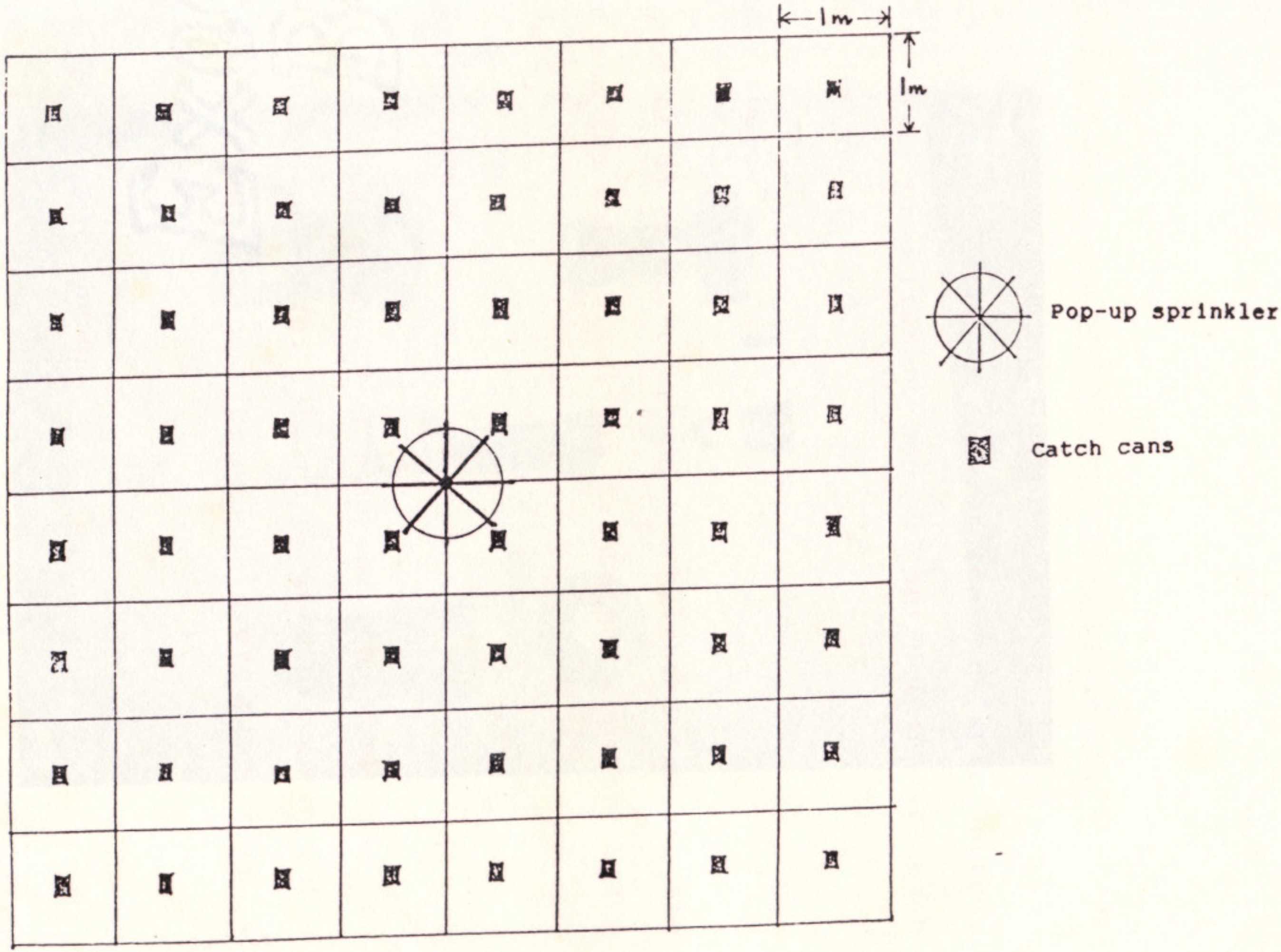


Fig:2 COLLECTOR PLACEMENT PATTERN

sprays water in a half circle only. In the case of three-quarter pop-up, the water distribution pattern is in the form of a three-quarter circle and quarter pop-up sprays water only to a 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.

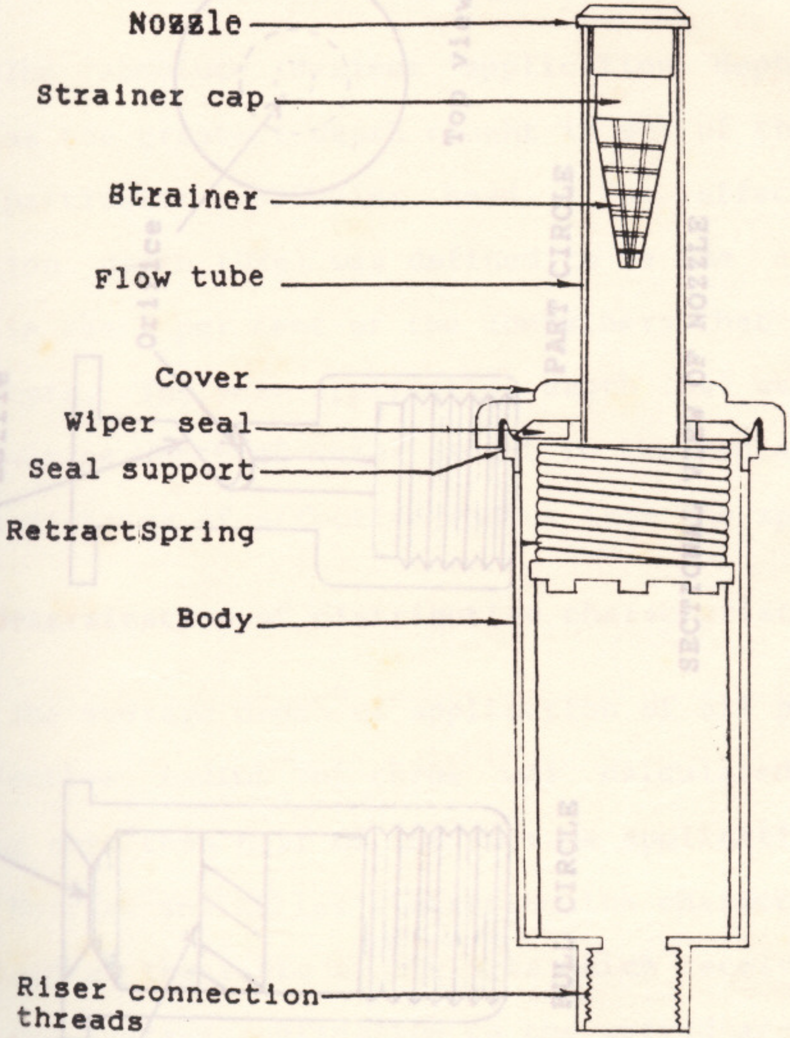
The sectional view of the pop-up sprinkler head and the nozzle are shown in Figs. 3 and 4 respectively.

3.1.3 Determination of distribution pattern

The volume of water collected in each can was measured 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.

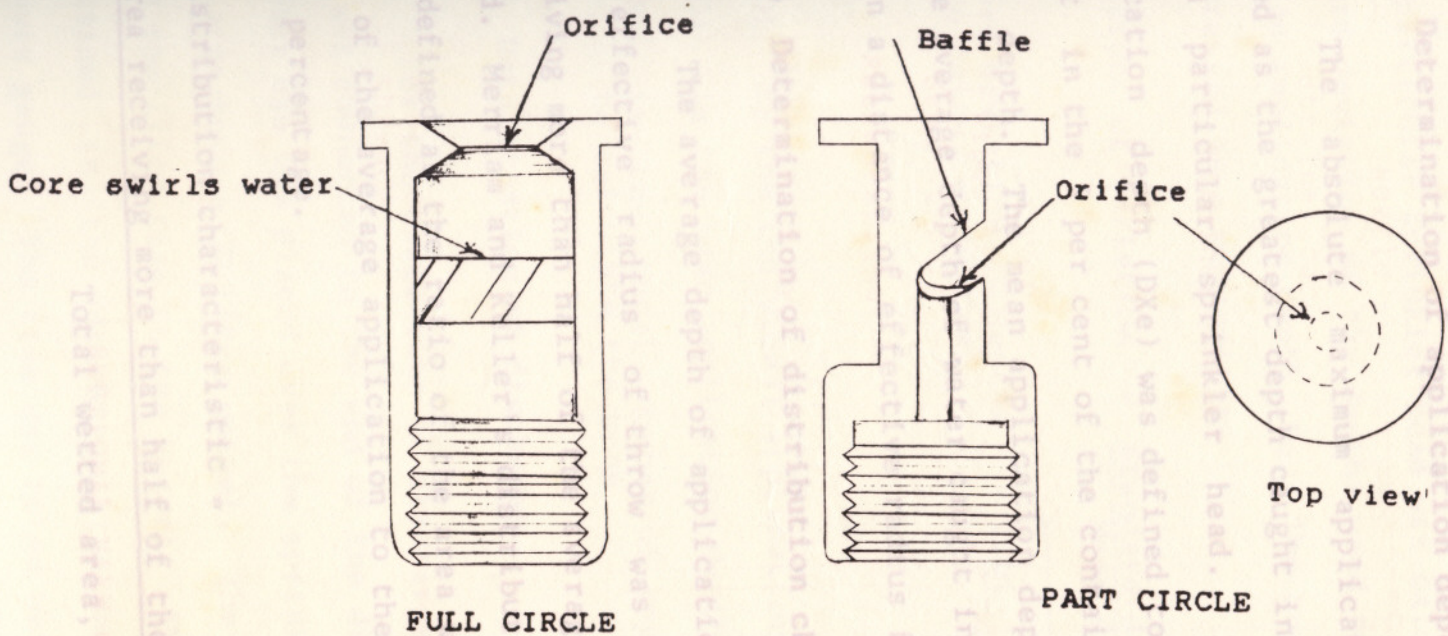
3.1.4 Determination of wetted radius

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



SECTIONAL VIEW OF POP-UP SPRINKLER

FIG. 3



SECTIONAL VIEW OF NOZZLE

FIG. 4

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.

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

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.

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

$$\text{Standard deviation of depths used to calcuate the mean} = \sqrt{\frac{\Sigma(Di - Da)^2}{N}}$$

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 litres per hour was obtained as

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

3.2 Master control unit

A master control unit was developed which simultaneously controls three types of irrigation systems - the drip, micro-sprinklers and the pop-up sprinklers with the objective of reducing the manual labour required in systems operation. The master controlled irrigation systems were installed in the garden in front of the Library of KCAET, Tavanur.

3.2.1 Site preparation

The selected plots - three in numbers of sizes 9 m x 6 m, 9 m x 7 m and 7 m x 4 m were cleared off all grasses and bushes and properly levelled. The soil was manipulated and farmyard manure was applied. A well graded mixture of sand, soil and manure was filled and levelled in the plots. The seedlings of lawn grass were planted in the three selected plots. Pots of flowering plants were placed on the ridges in between and around the plots which were irrigated by the drip system.

3.2.2 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 valve and pump, (iii) filter, (iv) main line, (v) submain and (vi) sprinkler heads.

3.2.2.1 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 drip system is obtained directly from the head of water stored in the tank. A cylindrical tank of diameter 55 cm and height 1 m, having a capacity of 200 litres was used as the storage tank to supply water to both pop-up and micro-sprinklers. The water level in the tank was controlled using a float valve.

3.2.2.2 Solenoid valve and pump

The flow of water from the tank to the drip system is controlled using a solenoid valve. 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 24 V dc operated closed solenoid valve working at a pressure range of 0 to 4 kg/cm^2 and made of brass was used in the irrigation system.

A centrifugal pump of 0.5 hp operated by a 230 V ac electric motor was used to deliver water to the microsprinkler and the pop-up sprinkler systems. The suction and delivery pipe diameters were 32 mm each.

3.2.2.3 Filter

A 40 mesh wire filter is 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 wire screen and appurtenance. The filter was washed and cleaned every week.

3.2.2.4 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.

3.2.2.5 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.

3.2.2.6 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.

3.3 Automatic control

A master 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
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

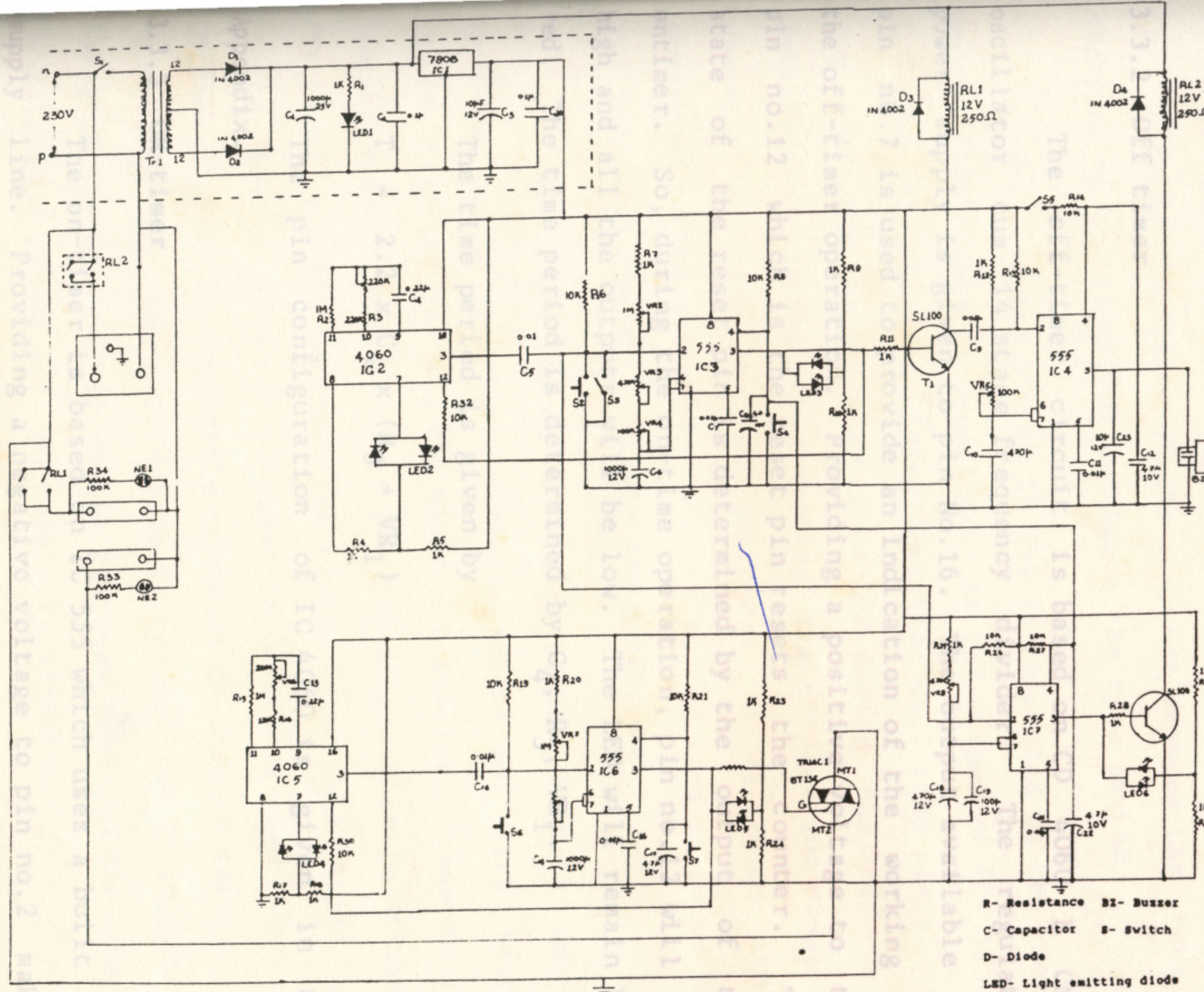


FIG. 5 Circuit Diagram of the Timer

R- Resistance BZ- Buzzer

C- Capacitor S- Switch

D- Diode

LED- Light emitting diode

VR- Voltage regulator

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.

3.3.2 Off timer

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

3.3.3 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-timer's 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 LED 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 systems. 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.

3.3.4 Controls of the drip system

The on-time of the drip system can be varied from 1.1 seconds to 40 minutes, 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.

3.3.5 Controls of the sprinkler system

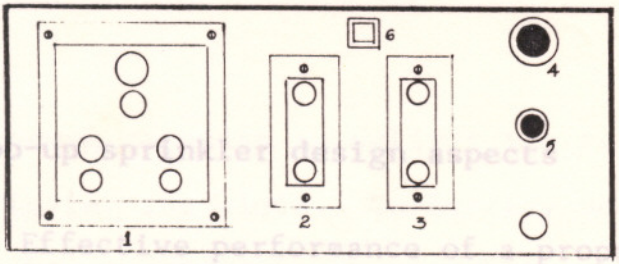
Both the pop-up and micro-sprinklers have the same off-timer circuit and the off period can be varied from 35 min to 1 hr, using a control knob. The off-timing begins only after the pop-ups are switched off. Both the pop-ups and the micro-sprinkler are switched on simultaneously. The on-period for the micro sprinklers can be varied from 1.1 sec to 5 min using a control knob. The on-delay for the pop-ups can be 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. LEDs 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.

3.3.6 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.



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)

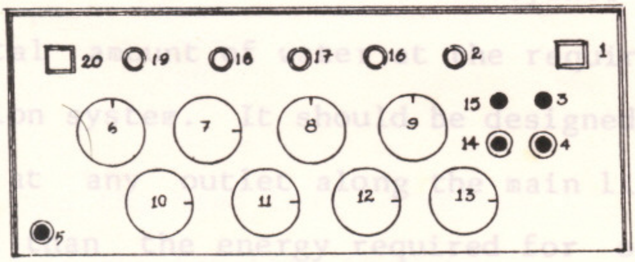


FIG. 6 (b) CONTROL PANEL-FRONT VIEW

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

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 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 approach is 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 Weisbach's equation as

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

where,

H_f 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^2

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 Weisbach'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, Three quarter, Half and Quarter circle pop-up sprinkler heads were determined according to the nature of the plot. Sprinkler head has an external threading which enables it to be threaded on to the internally threaded coupling fixed on lateral line.

3.4.5 Pump selection

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

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Ht = Hn + Hm + Hs + Hg

[wh]ere,

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

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

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

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

Hg is the distance between the pump centre and the junction of the lateral and the main, m

The amount of water that is required is determined by [mu]ltiplying the number of sprinklers by the capacity of each. [Wh]en the total head and rate of pumping are known, the pump [ma]y be selected from rating curves available from the [ma]nufacturers.

The drip system and the micro-sprinkler system are [al]so designed and laid out according to the design procedure [an]d specifications involved.

3.5 Installation

The three systems were laid out with a master control unit to control the irrigation. The micro-sprinkler system was installed in plot no.1, four quarter pop-up sprinklers and one full pop-up sprinkler were installed in plot no.2 and in plot no.3, one half pop-up was 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 front of the library. The controlled input to the solenoid valve and the 0.5 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 micro-sprinklers and the pop-ups were the same with both the systems switching on and off simultaneously.

The complete lay out of the system is shown in Fig.7.

The control unit was designed such that it can be used for a wide range of soil types, infiltration rates and

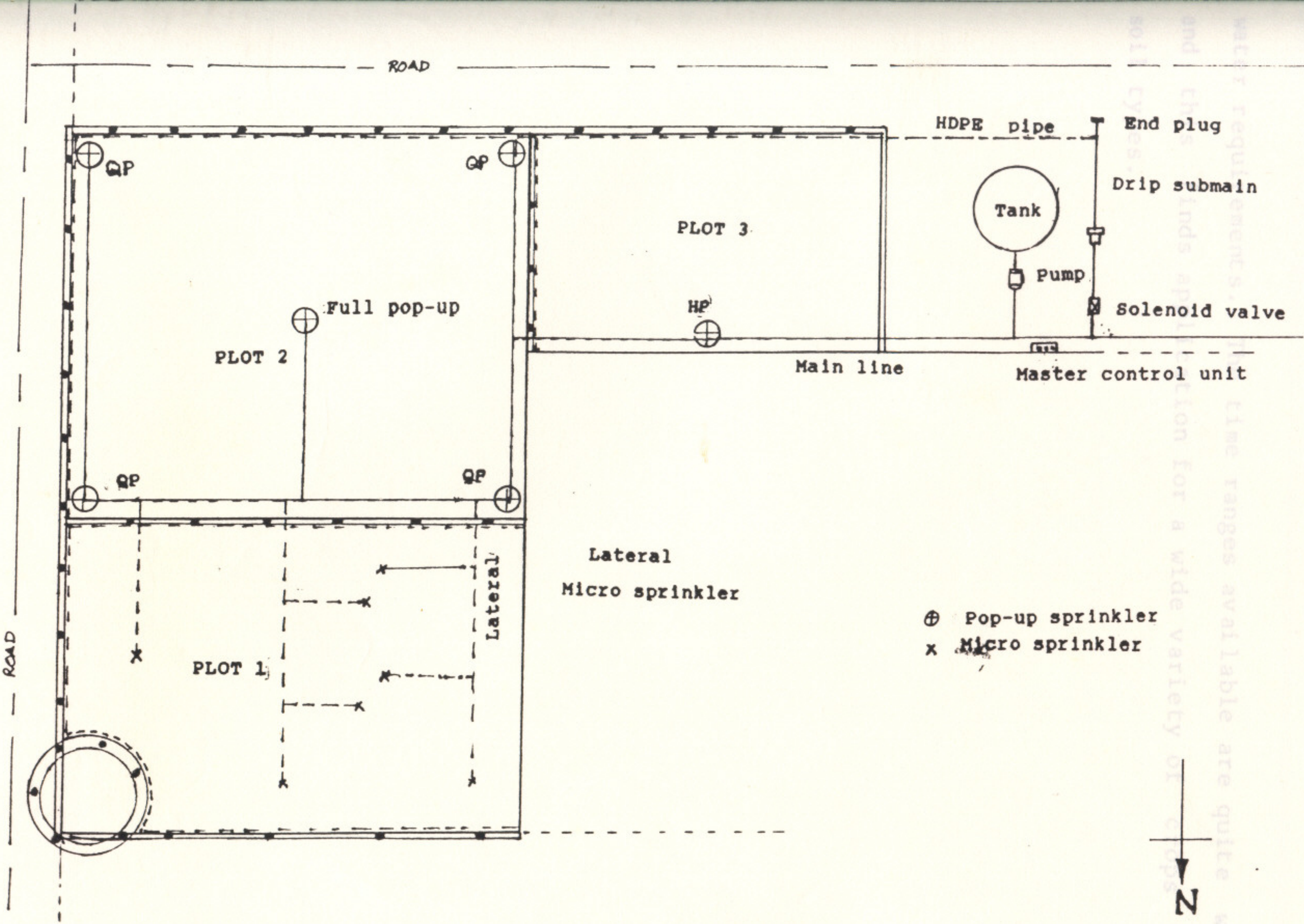


FIG. 7 LAYOUT OF IRRIGATION SYSTEMS

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

The results of the experiments conducted to evaluate the performance of the pop-up sprinkler heads were also used to identify the sprinkler head which showed a better performance. The development and installation of the master-control unit was also done. This chapter discusses the results of the above experiments.

4.1 Performance evaluation of pop-up sprinklers

The performance of four 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

All 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 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 different pop-ups were:

Full pop-up	-	2.5 m - 4.5 m
Three-quarter pop	-	3.0 m - 4.75 m
Half pop-up	-	3.5 m - 4.75 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
Three-quarter pop-up	-	21.2 m^2 - 53.16 m^2
Half pop-up	-	19.24 m^2 - 35.44 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 the different pop-up heads. As pressure increased with the increase in area of coverage from the quarter circle to the full-circle pop-ups, the wetted area increased greatly.

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 three-quarter pop-up; the application depth decreased with increase in pressure but at 2 kg/cm^2, the value showed a slight increase. The same was observed in the case of half pop-up also. For quarter pop-up, the mean application rate increased with increase in pressure. The wetted radius and application depths for the various 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. There was an increase in effective radii of the three-quarter pop-up with increase in pressure but the increase when the operating pressure varied from 1.5 kg/cm^2 to 2 kg/cm^2 was less, which caused the increase in application depths at 2 kg/cm^2. The variations in application depths of the half pop-ups were also due to the same phenomenon. 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

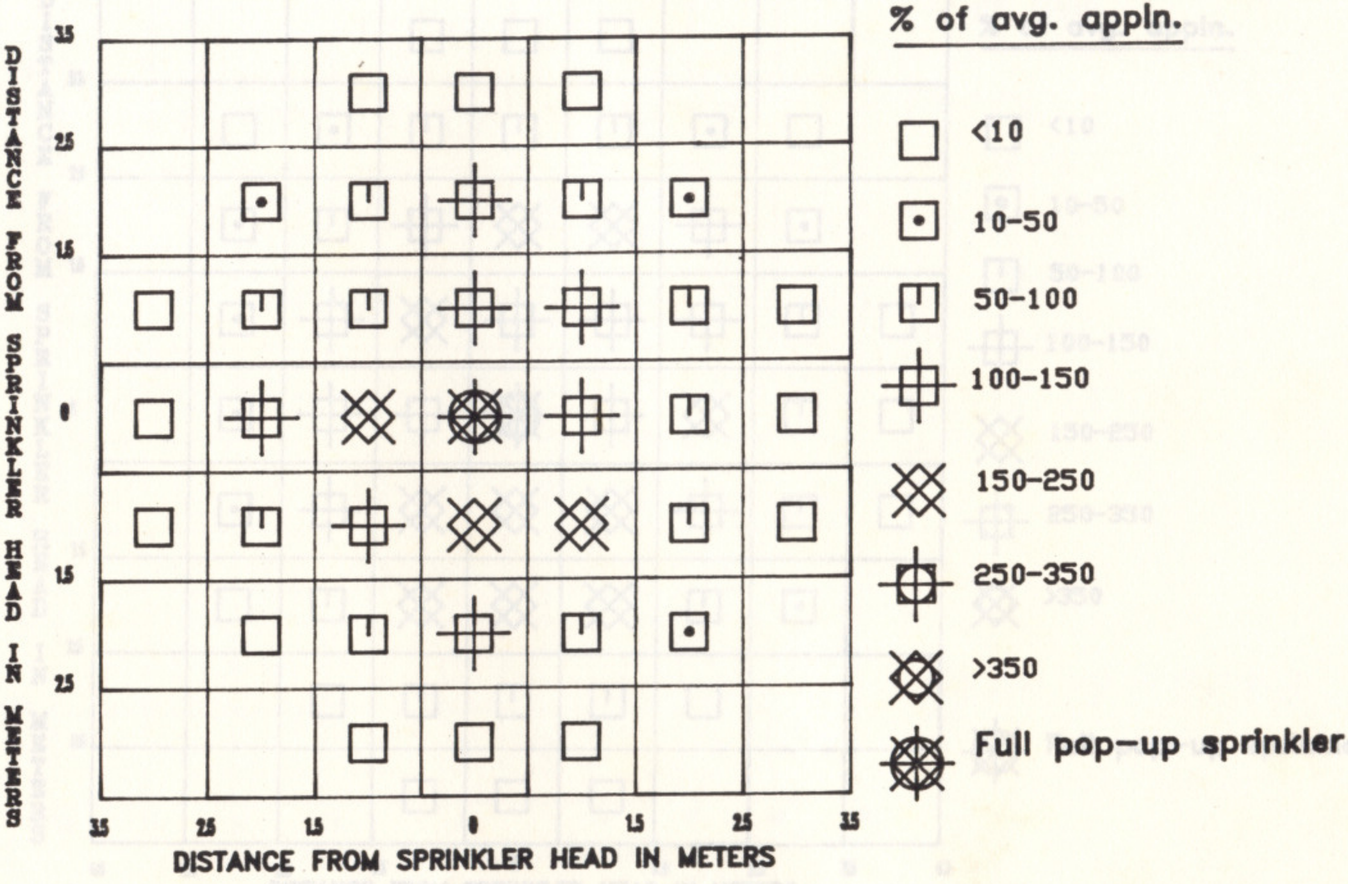
The moisture distribution pattern for the different pop-up heads was determined under different operating pressures. The percentages of average application depth collected in the cans within the effective radius from the sprinkler head were calculated. A graph, showing the percentages of average application 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 were used. It was observed that most of the area received less than 150 per cent of the average application.

It was seen that the full, three-quarter, half and quarter pop-ups wetted more than 50 per cent of the total wetted area with more than half of the average application. For three-quarter pop-up, the area wetted was found to be 66.4

per cent of the total wetted area. The percentage of area receiving less than 10 per cent of the average application was about 19 per cent for all the sprinkler heads. Three quarter pop-up, however, had only 13.8 per cent of the total wetted area receiving less than 10 per cent of the average application.

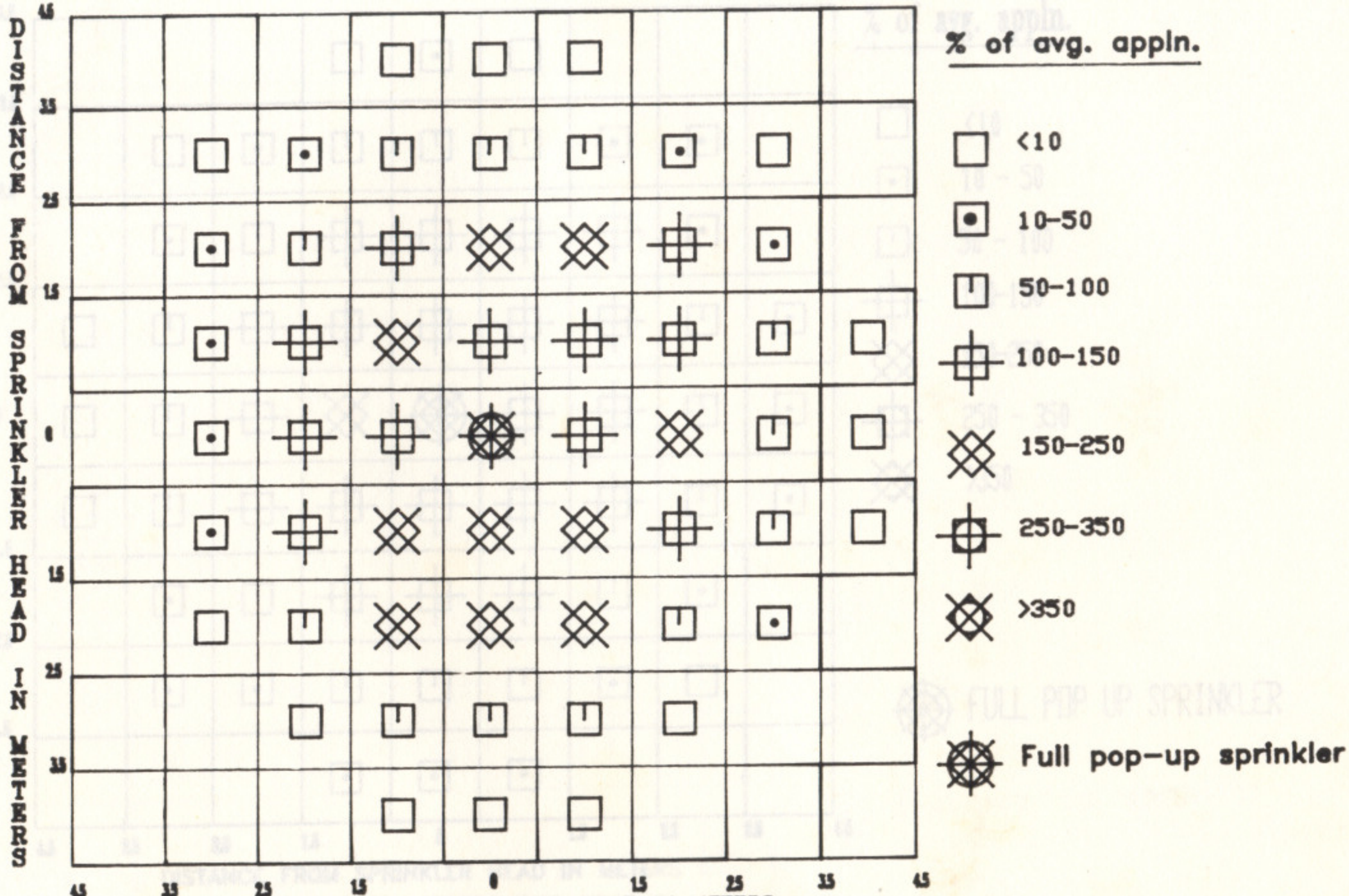
Figures 8, 9, 10 and 11 show the distribution patterns of full pop-up sprinkler heads. For all operating pressures, a minimum of 28 per cent of the total wetted area received water greater than the average application depth. An average of 42 per cent of the total wetted area received less than 50 per 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.

The distribution patterns of the three-quarter pop-up are shown in figures 12, 13, 14 and 15, for different operating pressures. For operating pressures of 1 kg/cm^2, 1.5 kg/cm^2 and 2 kg/cm^2, approximately 40 per cent of the total



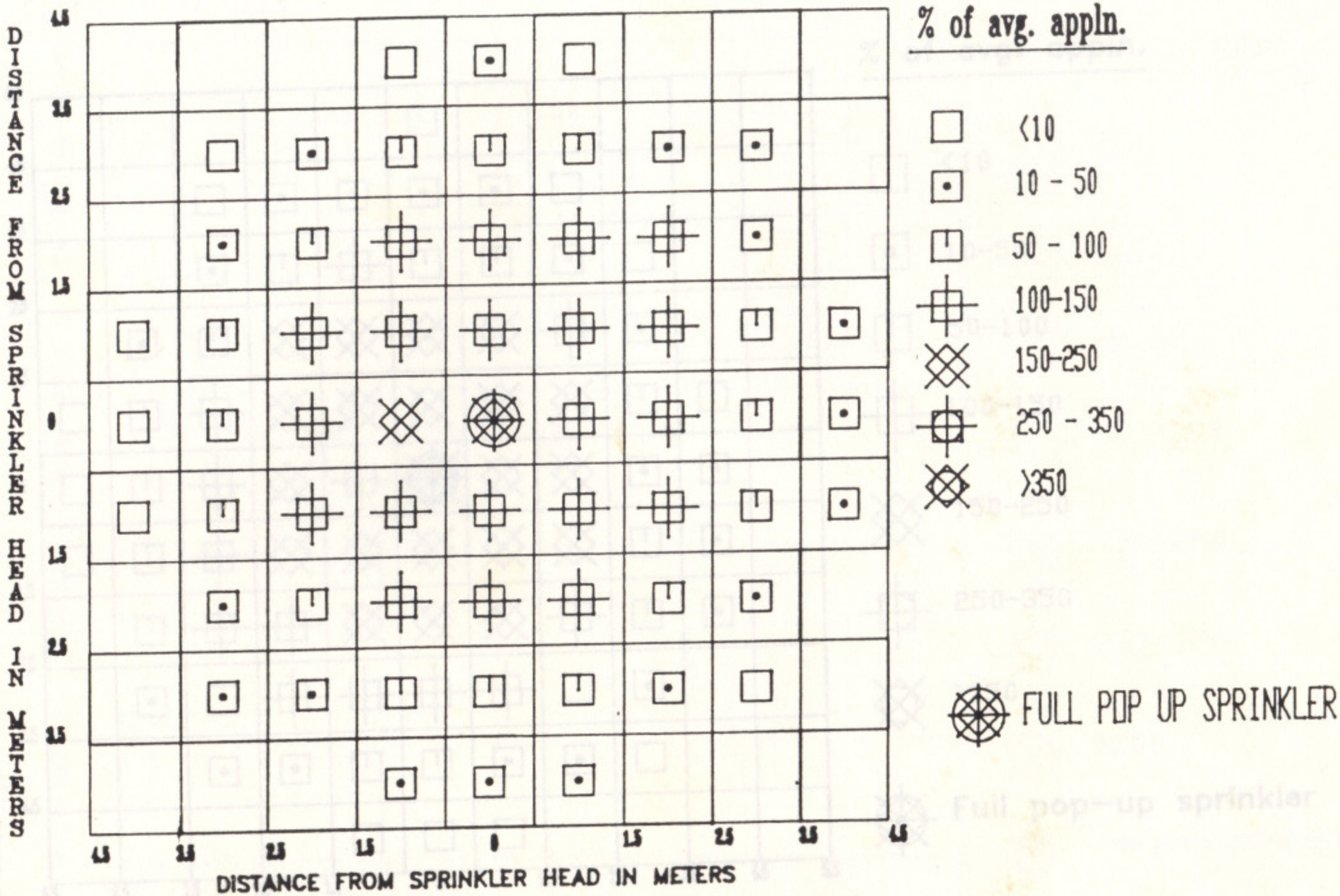
DISTRIBUTION PATTERN OF FP AT 0.5 kg/cm^2

Fig: 8



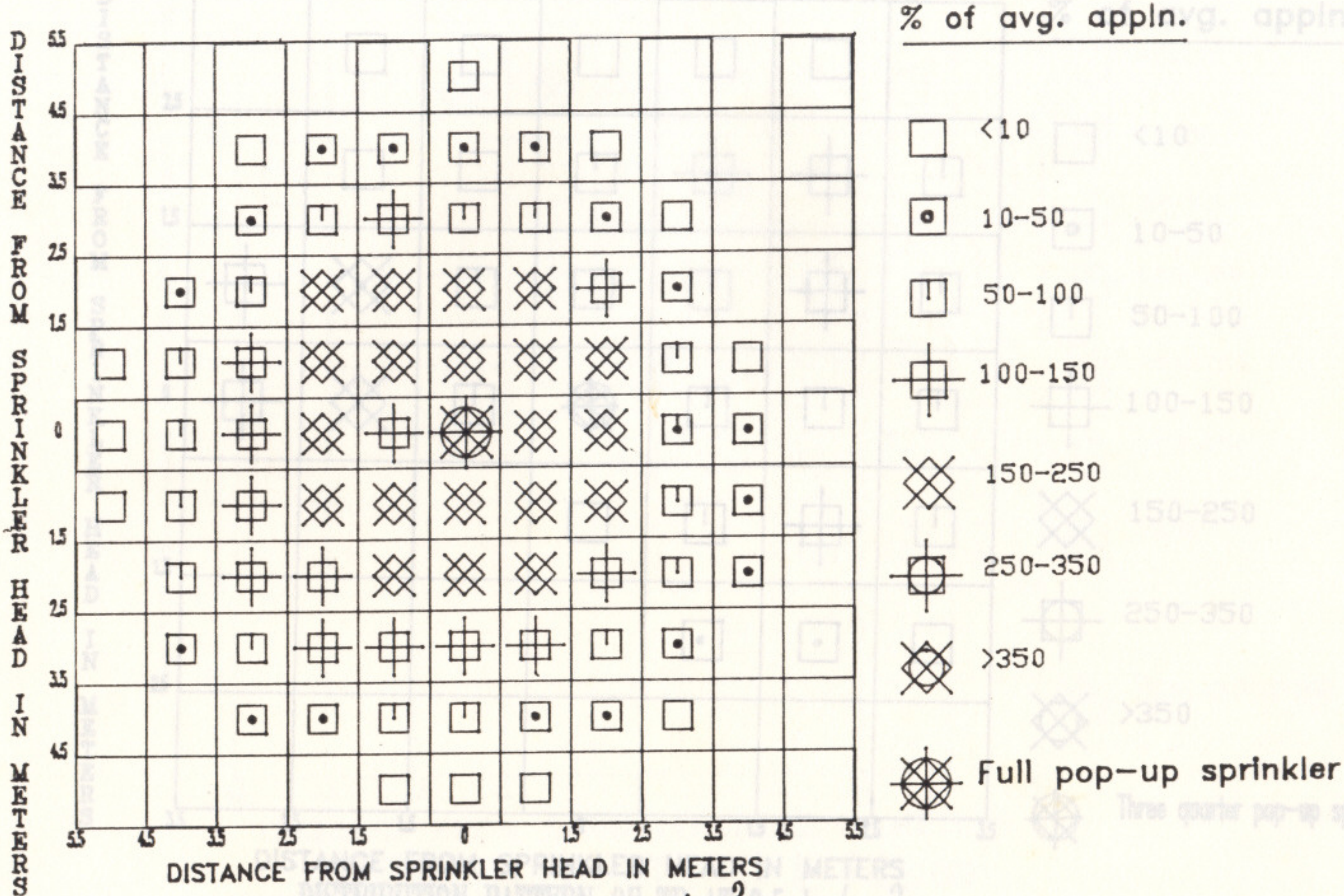
DISTRIBUTION PATTERN OF FP AT 1 kg/cm²

FIG: 9



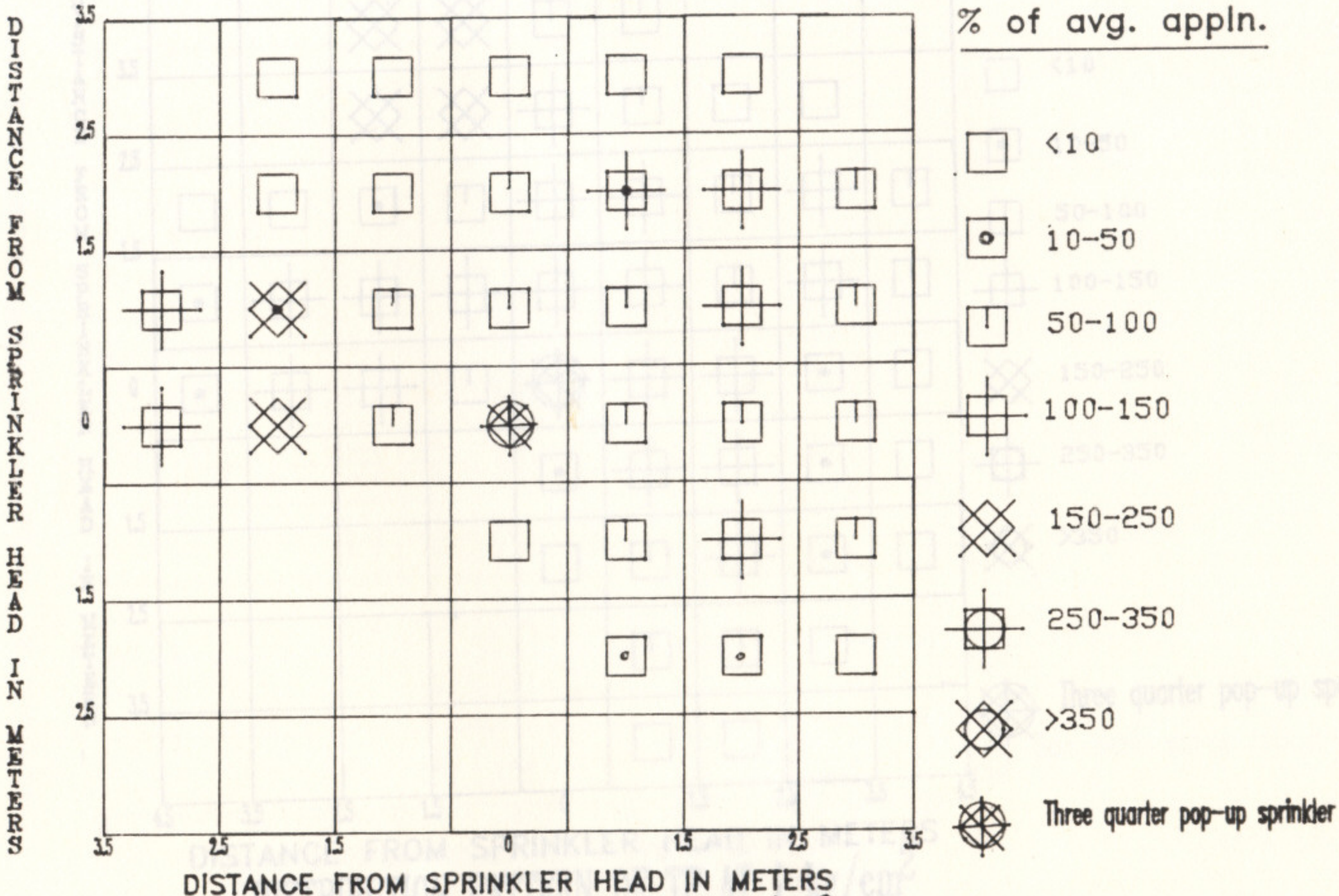
DISTRIBUTION PATTERN OF FP AT 1.5 kg/cm^2

FIG: 10



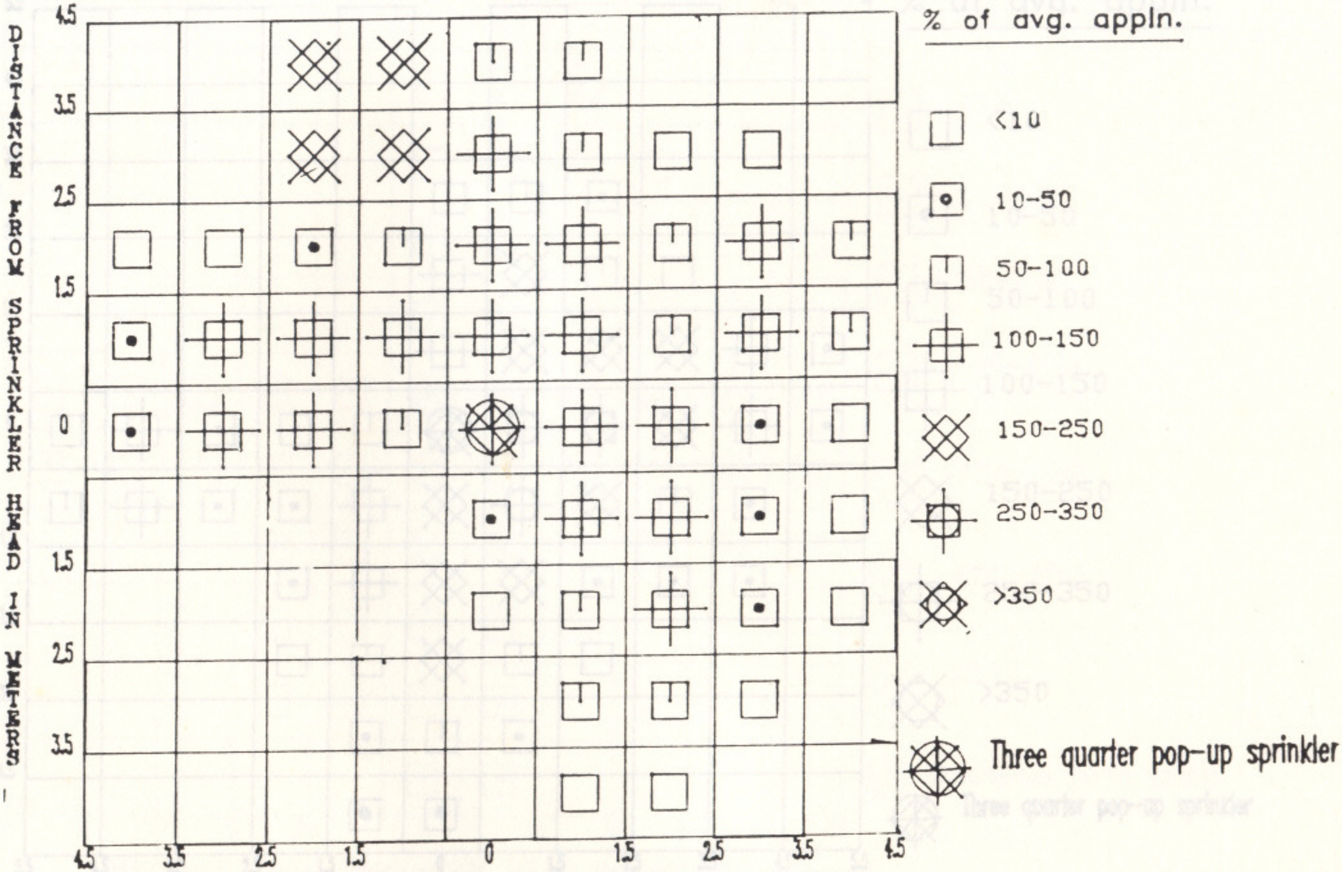
DISTRIBUTION PATTERN OF FP AT 2 kg/cm^2

FIG: 11



DISTRIBUTION PATTERN OF TP AT 0.5 kg/cm^2

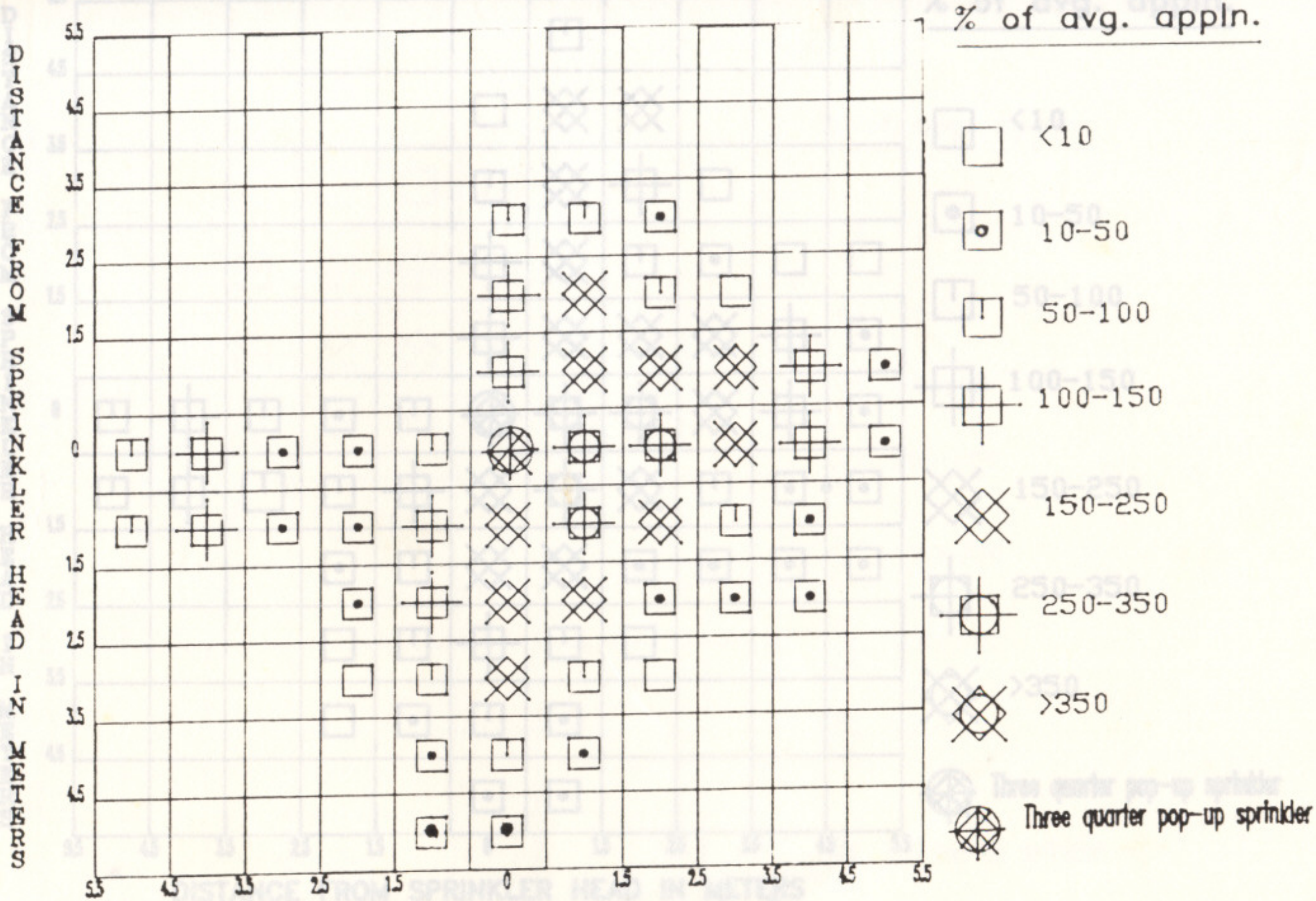
FIG: 12



DISTANCE FROM SPRINKLER HEAD IN METERS

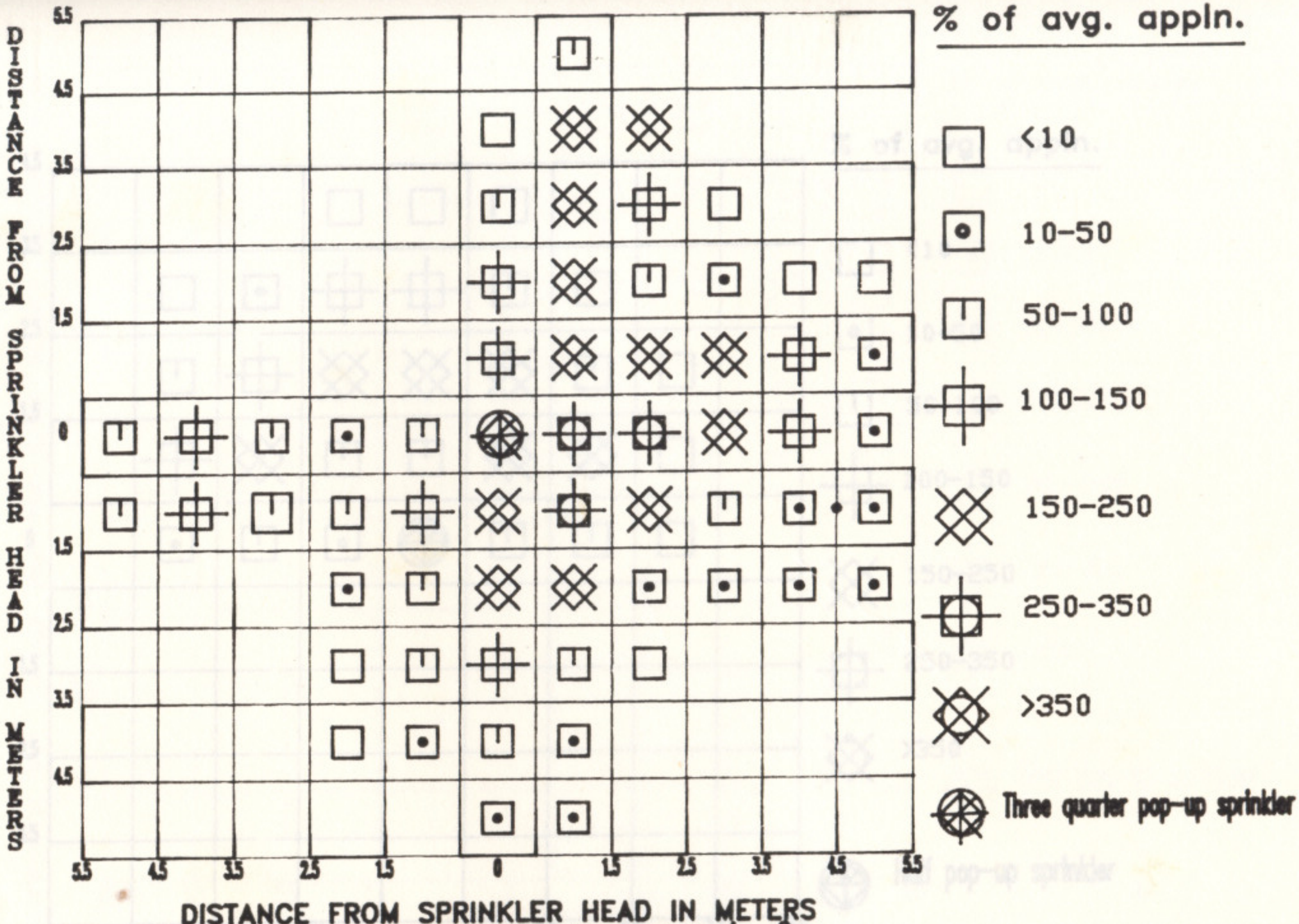
DISTRIBUTION PATTERN OF TP AT 1 kg/cm^2

FIG: 13



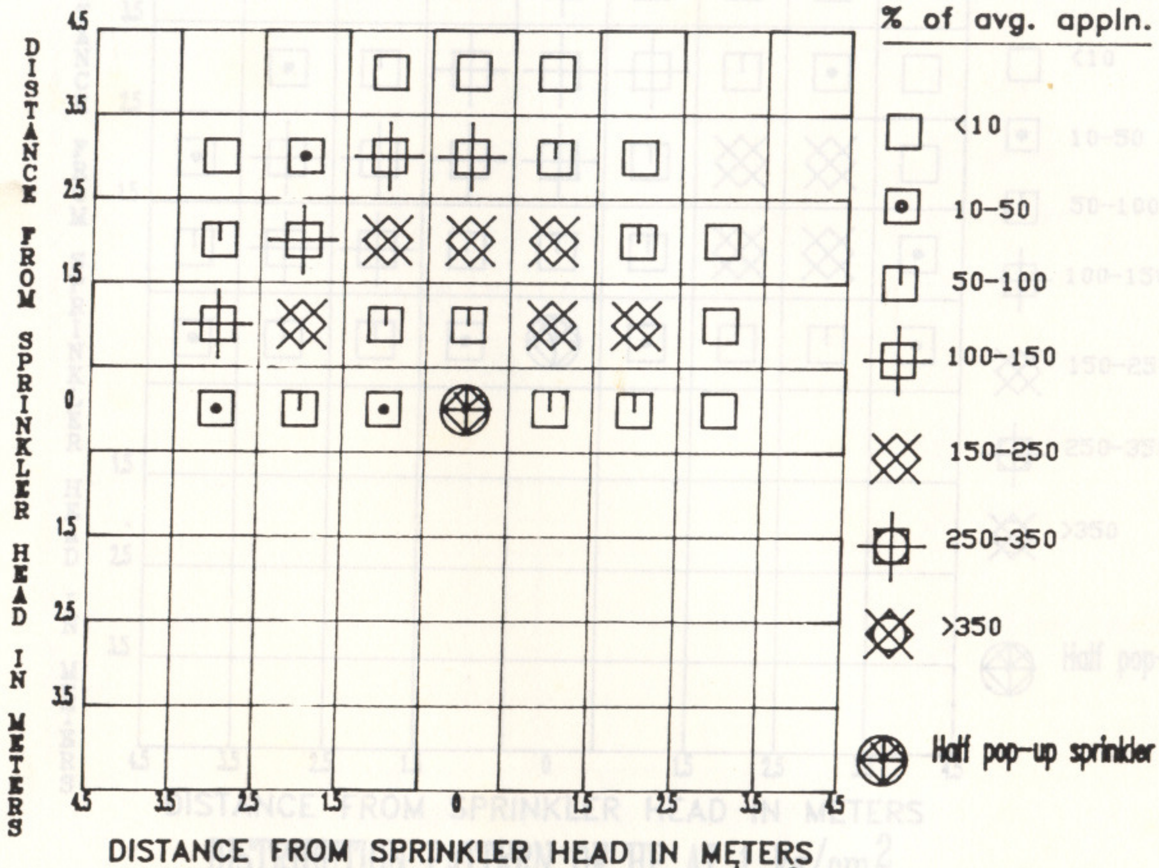
DISTRIBUTION PATTERN OF TP AT 1.5 kg/cm2

FIG: 14



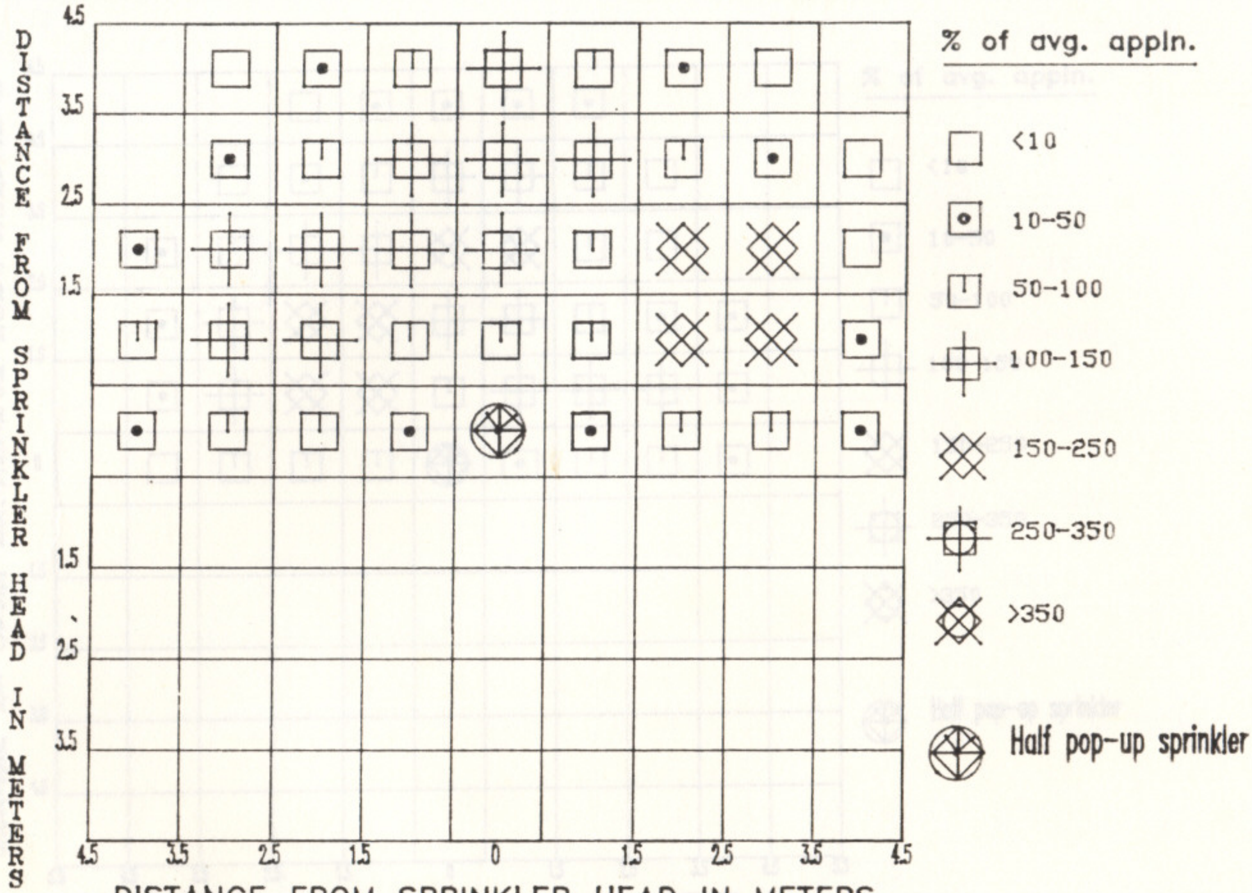
DISTRIBUTION PATTERN OF TP AT 2 kg/cm^2

FIG : 15



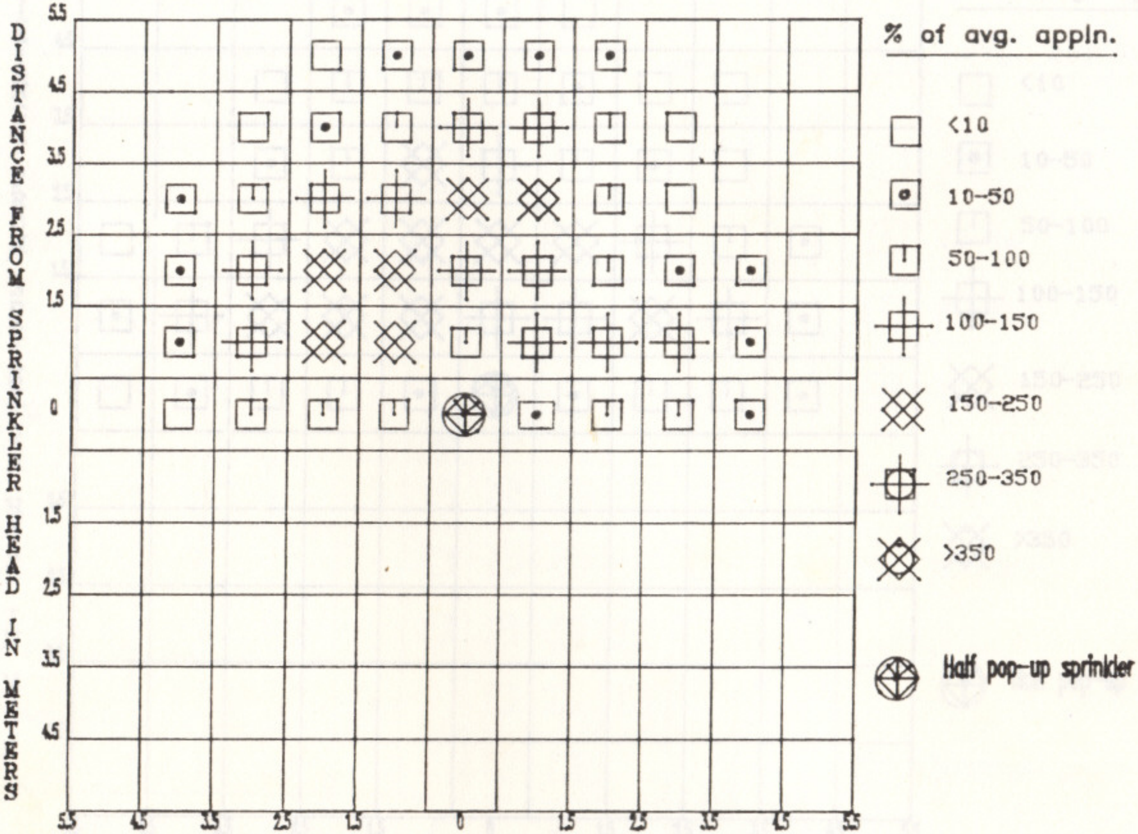
DISTRIBUTION PATTERN OF HP AT 0.5 kg/cm^2

FIG: 16



DISTRIBUTION PATTERN OF HP AT 1 kg/cm^2

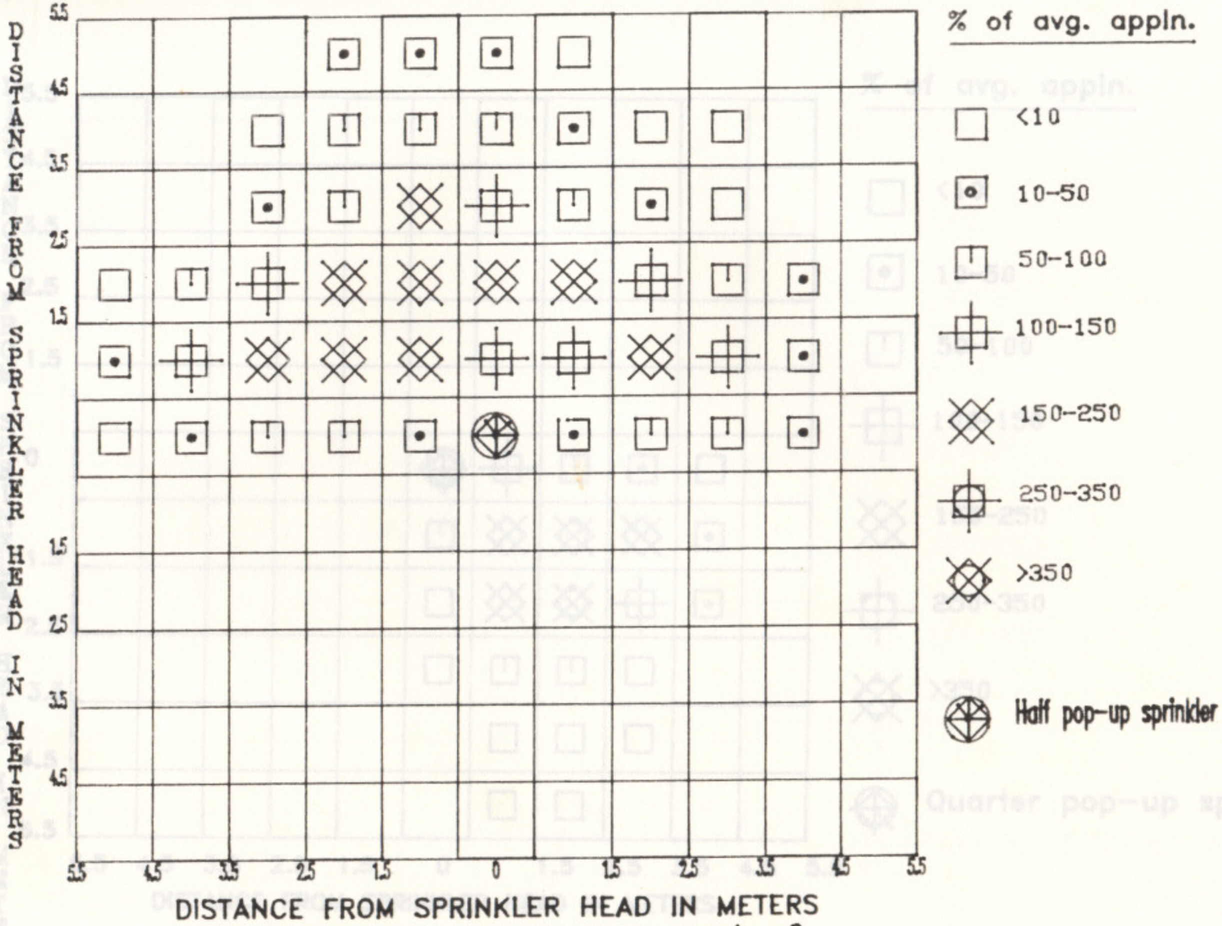
FIG: 17



DISTNCE FROM SPRINKLER HEAD IN METERS

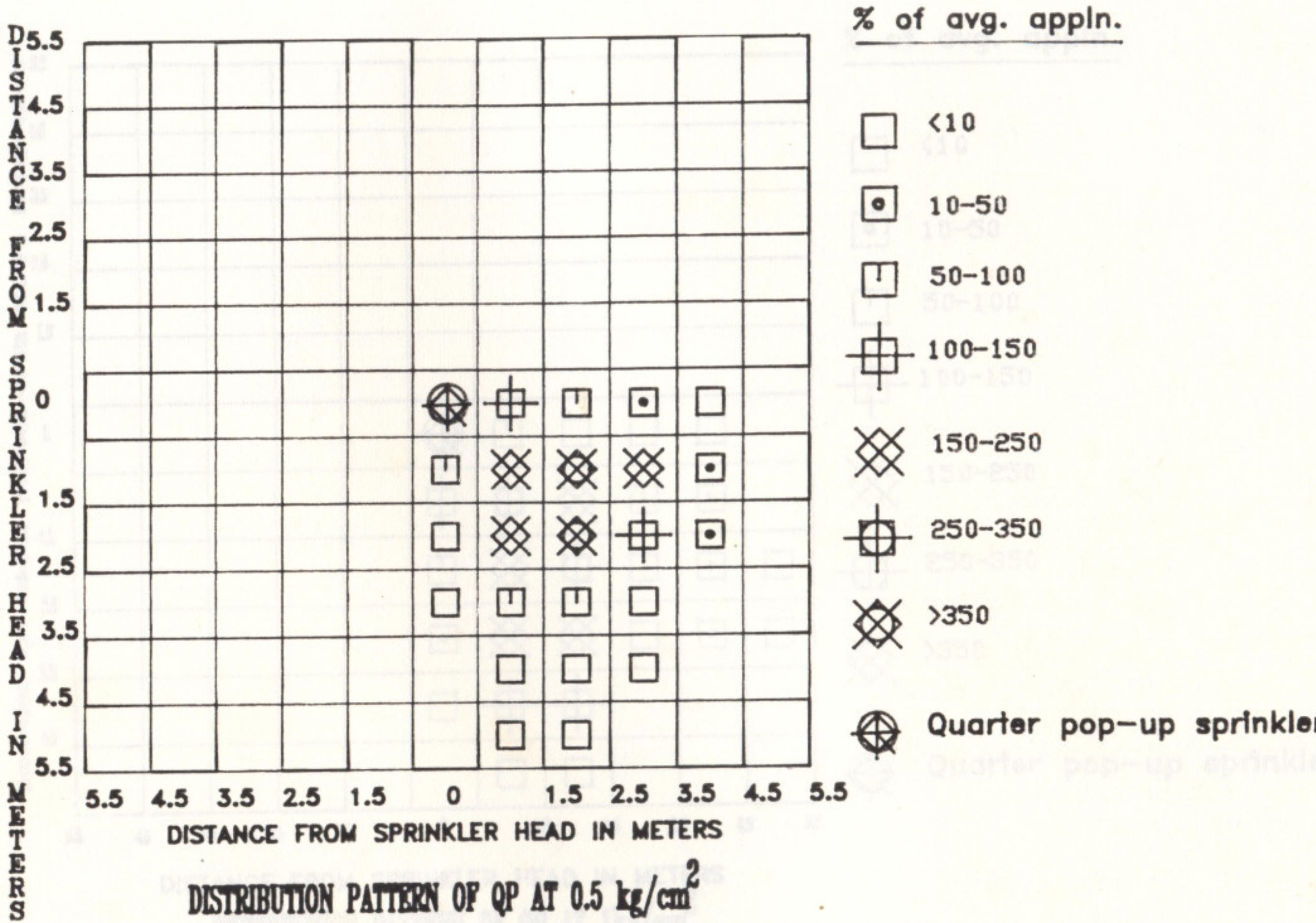
DISTRIBUTION PATTERN OF HP AT 1.5 kg/cm^2

FIG: 18



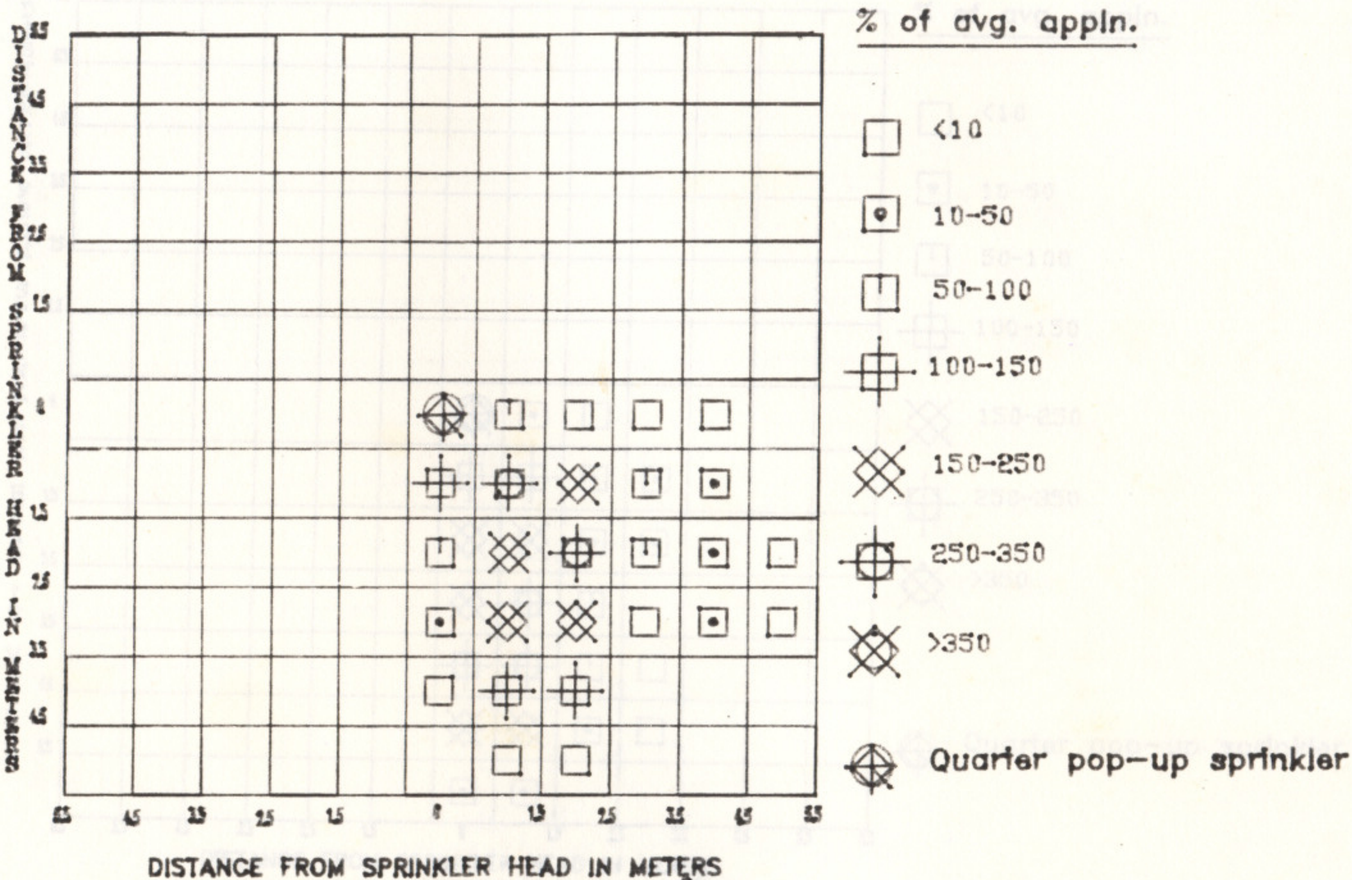
DISTRIBUTION PATTERN OF HP AT 2 kg/cm 2

FIG: 19



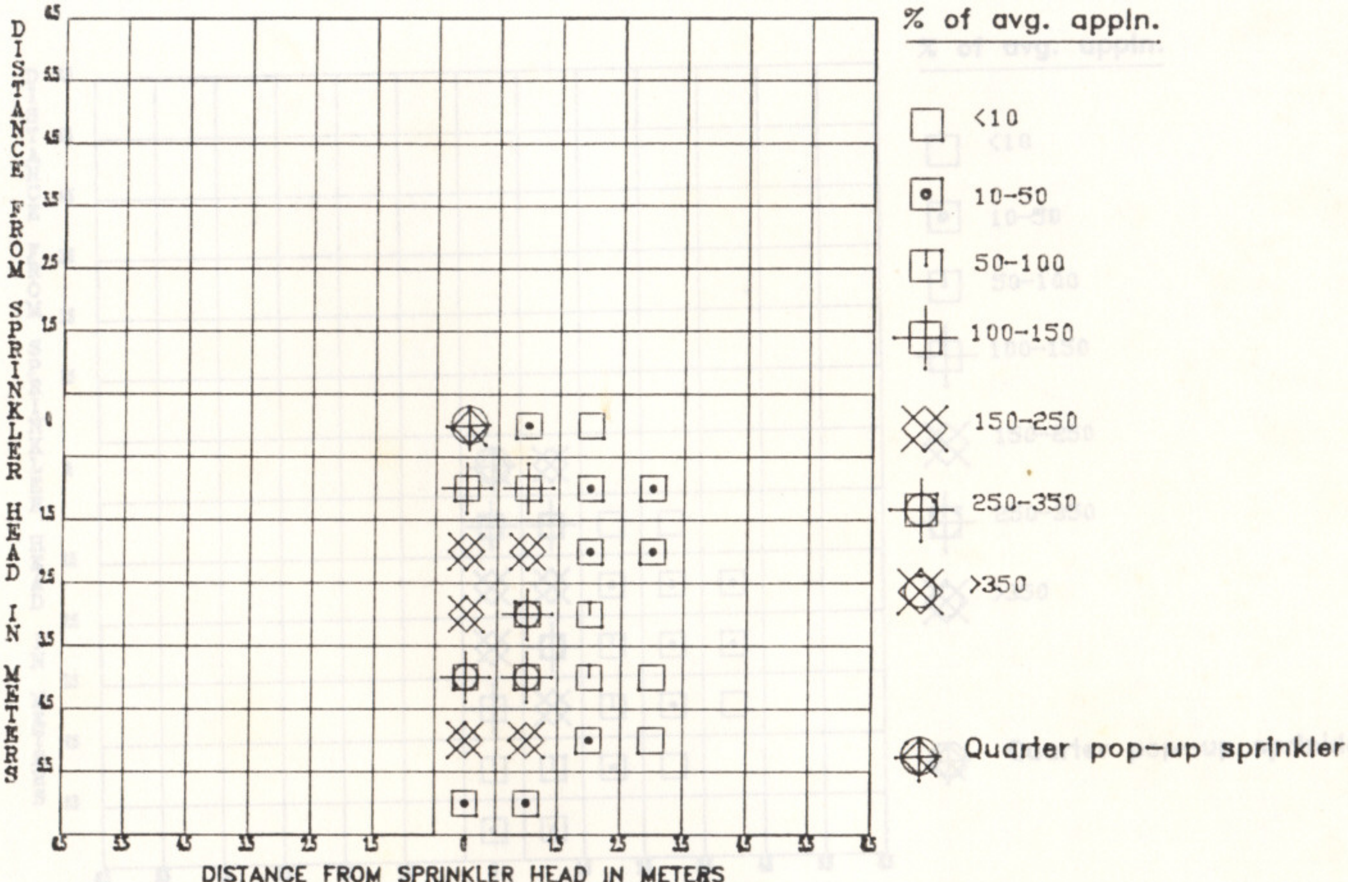
DISTRIBUTION PATTERN OF QP AT 0.5 kg/cm^2

FIG: 20



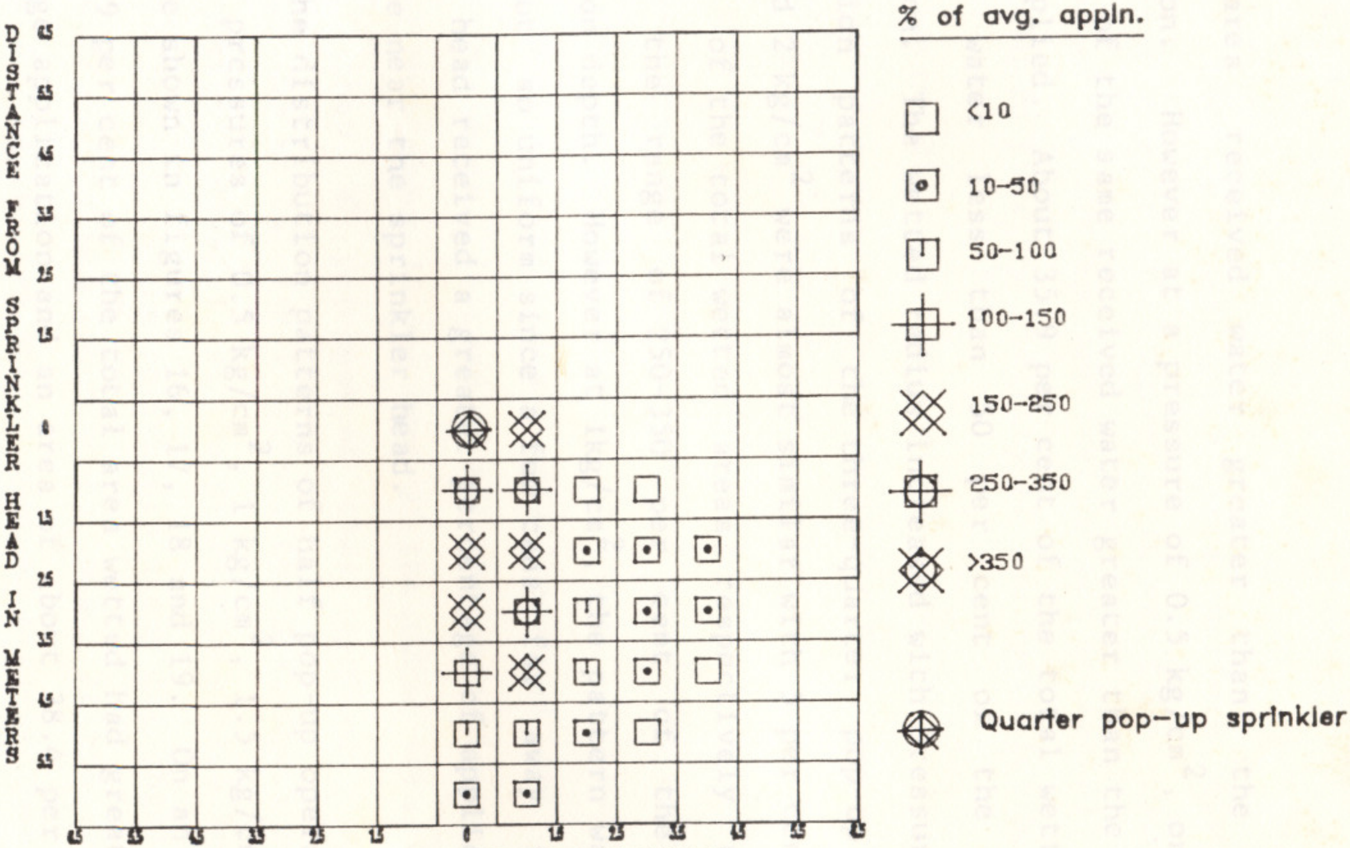
DISTRIBUTION PATTERN OF QP AT 1kg/cm^2

FIG: 21



DISTRIBUTION PATTERN OF QP AT 1.5 kg/cm^2

FIG: 22



DISTRIBUTION PATTERN OF QP AT 2 kg/cm^2

FIG: 23

wetted area received water greater than the average application. However at a pressure of 0.5 kg/cm^2, only 25.8 per cent of the same received water greater than the average water applied. About 35.9 per cent of the total wetted area received water less than 50 per cent of the average application. The wetted radius increased with pressure. The distribution patterns of the three-quarter pop-up at 1.5 kg/cm^2 and 2 kg/cm^2 were almost similar with 5 per cent and 6 per cent of the total wetted areas respectively receiving water in the range of 250-350 per cent of the average application depth. However at 1kg/cm^2, the pattern was found to be not so uniform since a few cans far away from the sprinkler head received a greater percentage of applied water than those near the sprinkler head.

The distribution patterns of half pop-up operating at different pressures of 0.5 kg/cm^2, 1 kg/cm^2, 1.5 kg/cm^2 and 2 kg/cm^2 are shown in figures 16, 17, 18 and 19. On an average, about 34.9 per cent of the total area wetted had greater than the average application and an area of about 38.4 per cent had less than half of the average application. However, at 2 kg/cm^2, 42.6 per cent of the total area wetted received less than half of the average application and at 1 kg/cm^2, 34.2 per cent of the total wetted area received the same. The distribution patterns were almost uniform for all operating pressures. Half pop-ups had a more uniform distribution pattern at a pressure of 2 kg/cm^2. It was found that higher percentage of the average application was collected in cans slightly removed from the vicinity of the sprinkler head.

Figures 20, 21, 22 and 23 show the distribution pattern of quarter pop-up operating under the pressures of 0.5 kg/cm^2, 1 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 grids 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 all other 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 pressure was due to a defect in the manufacture of the sprinkler head.

4.1.4 Discharge

The discharge of the full circle, three-quarter circle, half circle and quarter circle 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, of three-quarter pop-ups from 279.6 lph to 535.5 lph, of half pop-up from 210.6 lph to 480.2 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 all other pop-up heads as the area of coverage decreased. Figure 24 shows the variation of discharge of the different pop-up heads with the operating pressures. The values for the discharges at various pressures for different pop-ups are given in Table 1.

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:Da
	0.5	451.2	2.5	19.77	1.86
	1.0	638.8	3.5	19.64	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	279.6	3.0	12.78	5.98
	1.0	397.0	3.75	9.67	4.74
TP	1.5	441.1	4.5	4.64	2.33
	2.0	535.5	4.75	5.74	1.97
	0.5	341.6	3.5	13.35	2.96
	1.0	356.4	4.5	12.5	2.29
HP	1.5	562.1	4.75	8.27	2.50
	2.0	648.4	4.75	17.14	2.68
	0.5	120.2	5.0	4.48	4.98
	1.0	177.2	5.5	5.68	5.61
QP	1.5	217.4	5.5	7.49	5.78
	2.0	274.0	5.5	8.19	6.22

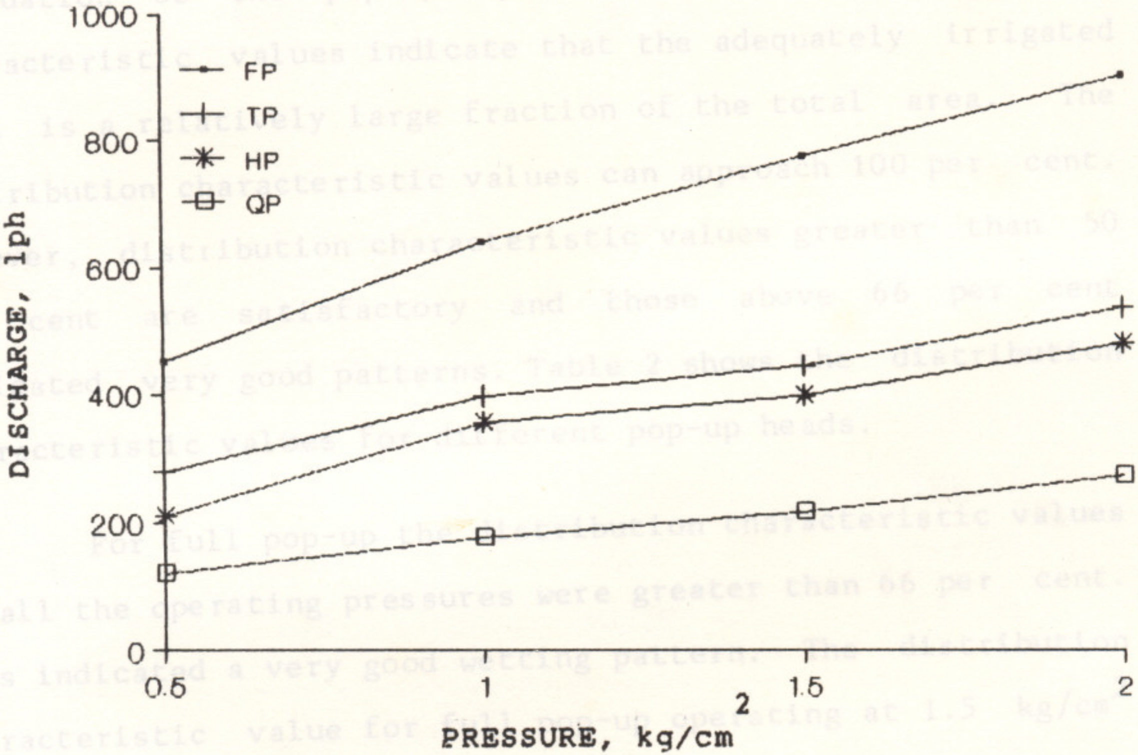

FP
TP
HP
QP
DISCHARGE, lph
1000
800
600
400
200
0
0.5
1
1.5
2
PRESSURE, kg/cm 2

FIG. 24

4.1.5 Distribution characteristics

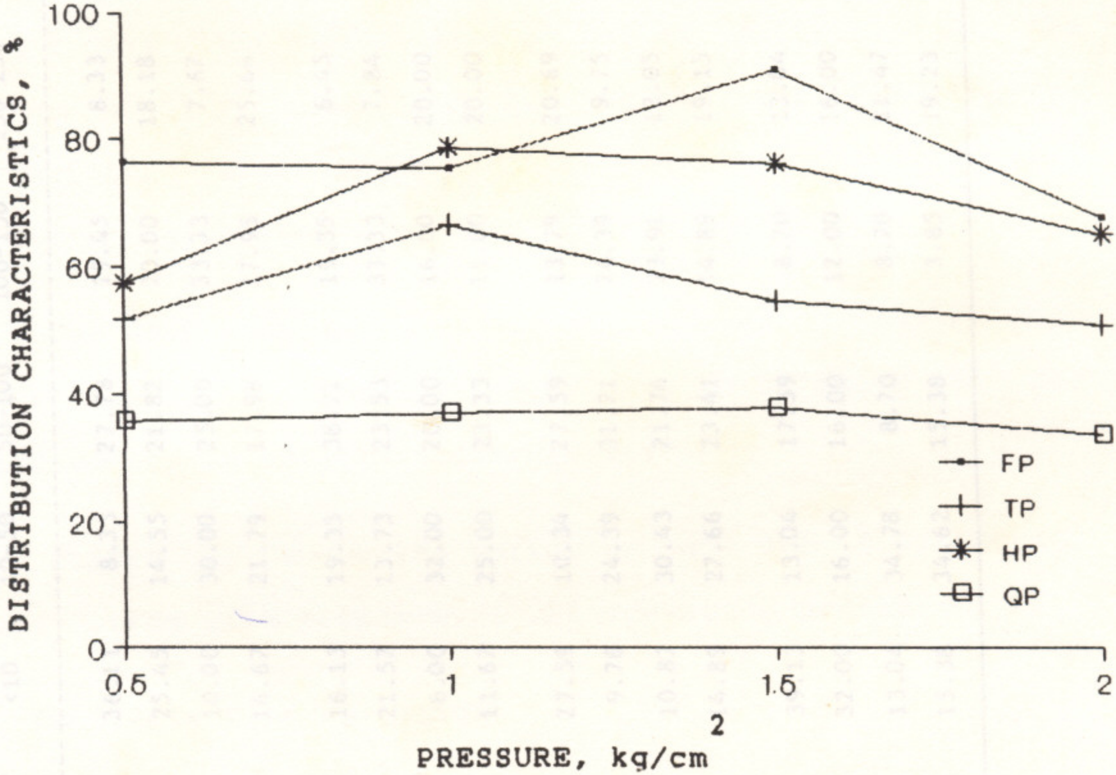
The distribution characteristic values are a means of evaluation of the pop-up sprinklers. High distribution characteristic values indicate that the adequately irrigated area is a relatively large fraction of the total area. The distribution characteristic values can approach 100 per cent. However, distribution 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 different pop-up heads.

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 the three-quarter pop-up for all operating pressures were above 50 per cent and hence satisfactory. The distribution patterns were however not very uniform since there were no values above 66 per cent. At 1 kg/cm^2, however, three-quarter pop-up had a distribution characteristic of 66.4 per cent which made the distribution pattern quite good.

Table 2. Uniformity parameters of pop-up sprinklers

Pop-up sprinkler	Pressure kg/cm^2	Distribution characteristic DC %	Coefficient of variation CV %
FP	0.5	76.4	88.89
	1.0	75.4	75.18
	1.5	90.9	43.85
	2.0	67.6	70.14
TP	0.5	51.87	139.70
	1.0	66.4	121.77
	1.5	57.5	118.03
	2.0	50.79	112.31
HP	0.5	57.17	107.76
	1.0	78.6	73.83
	1.5	76.18	74.02
	2.0	64.19	83.38
QP	0.5	35.70	166.22
	1.0	37.00	153.49
	1.5	37.90	167.59
	2.0	33.67	159.58



100
80
60
40
20
0
DISTRIBUTION CHARACTERISTICS, %
0.5
1
1.5
2
PRESSURE, kg/cm 2
FP
TP
HP
QP

FIG. 25

Table 3. Percentage of average application

Pop-up sprinkler	Pressure kg/cm^2	<10	10-50	50-100	100-150	150-250	250-350	>350
	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
FP	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
	0.5	16.13	19.35	38.71	19.35	6.45	0.00	0
	1.0	21.57	13.73	23.53	33.33	7.84	0.00	0
TP	1.5	6.00	32.00	20.00	16.00	20.00	6.00	0
	2.0	11.67	25.00	23.33	15.00	20.00	5.00	0
	0.5	27.59	10.34	27.59	13.79	20.69	0.00	0
	1.0	9.76	24.39	31.71	24.39	9.75	0.00	0
HP	1.5	10.87	30.43	21.74	23.91	13.05	0.00	0
	2.0	14.89	27.66	23.41	14.89	19.15	0.00	0
	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
QP	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

A variation in the distribution characteristic values of half pop-up for the different operating pressures was observed. At 0.5 kg/cm^2, the distribution characteristic value was 57.2 per cent which made the distribution pattern satisfactory. At 2 kg/cm^2, distribution characteristic value was 64.9 per cent which gave a better pattern. At the pressures of 1.0 kg/cm^2 and 1.5 kg/cm^2 the distribution characteristic values were 78.6 per cent and 76 per cent respectively which gave good distribution patterns.

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

Figure 25 shows the variation of the distribution characteristics with pressure at all operating pressures.

4.1.6 Coefficient of variation

Post <u>et al</u> (1986) recommended using an additional performance indicator, in addition to the distribution characteristics,to characterize sprinkler head performance better. 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 different sprinkler heads are shown in Table 2. Figure 26 shows the variation of the coefficient of variation with pressure for the different 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. All the values were less than 100 per cent.

The values of the coefficient of variation for three-quarter pop-up decreased with the increase in pressure. All the values were above 100 per cent but were found to be satisfactory. In case of the half pop-up, the values decreased in general, with increasing pressure. However, at a pressure of 2 kg/cm^2, the value was found to be greater than that of 1 kg/cm^2 and 1.5 kg/cm^2. The value at 0.5 kg/cm^2 was greater than 100 per cent whereas all other were below 100 per cent. The values of the coefficient of variation for the quarter pop-ups were all above 150 per cent. But no general trend was seen regarding these values, with respect to the operating pressures. These values were however satisfactory.

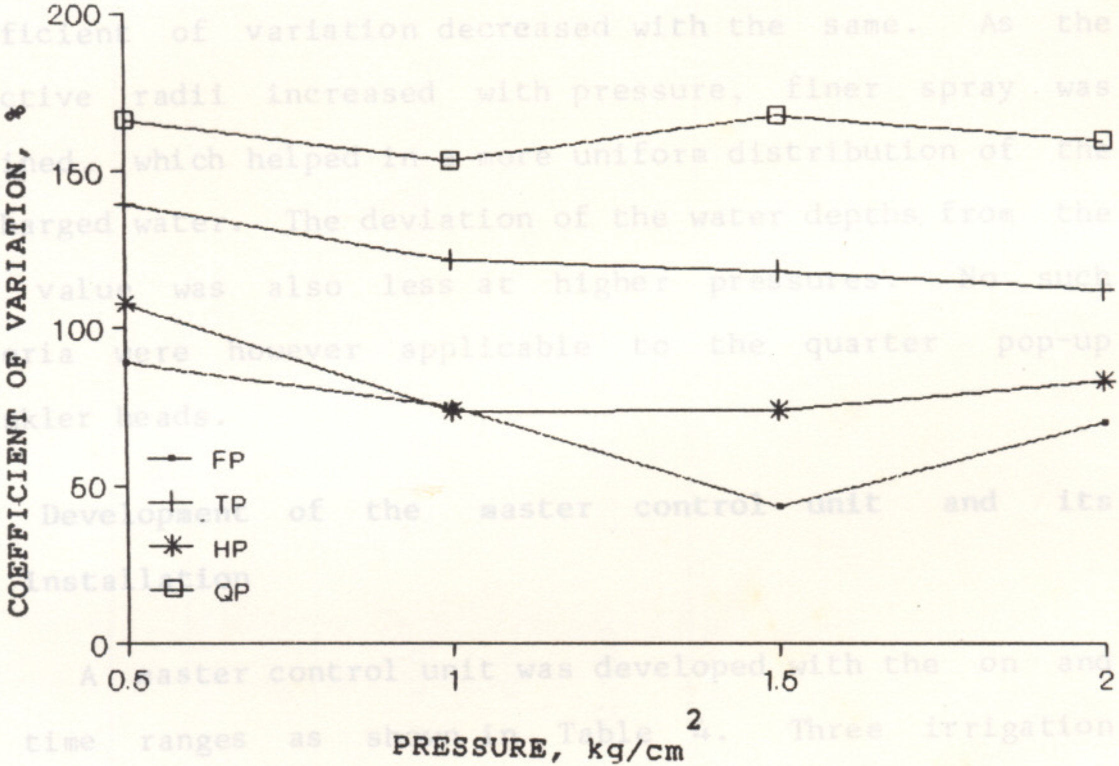

200
150
100
50
0
COEFFICIENT OF VARIATION, %
FP
TP
HP
QP
0.5
1
1.5
2
PRESSURE, kg/cm 2

FIG. 26

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 Development of the master control unit and its installation

A master control unit was developed with the on and 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 three plots while the drip system irrigated the pots kept on the ridges. The rate of application was decided based on the crop water requirement. 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

Table 4. ON-OFF time 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

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 a day. The plants were free from water stress. The controls of the drip system were arranged to have an on period of 10 minutes and off period of 50 minutes.

The plant response to irrigation was good which was indicated by the vigorous growth of grass and potted plants. The results showed 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 was conducted to evaluate the performance of different kinds of pop-up sprinklers under different operating pressures. The experiment was conducted by placing each of the sprinkler heads; namely, full-circle, three-quarter circle, half-circle and quarter-circle pop-ups; at the centre of a collector grid and operating the sprinkler for a specified time to collect the discharged water in the collector cans. The catch in each collector was measured at the end of the period of operation and the volume of water collected was used to determine the depths of application, wetted radius, distribution pattern, distribution characteristic and the coefficient of variation, for the different sprinkler heads at different operating pressures.

Distribution patterns of the full pop-up sprinkler head were found to be good, 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 coefficient of variation is another performance characteristic calculated by dividing the standard deviation of the depth used to calculate the mean by the mean application depth, expressed as percentage. The values of the coefficient of variation less than 100 per cent were considered good and those less than 200 per cent, satisfactory. On a whole, the full pop-up showed a satisfactory performance, with good distribution characteristics, is good distribution pattern and good coefficient of variation.

The pop-ups, micro sprinklers and the drip irrigation systems were installed in the plots provided. A full pop-up and four quarter pop-ups were installed at the centre and corners respectively of plot number 2. Plot number 3 had a half circle pop-up and the plot number 1 had sixteen micro sprinklers. The pop-up and the micro sprinkler systems were used to irrigate lawn grass. In order to irrigate the hundred pots kept on the ridges between these plots, the drip system was laid out. The three systems of irrigation were connected to the master-control unit which controls the irrigation automatically. The crop water requirement was found out to determine the time periods for which each system is to be kept on. 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 determined to be 3 minutes and the off-period as 57 minutes which applied water to the fields at a rate of 1 mm/hr. The total time of irrigation in a day was

6 hours. This rate of application suited the infiltration characteristics of the soil. The drip system is operated by a solenoid valve and the on and off periods determined for the potted plants were 10 minutes and 50 minutes respectively.

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. With slight modifications, the time ranges of the master control unit can be changed further. The master control unit provides a very useful means of removing 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. (1985). 555 Timer Applications source book with Experiments. BPB Publications. New Delhi. pp. 7-18.

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. 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.

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

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

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

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

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

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

Issacs, G.W. (1982). The electronics age in agriculture. Agricultural Engineering, ASAE.

IS: 12232 (Part I) (1987).

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

Karmeli, D. and Peri, G. (1977). Pulse Irrigation - Design for operating sets. Journal of the Irrigation and Drainage Division, ASCE. 103 (IR 1): 33-41.

Kay, M. (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 Sprinkler Irrigation System Design and Layout. pp. 1-30.

Kohl, R. A. (1974). Drop size distributions from medium sized Agricultural sprinklers. 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. (1976). Soil water flow and distribution in horizontal and vertical direction as influenced by intermittent water application. Soil Science. 124 (6): 355-365.

Marston, 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 evaluation - A guide for management. Utah State University, Logan.

Michael, A.M. (1978). Irrigation - Theory and Practice. Vikas Publishing House Pvt. Ltd. pp. 448-685.

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

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

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

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

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

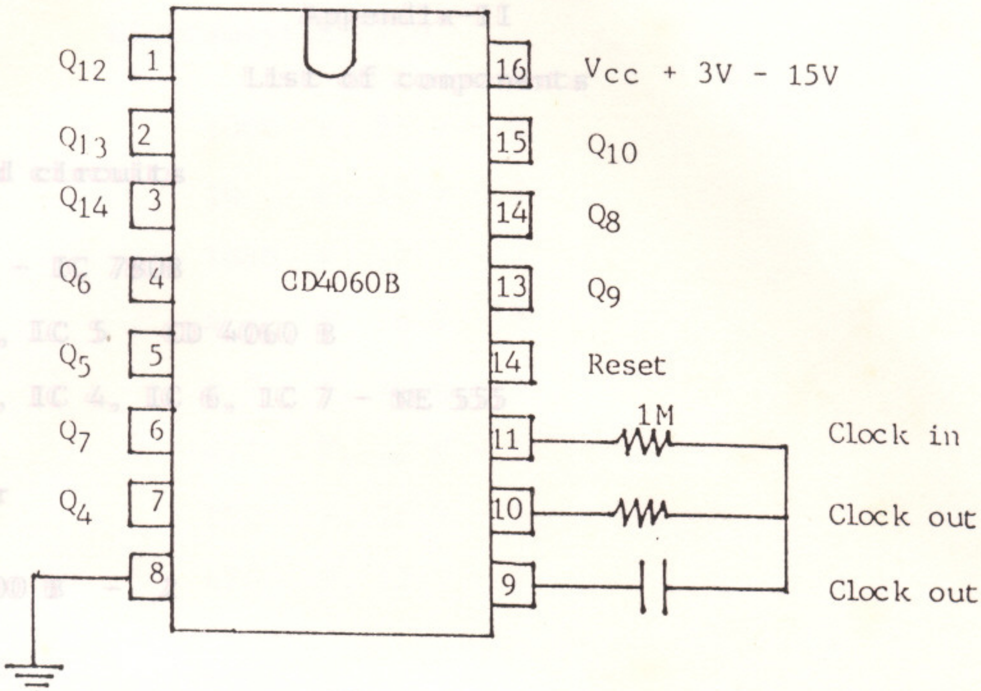
Sharma, R.K. (1984). Text-book of Irrigation Engineering and Hydraulic Structures. Oxford and IBH Publishing Co., New Delhi, Bombay and Calcutta.

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

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.

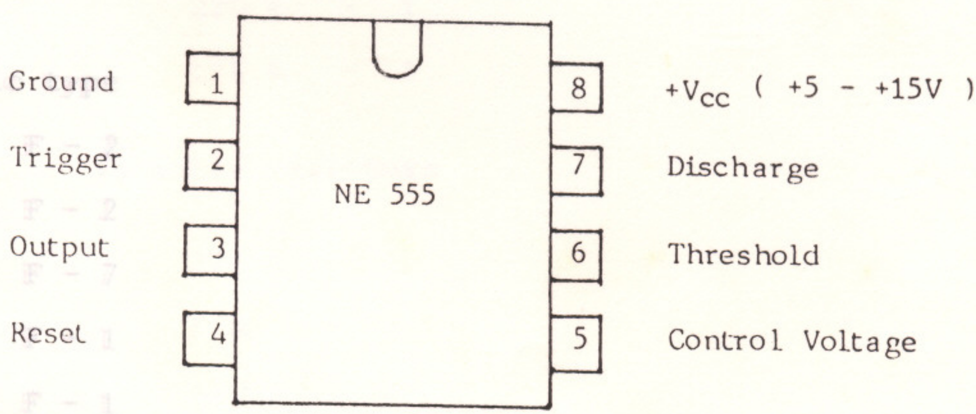
Appendix.1 PIN CONFIGURATIONS OF CD4060B AND NE555



Q_4 - - - Clock frequency divided by 2^4

\- -

Q_{14} - - - Clock frequency divided by 2^{14}



Appendix-II

List of components

Integrated circuits

IC 1 - IC 7808

IC 2, IC 5 - CD 4060 B

IC 3, IC 4, IC 6, IC 7 - NE 555

Transistor

SL 100 B - 2

Diode

IN 4002 - 4

LED - 1

B1 COLOUR LED - 5

Capacitors

Ceramic type

0.1 F - 2

0.22 F - 2

0.01 F - 7

470 F - 1

4.7 F - 1

Electrolytic type

1000 F, 25 V - 1

10 F, 12 V - 2

1000 F, 12 V - 2

4 F, 10 V - 1

4.7 F, 10 V - 1

4.7 F, 12 V - 1

100 F, 12 V - 1

470 F, 12 V - 1

Resistors

1 K - 17

10 K - 11

100 K - 2

1 K - 2

220 k - 1

120 k - 1

Variable resistors

220 K - 2

1 M - 2

470 K - 2

100 K - 2

Triac

BT 136 - 1

Relays

RL 1, RL 2 - 12 V, 250

Power supply

Transformer	-	230 V, 50 Hz primary
	-	12 - 0 - 12 V secondary
Diode	-	IN 4002 - 2
Integrated circuit	-	IC 7808, 8 V regulator

PERFORMANCE EVALUATION OF POP-UP SPRINKLERS AND DEVELOPMENT OF A MASTER CONTROL UNIT FOR IRRIGATION

By

INDU G. NAIR

MANOJ P. SAMUEL

SUMA NAIR

ABSTRACT OF THE PROJECT REPORT

Submitted in partial fulfilment of the requirement for the degree of

Bachelor of Technology in Agricultural Engineering

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Kerala Agricultural University

Department of Land & Water Resources & Conservation Engineering

Kelappaji College of Agricultural Engineering and Technology

Tavanur - 679 573

Malappuram

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ABSTRACT

A study was conducted to evaluate the performance of different pop-up sprinklers. Four types of pop-up sprinklers, namely, full-circle, three-quarter circle, half-circle and quarter-circle pop-up sprinkler heads were used for the study. The wetted radius, application depth, discharge, distribution pattern, distribution characteristics and coefficient of variation for different sprinkler heads was found out to evaluate their performance. The full pop-up sprinkler showed very good performance characteristics.

The master control unit was developed for controlling irrigation by various systems of pop-up sprinklers, microsprinklers and the drip systems. The unit had separate controls for the on and off periods which could be adjusted as per requirement. The on periods were determined based on the crop water requirement. The micro sprinklers and pop-up sprinklers were installed to irrigate lawn grass. The drip system was provided to irrigate the potted plants. The on and off periods determined for the pop-up sprinklers and micro sprinklers were 3 minutes and 57 minutes respectively and for the drip systems were 10 minutes and 50 minutes respectively. The master control unit provides for automation of any number of irrigation systems with suitable modifications and reduces human supervision.