Sprinkler Design

- In sprinkler irrigation system water is sprayed into the air and allowed to fall on the ground surface somehow resembling rainfall and this developed by flow under pressure through small orifices and nozzles.

This method is more useful where :

- 1.the land can not be prepared for surface methods
- 2.slope are excessive
- 3.topography is irregular
- 4.soil is erosive
- 5.soil is excessive permeable or impermeable
- 6.depth of soil is shallow over gravel or sand

Advantage of spk system

- 1.erosion can be controlled.
- 2.uniform application of water is possible.
- 3.irrigation is better controlled.
- 4.land preparation is not required, so labor cost is reduced.
- 5.small stream of irrigation can be used efficiently.
- 6. time and amount of ferilizers can be can be controlled for application.

Limitation

- 1.Wind may distort spk patterns.
- 2. a constant water supply is needed for economical use.
- 3.water should be clean and free from sand.
- 4.initial cost is high.
- 5.power requirement is high.

Type of spk system

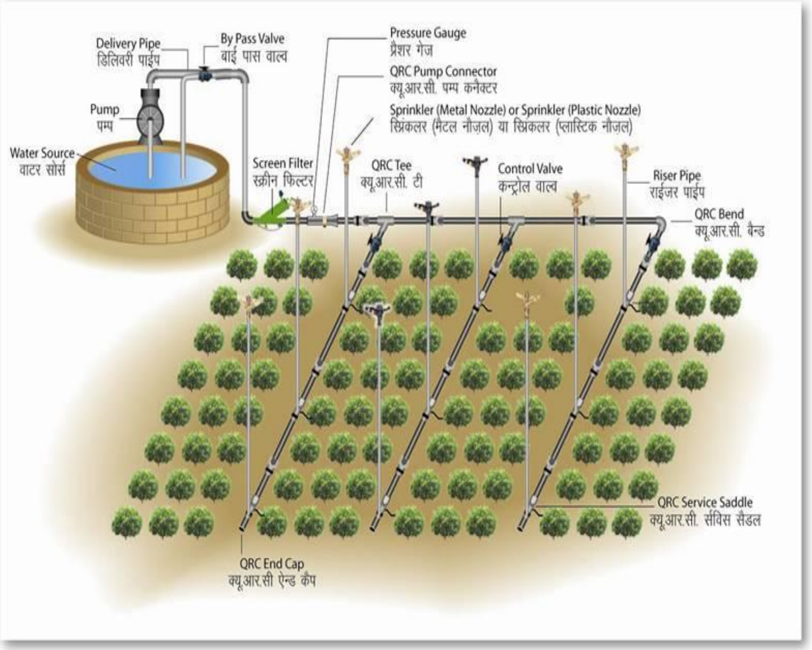
- A. Based of nozzle (Double or single nozzel)

- Single

Double

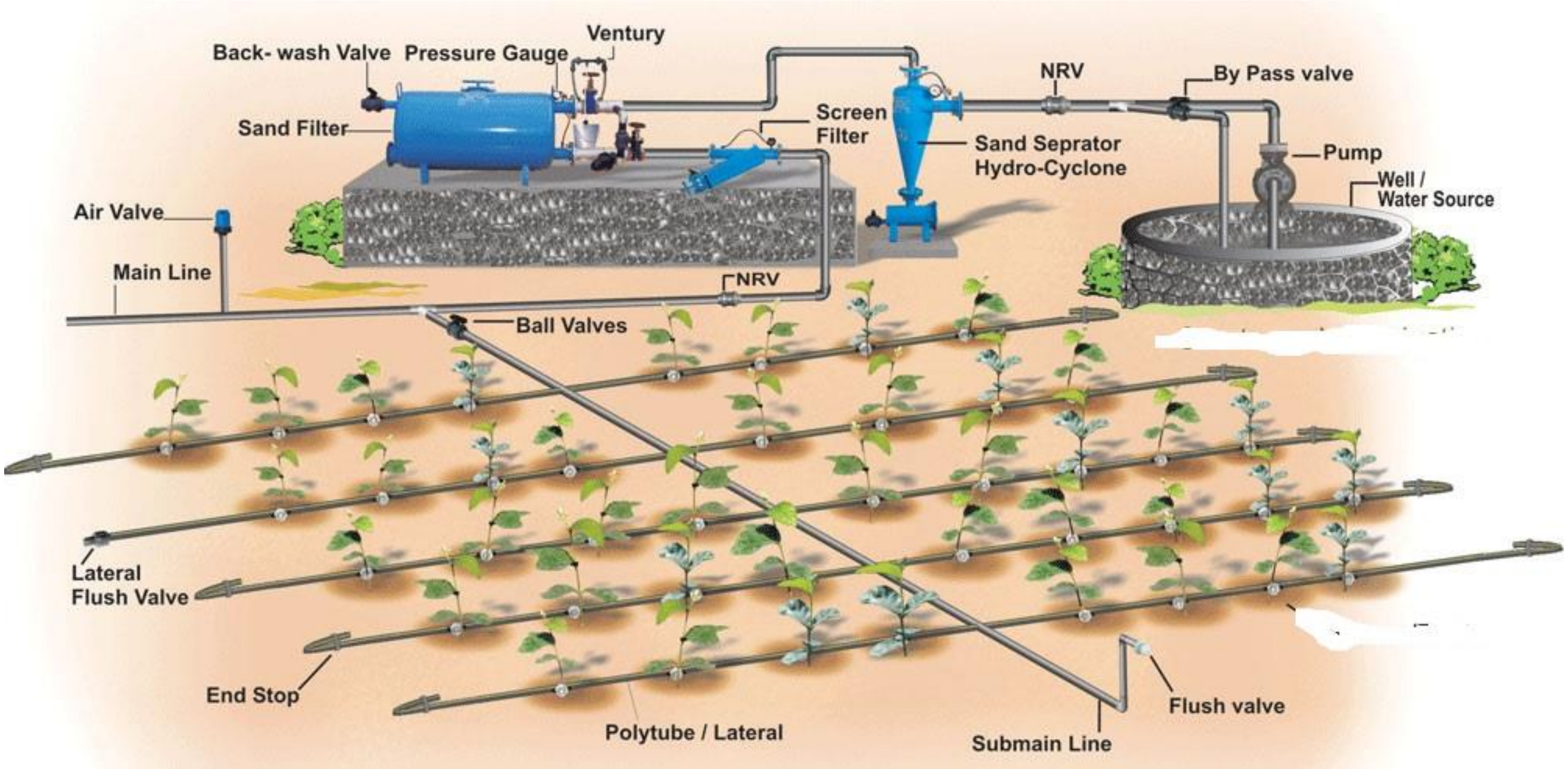
Type of spk system

- B. Based on portability
- 1.portable system
- 2.solid system



Layout of Sprinkler Irrigation System (छिड़काव सिंचाई प्रणाली का रेखाचित्र)

Component of spk system

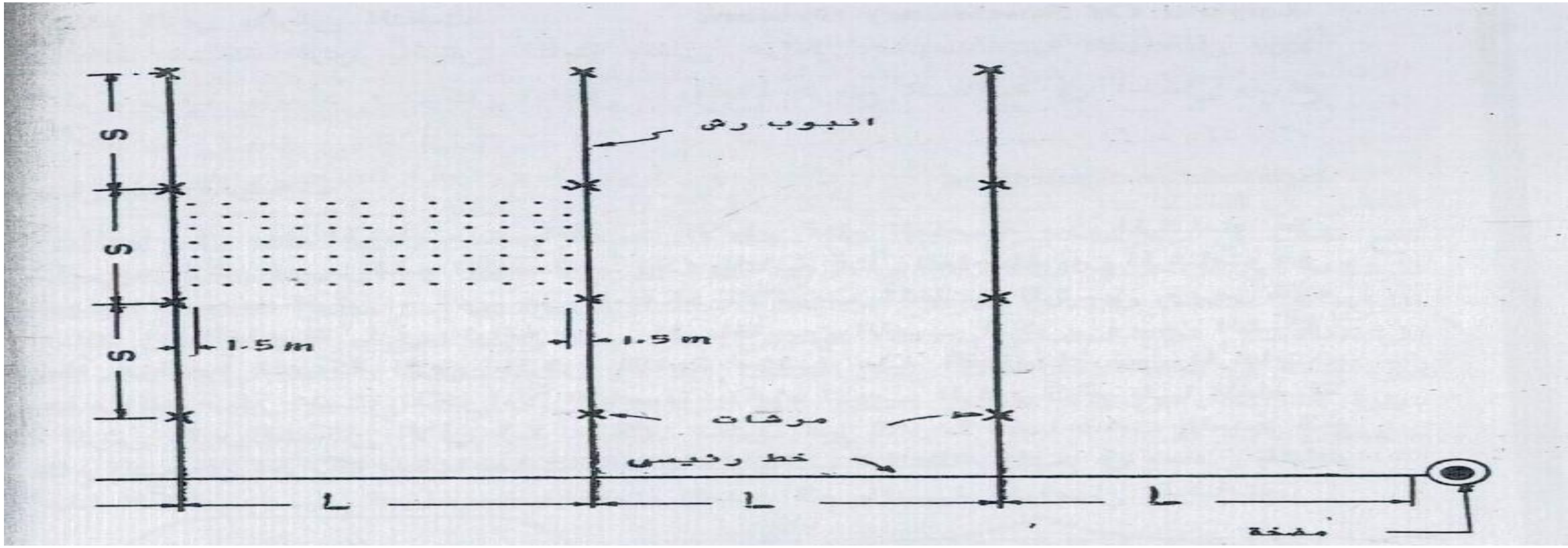


Component of spk system

- 1.pumping test
- 2.main line:
- For solid system(steel pipe,cement,PVC)
- For portable (aluminum pipe)
- 3. lateral line(aluminum pipe)
- 4.spk head . H(3.5-70 Mm)
- q=C× $A\sqrt{2gh}$

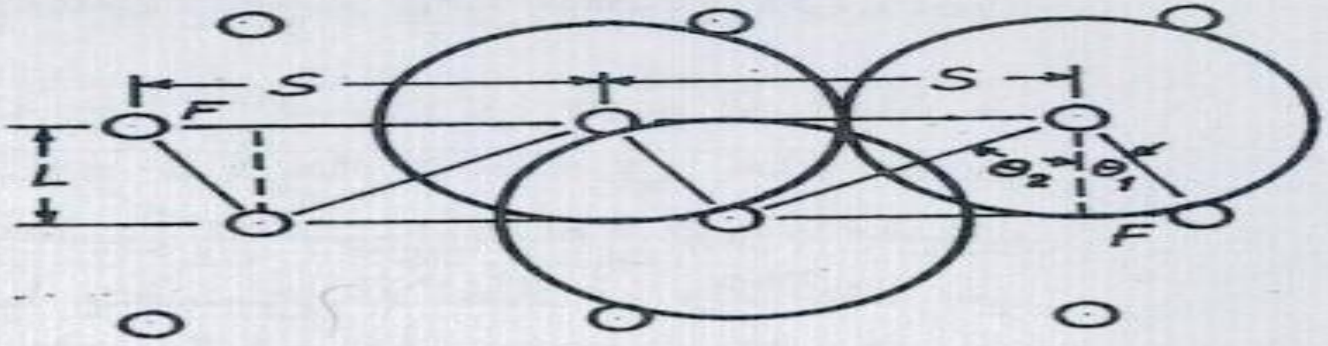
Spk spacing

- S=distance between spk on lateral line
- L=distance between lateral line on submain line



Spk arrangement

- 1.general triangle arrangement (wind velocity = 0 and operation under normal pressure)
- $D^2 = \frac{[(S-F)^2 + L^2] + [F^2 + L^2]}{L^2}$ where D^2 = wetted diameter



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example

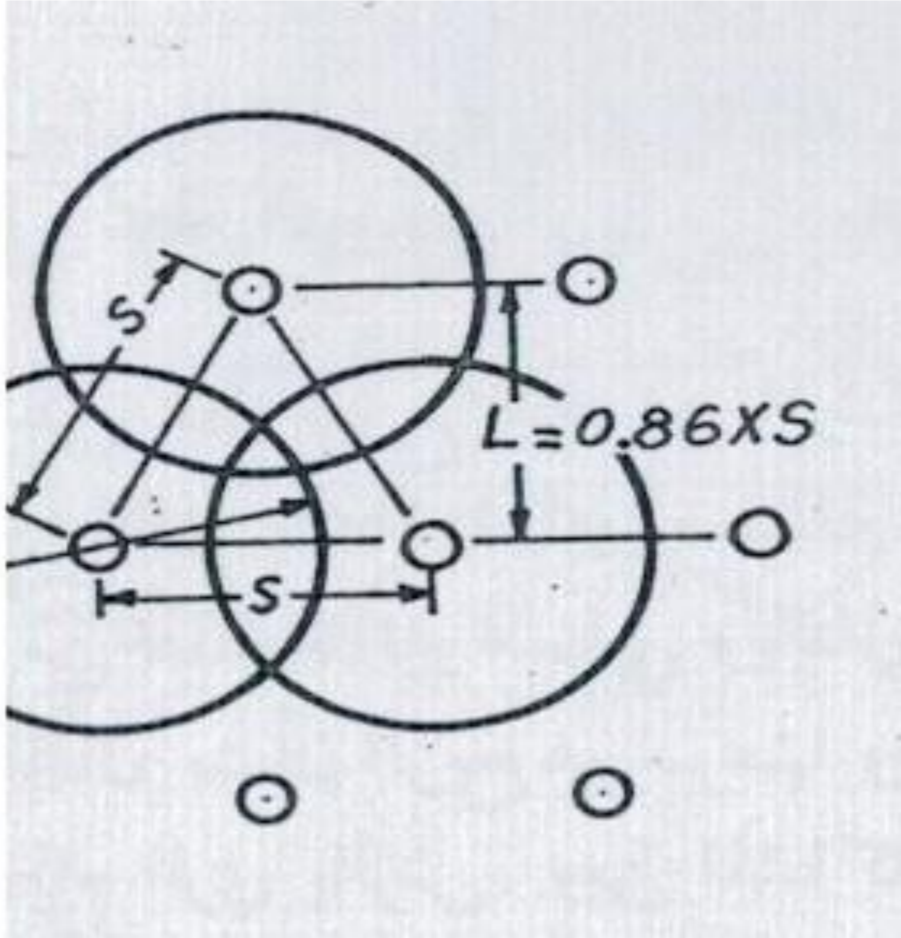
- If the shifting in spk position between two lateral pipe equal to $\frac{1}{4}$space between spk(S) compute maximum allowable space between the spk for general triangular arrangement for the case (nodry portion take place in the area. Take wetted diameter for spk D=30 and S=L

solution

- S=L F=0.25 S
- $D^2=\frac{[(S-F)^2+L^2]+[F^2+L^2]}{L^2}$
- $30^2=\frac{[(S-0.25S)^2+S^2]+[0.25S^2+S^2]}{S^2} \rightarrow S = 23.28\ m$
- Usa Standard=3,6,9,12,15,18,21,24,27,30,….
- British standard=2,4,6,8,10,12,14,16,18,20,22,24,….
- So in usa 21m S=21m L=21m
- In british=22m

Spk arrangement

- 2.equal triangular arrangement
- L+$\frac{S^2}{4L} = \mathrm{D}$

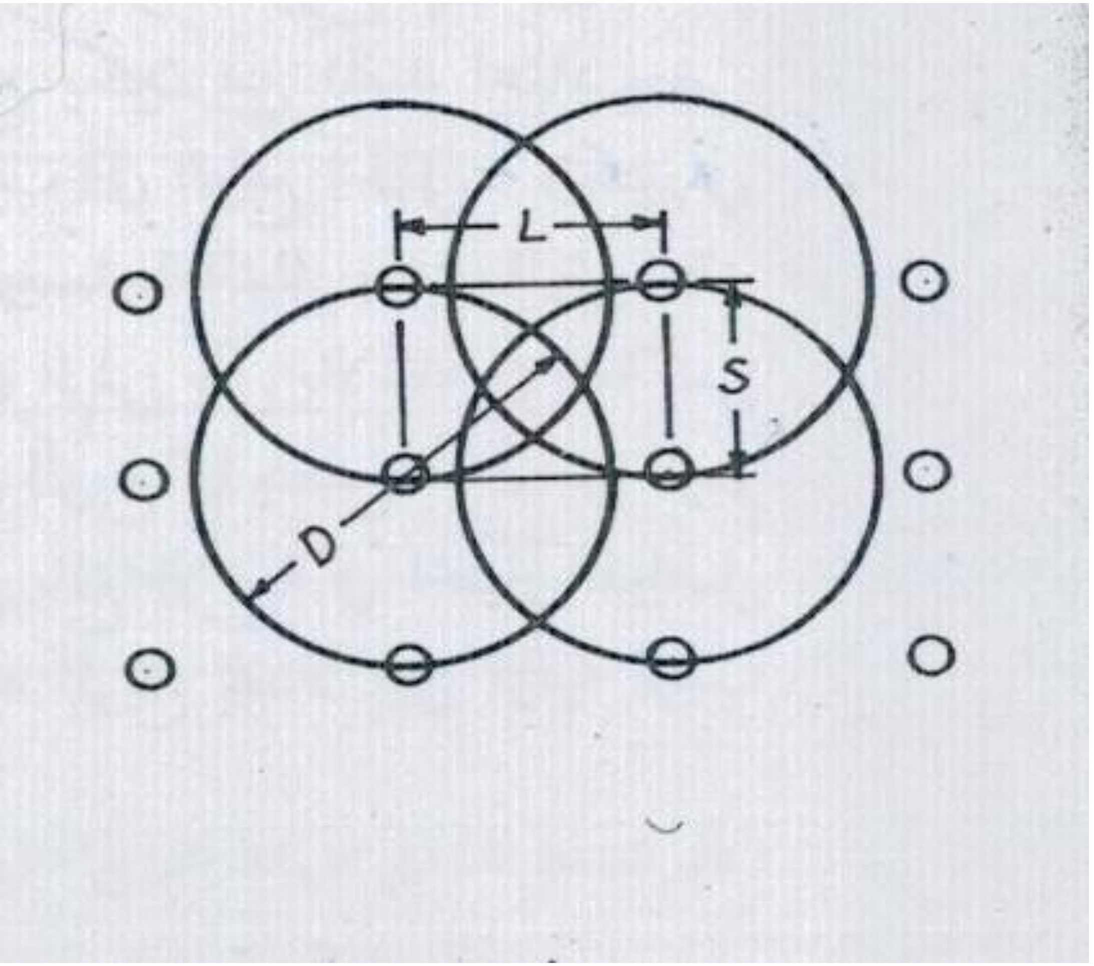


example

- L=0.866 S D=30m use equal triangular
- L+$\frac{S^2}{4L} = \mathrm{D}$ 0.866 S+$\frac{S^2}{4(0.866S)} = 30$
- S=26m $\rightarrow 24\ m\ usa$
- L=20.7 18m usa

Spk arrangement

- 3.rectangular arrangement
- $S^2 + L^2 = D^2$ S$\neq L$

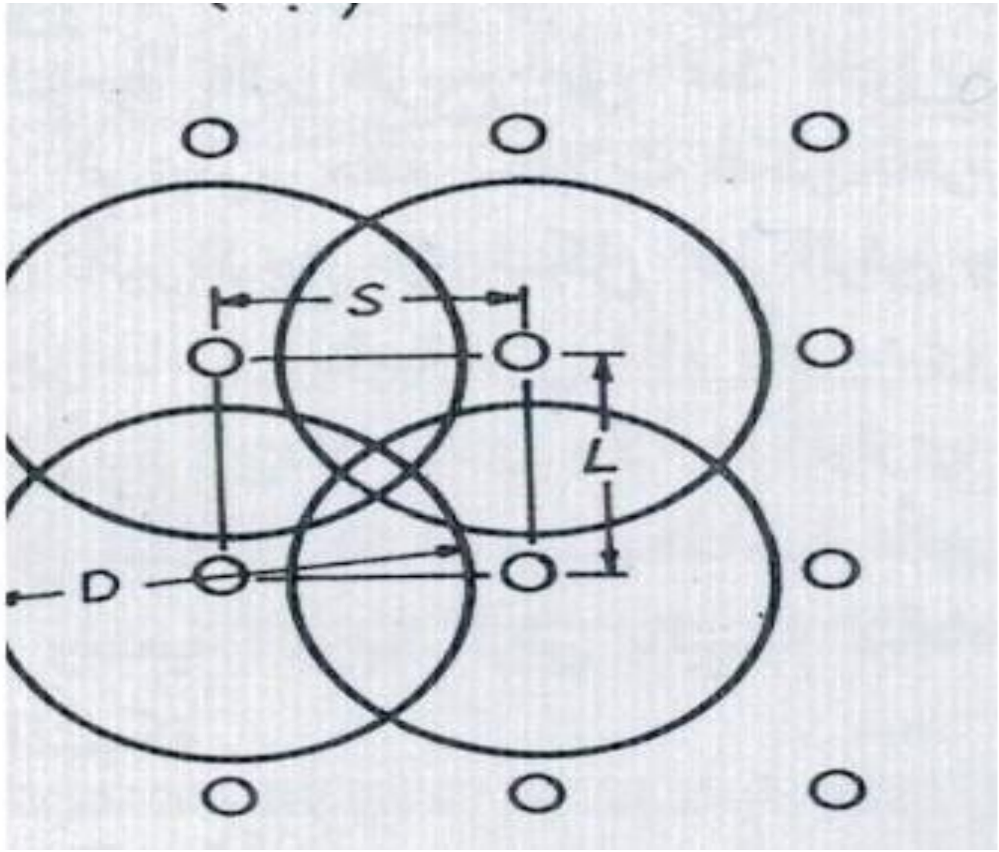


example

- L=2S D=30m
- $S^2 + L^2$=D^2
- $2S^2$+S^2=30^2
- S=13.4 so S=12m
- L=24 m

Spk arrangement

- 4.Square arrangement
- $S^2 + L^2 = D^2$ S=L



Effect of wind on spacing

- S≤ $K1D$ L≤ $K2D$

مثلث متساوي الاضلاع		مربع		مستطيل (*)		سرعة الريح م/ثا
ترتيب فواصل المرشات						
K_1	K_2	K_1	K_2	K_1	K_2	
0·60	0·52	0·55	0·55	0·50	0·60	0 – 1·5
0·55	0·48	0·50	0·50	0·45	0·60	1·5 – 3·0
0·50	0·43	0·45	0·45	0·40	0·60	3·0 – 5·5

(*) انبوب الرش عمودي على اتجاه الريح السائدة

Example

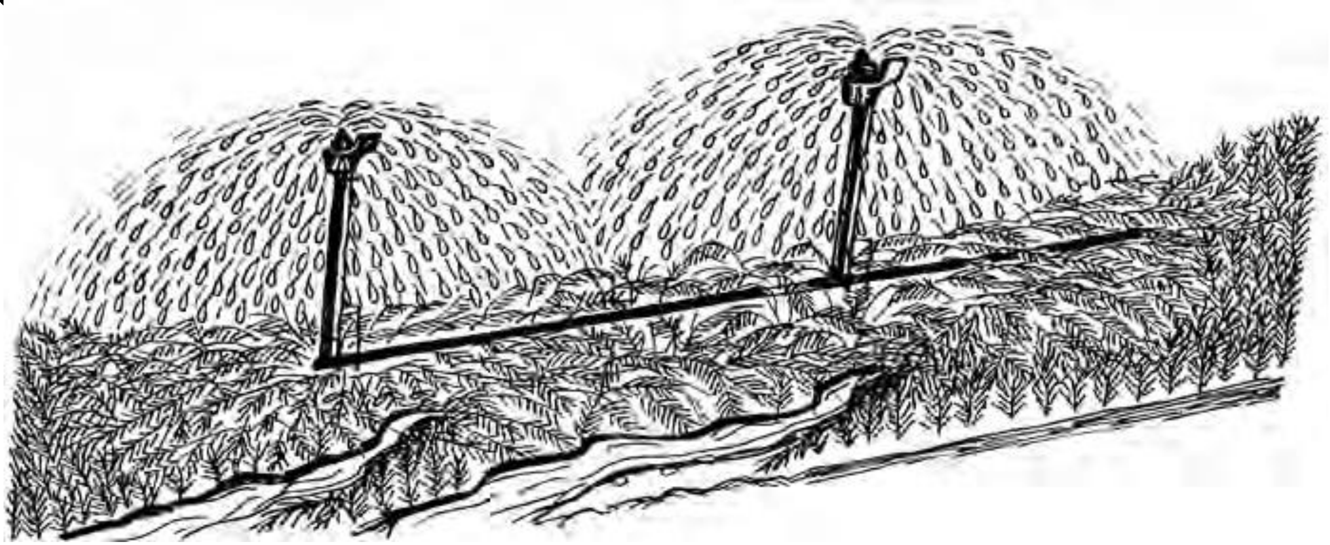
- Wind velocity u=2m/sec D=30m for square arrangement.

- S$\leq K1D$ S$\leq (0.5)30$ S $\leq 15m$ $S0$ L$\leq 15m$

Sprinkler application rate

- Ar=$\frac{Q\times10^3}{S\times L}$ Note: Ar$\leq Ib$
- Ar= spk application rate(mm/hr)
- Q=sprinkler discharge $(m^3$/hr)
- S , L (m)
- Ib (mm/hr

- Runoff due to high Ar



example

- If basic infiltration rate for soil sample equal to 9 mm/hr and spk discharge is 1.2 $(m^3$/hr). Compute the maximum Spk space of the arrangement for square case.

- Solution:
- Ib=Ar
- Ar=$\frac{Q\times10^3}{S\times L}$ 9= $\frac{1.2\times10^3}{S^2}$ $\rightarrow S = 12m \;\; so\; L = 12m$

Orifice equation for single nozzle

- q=C× $A\sqrt{2gh}$
- q= nozzle discharge m^3/sec
- a= cross sectional area of nozzle a=$\frac{\pi d^2}{4}$
- d=nozzle diameter (mm)
- H=water pressure head (m)
- g= gravity acceleration 9.8 m/sec
- c= discharge coefficient vary from 0.95-0.98

For double nozzle

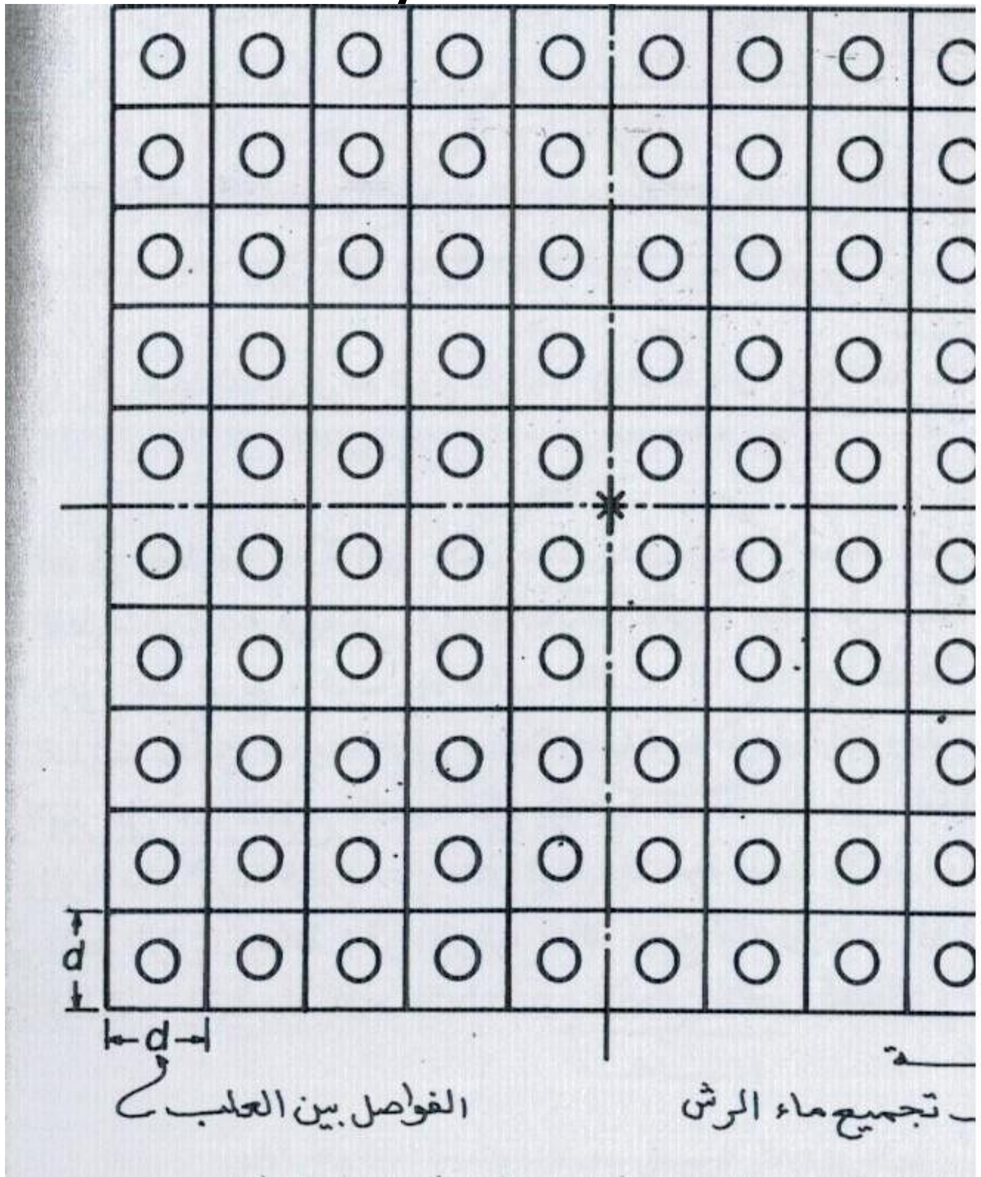
- q=$12.55 \times c \times (d1^2 + d2^2\sqrt{H}$
- Where:
- q= discharge for nozzle L/hr
- d1 , d2 =nozzle diameter
- H = water pressure head (m)

- Table below show working pressure with respect to nozzle diameter

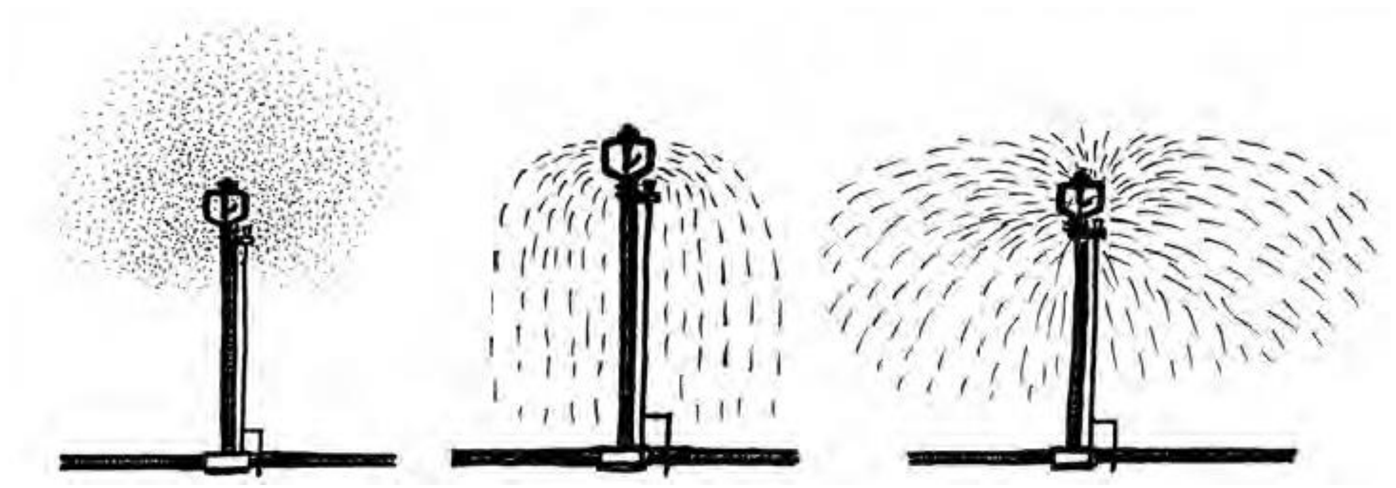
H(m)	d(mm)
25-35	$3 < d \leq 4.8$
30-40	$4.8 < d \leq 6.4$
35-60	$6.4 < d \leq 9.6$

- Note: assume d is 4.4 mm .increase 0.4mm or decrease 0.4 mm if H is not in the range

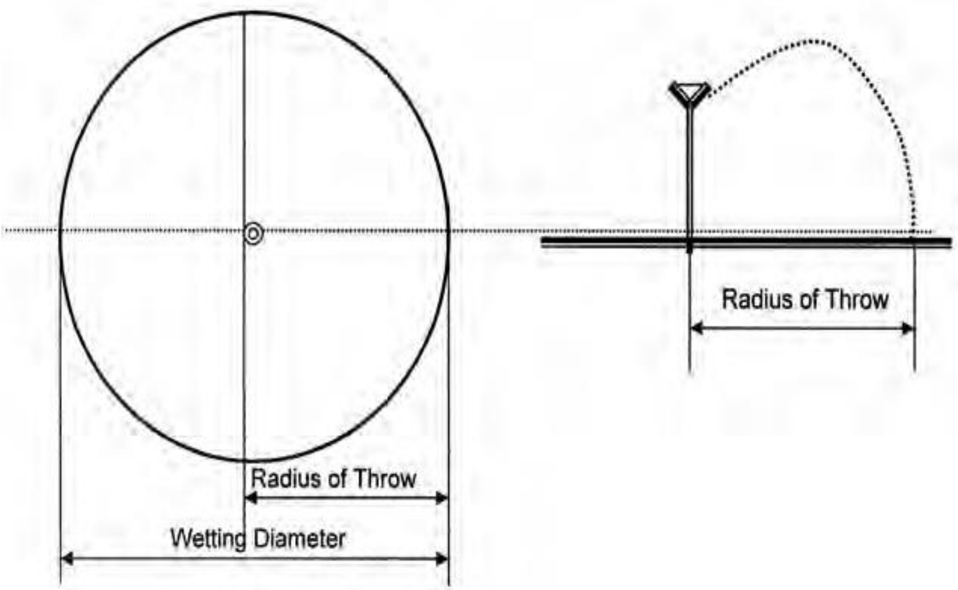
Uniformity coefficient for spk water

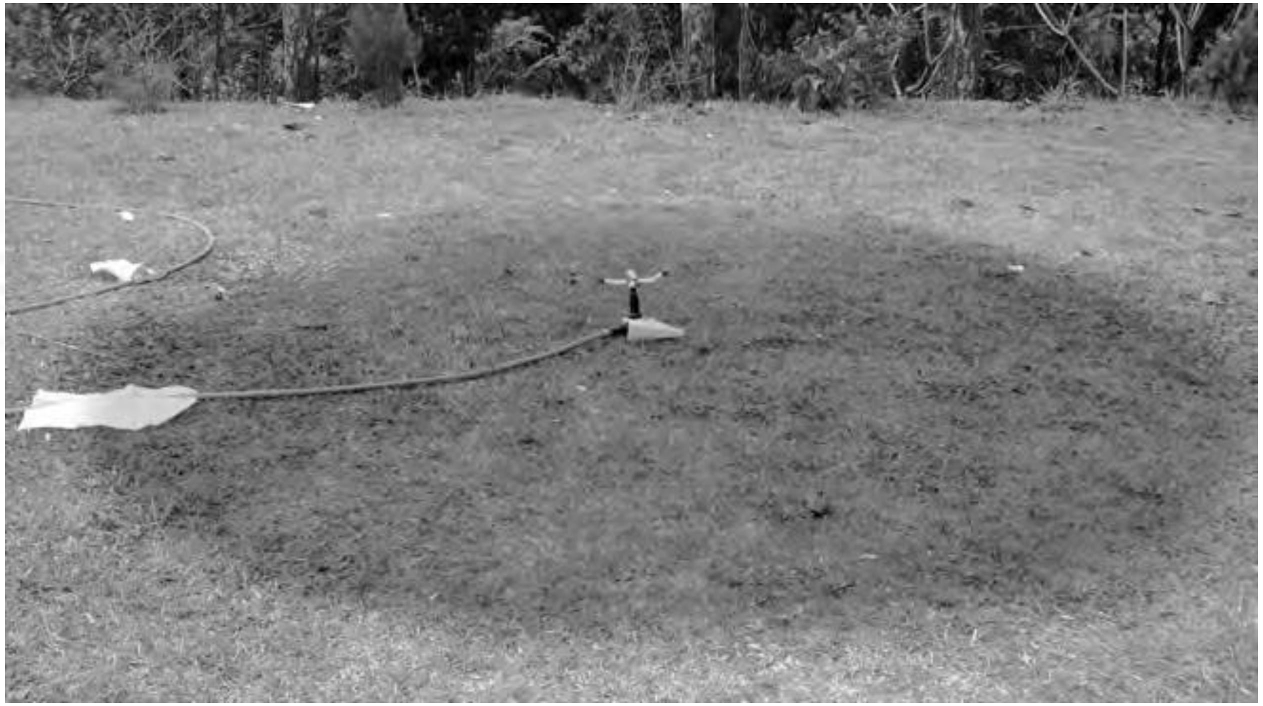


- Dimension of collector for research (1*1 m) , for design (3*3 m) operation time 3 hr or 1/3 application time



Too high pressure causes misting *Optimum pressure is ideal condition* *Too low pressure affects distribution uniformity*


Radius of Throw
Wetting Diameter
Radius of Throw



Christiansen Equation

- Uc=(1-$\frac{\Sigma X}{\Sigma R}$)$\times 100$
- Uc=(1-$\frac{X'}{R'}$)$\times 100$
- R'=$\frac{\Sigma R}{N}$
- X=$|R - R'|$
- X'=$\frac{\Sigma X}{N}$

- X=absolute deviation of water depth which reach to soil surface.
- ΣX=summation of all absolute deviation
- X'=average absolute deviation (mm)
- R= depth of water reach to soil
- R'=Average water depth

Example

- Compute the Christiansen coefficient from figure below showing Christiansen of water for application rate (Ar) single nozzle of sprinkler of discharge = 0.63 m^3/hr for 3 hours working time with water collector dimension (3×3) m and S=9m L=12m

L=12 m | L=12 m 3m

0	**0**	**2**	**6**	**5**	**4**	**0**	**0**
0	3	10	13	12	6	3	0
0	5	11	16	13	8	4	0
0	0	7	10	14	6	5	0
0	0	3	4	6	4	0	0
0	0	0	0	0	0	0	0

13 m | S=9m

| S=9m

Solution

- 1 overlapping between spk on spk line

0	0+0 =0	2+7 =9	6+10 =16	5+14 =19	4+6 =10	0+5 =5	0
0	3+0 =3	10+3 =13	13+4 =17	12+6 =18	6+4 =10	3+0 =3	0
0	5+0 =5	11+0 =11	16+0 =16	13+0 =13	8+0 =8	4+0 =4	0

S = 9m

L = 12 m

L = 12 m

- 2.over laping between two lateral subline

L=12M

19+0 =19	**0+10 =10**	**9+5 =14**	**16+0 =16**
0+18 =18	3+10 =13	13+3 =16	0+17 =17
0+13 =13	5+8 =13	11+4 =15	0+16 =16

S=9m

- R‘=$\frac{\Sigma R}{N}$ R‘=$\frac{180}{12}$ =15 mm
- X‘=$\frac{\Sigma X}{N}$ X‘=$\frac{24}{12}$ = 2mm

- Uc=(1-$\frac{\Sigma X}{\Sigma R}$)$\times 100$ Uc=(1-$\frac{24}{180}$)$\times 100$=86.7% $> 80\%$ ok
- Uc=(1-$\frac{X'}{R'}$)$\times 100$ Uc=(1-$\frac{2}{15'}$)$\times 100$= 86.7% $> 80\%$ ok
-

Ni	R (mm)	X=$\lvert R - R' \rvert$
1	19	4
2	10	5
3	14	1
4	16	1
5	18	3
6	13	2
7	16	1
8	17	2
9	13	2
10	13	2
11	15	0
12	16	1
Σ	180 (mm)	X=24

Sprinkler application efficiency(Espk)

- Espk=90%$\times$ $(1 - SSL) \times 100$
- SSL=spk spray losses
- $\frac{Volume\ of\ water\ delivered - volume\ of\ water\ reach\ to\ the\ soil\ surface}{volume\ of\ water\ delivered}$ $\times$100
- Volume of water delivered=q$\times$ Ta(application time)
- Volume of water reach the soil=$\frac{R'}{1000} \times S \times L$

Example

- Compute the Espk from data in perevious example.
- Volume of water reach the soil=$\frac{R'}{1000} \times S \times L$
- Volume of water reach the soil=$\frac{15}{1000} \times 9 \times 12 = 1.62m^3$
- Volume of water delivered=q$\times$ Ta(application time)
- Volume of water delivered=$0.63 \times 3\ hr = 1.89\ m^3$
- SSL=$\frac{1.89-1.62}{1.89}$=14%
- Espk=0.9$\times$ $(1 - 0.14) \times 100 = 77\%$

Example

- Compute diameter of single nozzle from given data:
- Ar=8.95   S=18m   L=9m   c=0.967
- Solution:

- Ar=$\frac{Q\times10^3}{S\times L}$ 8.95=$\frac{Q\times10^3}{18\times9}$ $\rightarrow q = 1.45\ m^3$/hr
- q=C× $A\sqrt{2gh}$ Assume nozzle Diameter 4.8mm
- A=$\frac{\pi d^2}{4}$

solution

- $\frac{1.45}{3600} = 0.967 \times \frac{\pi}{4} \times (\frac{4.8}{1000})^2 \times \sqrt{2 \times 9.8 \times h}$ so h=27 m
- Check with table

H(m)	d(mm)
25-35	$3 < d \leq 4.8$
30-40	$4.8 < d \leq 6.4$
35-60	$6.4 < d \leq 9.6$

- Note: assume d is 4.4 mm .increase 0.4mm or decrease 0.4 mm if H is not in the range

Sprinkler application efficiency(Espk)

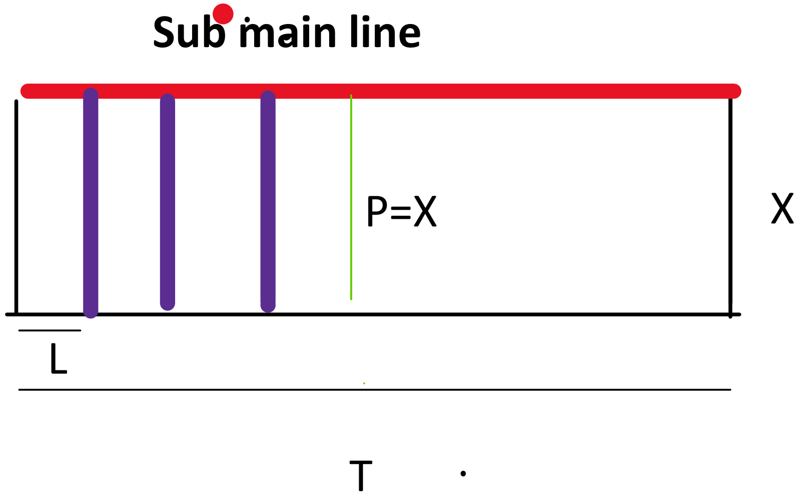
Wind velocity (m/sec)	Max. consumptive use (CU) mm/day		
	< 2	2-7.5	> 7.5
0-1.5	75	71	68
1.5-7.5	71	68	65
> 7.5	65	65	62

Lateral design

- 1-UC more than 80%
- 2.Q spk
- 3.S and L
- 4.Espk
- 5.Ar=$\frac{GDI}{HRS}$
- HRS= 7 hr or 11 hr or 23 hr note=Ar$\leq Ib$

Number of lateral line

- Case 1

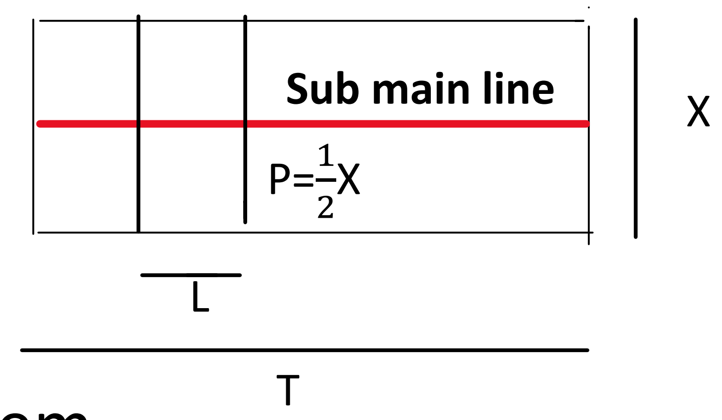


- For solid system

$n=\frac{T\times X}{L\times X}$ So $n=\frac{T}{L}$

- For portable system
- n=$\frac{T\times X}{P\times L\times m\times II}$ n=$\frac{T}{L\times m\times II}$
- m=number of changing location in one day
- m=$\frac{working\ time-shout\ down\ time}{Hrs+1(rest\ time}$
- Hours= 7 hs or 11 hr or 23 hr.

- Case 2



- For soild system

for portable system

- n=$\frac{T\times X}{\frac{1}{2}X \times X}=\frac{2T}{L}$

n=$\frac{2T}{m\times L\times II}$

- General form of equation for calculating friction losses in pipe line:
- William hozen eqtaion:
- Hf=1.14$\times 10^9 \times (\frac{Ql}{c})^{1.852} \times (\frac{L}{D^{4.87}})$ where
- Hf= friction losses (m)
- QL= discharge through spk line (m^3/hr)
- L=length of pipe (m)
- D=inside diameter of the pipe (mm)
- C=friction factor depend on pipe material

Pipe type	C
Concrete	100
Aluminum	120
Steel pipe	130
Asbest	140
plastic	150

Multi opening outlet pipe:

- Hf lateral= Hf closed pipe$\times F$ So $1.14\times 10^9 \times (\frac{Ql}{c})^{1.852} \times (\frac{L}{D^{4.87}}) \times F$
- F=Friction factor depend on number of opening F$<$ 1
- F=$\frac{1}{m+1}+\frac{1}{2N}$ where
- M= from w.H. Equation m=1.852
- N=number of spk on spk line
- P=length of spk line(L)
- P=N$\times S$ so $N=\frac{P}{S}$
- QL=N$\times q\ spk$ qspk=Ar$\times S \times L$

Calculating size of spk line(diameter of spk pipe)

- It depend on friction losses Hf .allowable friction losses in spk line should not exceed 20% water pressure head(H).
- Hf allow=20% Ha
- $Q = c \times a \times \sqrt{2gha}$
- Also it depend on topography condition:
- 1.slope up case Hf=20%Ha-ΔZ
- 2.level case Hf=20%Ha
- 3.slope down case Hf=20%Ha+ΔZ
- ΔZ=E1-E2

- Solve D and then check with market size(manufacturing size)
- Hf adjust=Hf allow× $(\frac{D1}{D2})^{4.87}$ where
- D1= D design D2= D market
- Note : D from 50mm to 150 mm increased by 10mm
- From 150mm to 500 mm increased by 25 mm
- Greater than 500 mm increased by 50mm

Pressure head calculation

- 1. for level Case
- $Hi=Ha+0.75Hf$ $Hd=Hi-Hf$
- 2.slope up case
- $Hi=Ha+0.75Hf+0.5\Delta Z$ $Hd=Hi-Hf-\Delta Z$
- 3.slope down
- $Hi=Ha+0.75Hf-0.5\Delta Z$ $Hd=Hi-Hf+\Delta Z$

example

- From figure below and available data compute the following:
- 1.NDI 2.I.I 3.GDI 4. no. of sprinkler line(for solid and portable system)
- 5.discharge for spk
- 6.diameter of nozzle 6.diameter of nozzle
- 7.diameter of spk line for (level case and slope down case by 1% slope)
- 9.pressure head at the head of spk line
- 10.pressure head at end of spk line

- Given data:
- 1.De= 80 cm 2.CU=8 mm/day
- 3L=18m 4. S=9m 5.wind=2m/sec
- 6.whc=1.7mm/cm 7.Ib=10.2m^3/hr 8.Dp=50%
- Cd=0.967 C alluminum=120

solution

- NDI=WHC×De× Dp so NDI=1.7× $80 \times 0.5 = 68mm$
- I.I=$\frac{NDI}{CU}$ so I.I=$\frac{68}{8}$ = 8.5 day so 8 day
- correction NDI=8× $8 = 64mm$

- GDI=$\frac{NDI}{E\ spk}$
- Espk=90%× $(1 - SSL) \times 100$
- U=2m/s and CU=8mm/day from table Espk=65%

- GDI=$\frac{64}{0.65}$=98.5mm
- No.of spk line:
- a.solid system n=$\frac{T}{L}$ so n=$\frac{1080}{18}$ =60
- b.for portable n=$\frac{T}{L \times m \times II}$ so M=$\frac{Workinh\ time - shutting\ time}{HRS+1(rest\ time)}$
- HRS=(7 or 11 or 23 hours)
- Ar=$\frac{GDI}{HRs}$ $\frac{98.5}{7}$=14 it is not ok cause bigger than Ib 14$>$ 10.2
- $\frac{98.5}{11}$=8.95mm ok

- M=$\frac{Workinh\ time-shutting\ time}{HRS+1(rest\ time)}$=$\frac{24-0}{11}$ so $\mathrm{M}=2$
- n=$\frac{1080}{18\times2\times8}$=3.75 lets say n=4
- Ar=$\frac{q\times10^3}{S\times L}$ so 8.95=$\frac{q\times10^3}{9\times18}$ so q=1.45m^3/hr for one nozzle
- qspk=C× $A\sqrt{2gh}$ assume nozzle diameter 4.8mm
- $\frac{1.45}{3600}$=0.967× $\frac{\pi}{4}\times(\frac{4.8}{1000})^2\times\sqrt{2\times9.8\times ha}$ Ha=27 m

- QL(laterl)=N$\times$ $q\ spk$
- $N(no.spk) = \frac{P}{S}$ so $\frac{360}{12}$ $\text{so number of spk} = 40\text{spk}$
- Q L=40$\times$ $1.45 = 58m^3$/hr
- Hf laterl=$1.14\times 10^9 \times (\frac{Ql}{c})^{1.852} \times (\frac{L}{D^{4.87}}) \times F$
- F=$\frac{1}{m+1}$+ $\frac{1}{2N}$ F=$\frac{1}{1.852+1}$+ $\frac{1}{2(40)}$ so F=0.363
- Hf allowable=20%ha
- Hf allow=20%$\times$ $27 = 5.4m$

- $5.4 = 1.14 \times 10^{9} \times \left(\frac{58}{120}\right)^{1.852} \times \left(\frac{360}{D^{4.87}}\right) \times 0.363$ so D=105.7
- D market =100 or 110 we choose 110

- Hf adjust=Hf allow$\times \left(\frac{D1}{D2}\right)^{4.87}$ so Hf adj=$5.4 \times \left(\frac{105.7}{110}\right)^{4.87}$
- Hf adjust=4.43m

- Pressure Head
- a.At head level Case: Hi=Ha+0.75Hf so Hi=27$\times$ $0.75(4.43) = 30.32m$
- Hd=Hi-Hf so Hd=30.32-4.43=25.98m
- b.for slope sown
- Δz=1% $1\% \times 360 = 3.6\ so$ Δz=3.6m
- Hf=20%Ha+ΔZ So Hf allow=0.2$\times$ $27 \times 3.6 = 9m$
- 9=$1.14\times 10^9 \times (\frac{58}{120})^{1.852} \times (\frac{360}{D^{4.87}})$ $\times$0.363 so D=95.1
- D market=100mm

- Hf adj=9 $\times (\frac{95.1}{100})^{4.87}$=
- Hf adj=7.05m

- Hi=Ha+0.75Hf-0.5ΔZ   Hi=27+0.75(7.05)-0.5(3.6)=30.49m

- Hd=Hi-Hf+ ΔZ   so Hd=30.49-7.05+3.6=27.04