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Improving Efficiency in a Sprinkler Irrigation System

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Abstract-- In this study, the main concentration has been given in saving the consumption of energy in a conventional irrigation practice followed in a tea garden mostly in North Bengal. In other words, it is to derive a most efficient system under the guidelines provided in National Engineering Handbook / Section / Chapter 11. An attempt was made by increasing the diameter of the main pipeline up to a certain limit, the major head loss in the main pipe could be decreased and can be kept within the permissible limit i.e. 10 m (as per National Engineering Handbook / Section / Chapter 11). Later, by increasing the lateral pipe diameter or by reducing the lateral pipe length up to a certain limit , the major head loss in lateral pipes can be kept within 20% of the higher pressure (as per National Engineering Handbook / Section / Chapter 11). Regular intervals of riser pipes along the lateral pipes was to be maintained so that uniform distribution of water remains for reducing the pumping time as well as the energy consumption remains appreciable. An overhead tank with same capacity instead off underground reservoir can be constructed to create sufficient hydraulic head for supplying required water by utilizing the gravitational head. Thus, it may reduce the consumption of electricity in operating the delivery pump which may be omitted. The application rate of each sprinkler may also be increased with a reduction in spacing between each sprinkler. Other factors like reduction in height of riser, acid wash at periodic intervals can also contribute in saving the energy of the SIS.

Keywords: *SIS – Sprinkler Irrigation System, Energy consumption or saving energy, Irrigation efficiency.*

I. INTRODUCTION

Sprinkler Irrigation is an application of water in terms of spray formed from the flow of water under pressure through small orifices and nozzles. The flexibility of present day, sprinkler equipments and its efficient control on water application make the method's usefulness on most of the topographic conditions. The most common intent of sprinkler irrigation is to apply water uniformly to the soil surface to replace the water extracted by the plants. The pressure exerted in the sprinkler irrigation system is mostly by pumping, although, the same may be practiced by using gravity if the water source is high above the area to be irrigated. In a fixed system, the sprinkler is kept at a fixed position while irrigating the field and in the continuous move system, the sprinkler either move in a circular or straight line. With a careful design and application in periodic move and fixed system, water can be applied uniformly at a rate based on the infiltration rate of the soil, thereby preventing run-off and consequent damages to the land and crops as well as the sprinkler system.

II. FORMULATION

Sprinklers have been used on all types of soils and lands of different topography & slopes and for various crops. Few favorable conditions for the SIS may be like very pervious soils which do not permit good distribution of water by surface irrigation method, or when slope of the land is very steep and soils are erodible by nature, . However a study must be taken to take care of economic analysis before adopting the system. Problematic soils with intermixed textures and profiles can be properly irrigated. Weather extremes can also be modified by increasing the humidity, cooling crops and alleviating freezing by taking care of special design. Lastly, high application efficiency can be achieved by a properly designed and operated system.

A. The Challenges were to be handled

High winds were distorting the sprinkler pattern causing non-uniform distribution of water on the plants. Evaporation losses were unavoidable due to high ambient temperature along with high wind velocity. Heavy soils with large intake were not being irrigated properly. Selecting a particular type of SIS was also a major decision in view of increasing the irrigation efficiency.

B. Additional Advantages Extracted

Soluble chemical fertilizer was injected through the Fertilizer Application Unit attached with the system to take the advantage of the system. Even pesticides were also applied through the system with a dose prescribed by the specialist. A venture injector was preferred and connected in the main line which created a difference in pressure to suck the fertilizer or pesticides solution and push it in the mains. The dozing formula which was used as follows:

As per Michael (2010),

$$W_F = \frac{D_S D_l N_S Q_f}{10000}$$

Where,

W_F = Amount of fertilizer required in per setting, Kg

D_S = Distance between the sprinklers, m

D_l = Distance between laterals, m

N_S = Number of sprinklers

Q_f = Recommended fertilizer dose, Kg/Ha

C. Uniformity related issues

Christiansen Co-efficient of Uniformity – The % CU is a measurement of uniformity, expressed as the average rate (%) of deviation from the overall average application. A perfectly uniform application is represented by a CU of 100 % whereas the lower uniformity applications are represented by lower percentages.

Distribution Uniformity (%DU) – The %DU is a measurement of uniformity, based on component of the driest 25% of the surveyed area with overall average net application as a percentage/

%DU = (average of the lowest 25%/overall average) X 10

A perfectly uniform application is represented by a DU of 100%.

Scheduling Coefficient (SC) – The scheduling coefficient is a run time multiplier. I (t is the amount of time one needs to over-irrigate to achieve the average application rate of the entire area in the driest part of the irrigated area. Thus

SC = overall average net application / average net application in the driest 5% of the irrigated area

Sprinkler water Trajectory – It was controlled by taking care of basic factors like sprinkler nozzle angle, elevation of sprinkler nozzle above ground, elevation of max. Trajectory height from the sprinkler nozzle and max wetted distance which is further depend3ent on sprinkler nozzle elevation above the ground.

D. Governing equations

The height of the riser pipes were kept just above the crops to be irrigated. Partial overlapping was allowed in order to achieve uniform application of water. The overlap required to be provided were to increase with the increase in wind velocity as shown in the table below:

III. **MAXIMUM SPACING OF SPRINKLERS**

SR. No.	**Average wind speed**	**%**	**Spacing**
1.	No wind	65	of the diameter of the water spreaded area
2.	0 to 605 Kmph	60	
3.	6.5 to 13 Kmph	50	
4.	Above 13 Kmph	30	

The required discharge of each sprinkler is a function of the water application rate, the spacing of the sprinklers along the lateral pipelines and the spacing of lateral pipelines along the main pipeline which can be determined by the following formula:

$$q = S_t \text{ X } S_m \text{ X } \frac{I}{3600}$$

Where,

q = required discharge of each sprinkler in litre/sec

S_t = spacing of sprinklers along the lateral pipelines in m

S_m = spacing of laterals along the main pipeline in m

I = optimum water application rate in mm/hr.

The capacity of the system was computed by the following formula:

$$Q = 453 \frac{Ad}{fT}$$

Where,

Q = system discharge capacity in gpm

A = Design area in Ha

d = Gross depth of application in m

f = time allowed for completion of one irrigation nine days

T = Actual operating time in Hr. /day

Hydraulic Design -

Computation of pressure variation in Pipes:

The performance of SIS is related to operating pressure in the pipeline, the frictional loss in pipe and fittings and differential elevations caused pressure s to vary in a field. Frictional loss causes the pressure to decrease in the downstream direction. Thus, the difference in pressure between upstream and downstream of a pipeline can be estimated as

$$H_d = H_u - 9.81\,(h_l \pm \Delta Z)$$

Where,

H_d, H_u = pressure at downstream and upstream pipeline in KPa

h_l = energy lost in pipe between upstream and downstream

ΔZ = difference in elevation between upstream and downstream position in m

Again, $h_l = F\, H_f + M_l$

Where,

F = constant that depends on number of outlets (sprinklers or laterals) removing water from the pipe between the upstream and downstream location

F also can be computed as follows:

$F = \frac{1}{m+1} + \frac{1}{(2N} + \frac{\sqrt{m-1}}{6N^2}$ where the value of F can be estimated when the distance to the first sprinkler equals one-half of the sprinkler head spacing

Again, $F = \frac{1}{2N-1} + \frac{2}{(2N-1)N^m} [\sum_{i=1}^{N-1} (N - i)^m]$

Where,

And the major loss can be computed by Darcy-Weisvbach formula as

$$H_f = \frac{fLv^2}{2gD}$$

Where,

f = friction factor

L = length of pipeline in m

v = velocity of flow in m/sec

g = gravitational acceleration in m^2/sec

D = diameter of pipeline in m

Design of Sprinkler laterals:

The average head (H_a) in a sprinkler line can be expressed approximately as

$$H_a = H_o + \frac{1}{4} H_f$$

Where,

H_o = pressure at the sprinkler on the farthest end

H_f = head loss due to friction

If the lateral is on nearly level land or on the contour, the pressure head (H_n) are the main is given by

$$H_n = H_o + H_f$$

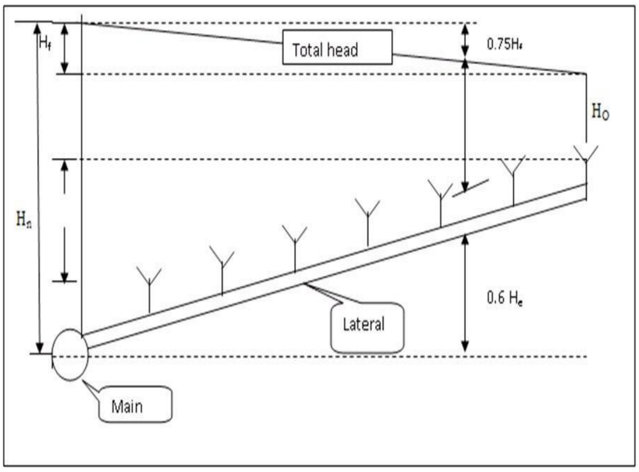
To determine the H_o, by making an allowance for differences in elevation along the lateral can be expressed as

$$H_n = H_a + \frac{3}{4} H_f \pm \frac{3}{4} H_e + H_r$$

Where,

H_e = max. difference in elevation between the first and last sprinkler in m

H_r = the riser height in m



Allowance due to lateral running on uphill and downhill conditions should be made while determining the head variation. The design capacity for sprinklers on lateral is based on the average operating pressure.

To match the capacity of the existing pump with the required capacity of the pump, the max total head was required to determine by

$$H_t = H_n + H_m \pm H_J + H_S$$

Where,

H_t = total design head against which the pump is working in m

H_n = max head required at the main to operate the sprinklers on the lateral at the required average pressure including the riser height in m

H_m = max frictional loss in the main and in suction line in m

H_J = elevation difference between the pump and the junction of the lateral and the main in m

H_S = elevation difference between the pump and the source of water after drawdown in m

The amount of water required was determined by multiplying the number of sprinklers by the capacity of each. The horse power requirement of pump can be estimated by

$$HP = \frac{YQH}{75\eta}$$

Where,

Y = unit weight of water

Q = Pump discharge

H = Total head

η = efficiency of the pump

E. Solution methodology

However, planning and design considerations and guidelines should be referenced to NEH (Part 623, Section 15, and Chapter 11) of Sprinkler Irrigation. Operating pressure can be grouped as follows:

Low Pressure –	2 -35 psi
Moderate pressure -	35 – 50 psi
Medium pressure -	50 – 75 psi
High pressure -	75+

Nozzle size inches	Pressure psi	Discharge rate gpm	Head spacing x Lateral spacing			
			30 ft x 30 ft	30 ft x 33.3 ft	30 ft x 36.6 ft	30 ft x 40 ft
3/32	40	1.69	0.18	0.16	0.15	0.14
	45	1.80	0.19	0.17	0.16	0.14
	50	1.89	0.20	0.18	0.17	0.15
	55	1.97	0.21	0.19	0.17	0.16
	60	2.02	0.22	0.19	0.18	0.16
	65	2.06	0.22	0.20	0.18	0.16
	70	2.07	0.22	0.20	0.18	0.17
7/64	40	2.49	0.27	0.24	0.22	0.20
	45	2.63	0.28	0.25	0.23	0.21
	50	2.74	0.29	0.26	0.24	0.22
	55	2.83	0.30	0.27	0.25	0.23
	60	2.91	0.31	0.28	0.25	0.23
	65	2.97	0.32	0.29	0.26	0.24
	70	3.01	0.32	0.29	0.26	0.24
1/8	40	3.30	0.35	0.32	0.29	0.26
	45	3.45	0.37	0.33	0.30	0.28
	50	3.59	0.38	0.35	0.31	0.29
	55	3.70	0.40	0.36	0.32	0.30
	60	3.80	0.41	0.37	0.33	0.30
	65	3.88	0.41	0.37	0.34	0.31
	70	3.94	0.42	0.38	0.34	0.32
9/64	40	4.10	0.44	0.39	0.36	0.33
	45	4.27	0.46	0.41	0.37	0.34
	50	4.43	0.47	0.43	0.39	0.36
	55	4.57	0.49	0.44	0.40	0.37
	60	4.69	0.50	0.45	0.41	0.38
	65	4.79	0.51	0.46	0.42	0.38
	70	4.87	0.52	0.47	0.43	0.39
5/32	40	4.90	0.52	0.47	0.43	0.39
	45	5.10	0.54	0.49	0.45	0.41
	50	5.28	0.56	0.51	0.46	0.42
	55	5.44	0.58	0.52	0.48	0.44
	60	5.58	0.60	0.54	0.49	0.45
	65	5.70	0.61	0.55	0.50	0.46
	70	5.81	0.62	0.56	0.51	0.47

A graph can be plotted between area covered & application rate

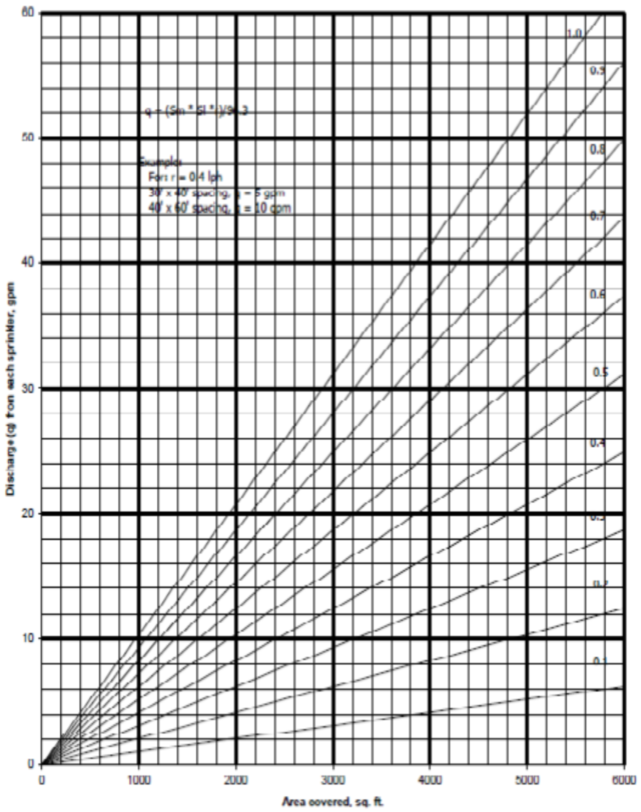


Figure 1: Sprinkler discharge rates for common spacing and application rates

F. Results and Discussion

Collected raw data:

1. Capacity of submersible (Bore well) pump – 15 HP

2. Size of storage tank – 15 X 5 X 4 ft^3

3. Capacity of Delivery Pump – 40 HP

4. Discharge of delivery pump – 0.0157 m^3/sec

5. Length of main line`- 912 m (152 nos. of full pipes of 6 m length each)

6. Diameter of main pipe – 125 mm

7. Length of laterals – 4 sprinkler of 25 m head spacing + 2 sprinklers of 20 m head spacing

No. of joints – 152 nos.

8. Diameter of lateral pipe – 100 mm

9. No. of Gate valve - 1

10. Nos. of bends – 2 nos. of 90^o bends & 1 no of 45^o bend

11. Size of sprinkler – 15 X 32 X ¼ "

Result obtained after Analysis:

1. Total major head loss in main & laterals = 15.2 m

2. Total Minor head loss = 0.18 m

3. H_f = 10.35 m as against the permissible limit of 10.0 m

4. Total power required to run the irrigation = 13.92 HP

IV. VALIDATION STUDY

Wind drift and evaporation losses may be less than 5 % while irrigating a crop with a full vegetative canopy in low wind but may be between 5 – 10 % in a moderate condition. However, under very severe condition they can be considerably greater. It has been developed as a guide for estimating the effective portion of the water applied that reaches the soil plant surface. The value taken for effectiveness for different potential evapotranspiration rates are based on an assumed full plant canopy and 24 hrs applications. The fine spray curves are based on 3/16" nozzles operating at 60 psi in a 40 X 60) ft spacing. The coarse spray is for 3/16" spacing in nozzles operating at (30 X 60) ft spacing.

It is necessary to know whether the spray from a sprinkler is coarse, fine or somewhere in between. To make this determination coarseness index (CI) is used which can be calculated by the following method:

$$CI = P^{1.3} / B$$

Where,

P = nozzle operating pressure in psi

B = Nozzle size (64th of an inch)

If the value of CI<7, the spray is coarse and if > 17, the spray is fine. And when this value is between 7 and 17, R_e(effective portion of applied water) value may be interpolated by the formula as

$$R_e = (CI – 7) / 10 X (R_e) + (17 – CI) / 10X (R_e)_f$$

CONCLUSION

In this paper, the author have tried to investigate the behavior pattern of the existing practice followed in a general Tea garden of North Bengal and a vis-à-vis study carried out with a scientific approach to optimize the efficiency and the saving in energy consumption by making few changes in the practice and replacing few equipments which may yield a better productivity with improved quality but at a lower cost in the long run.

References

[1] National Engineering Hand Book / Section 15 / Chapter 11
[2] http://en.wikipedia.org/wiki/Sprinklerirrigation
[3] http://www.ecourseonline.iasri.res.in/mod/page/view.php?id=2024
[4] Irrigation Engineering & Hydraulic Structure by S K Garg
[5] Irrigation, Water Resource & Water Power Engineering by Dr. P N Modi