Sprinkler Irrigation

Definition

- Pressurized irrigation through devices called sprinklers
- Sprinklers are usually located on pipes called laterals
- Water is discharged into the air and hopefully infiltrates near where it lands

Types of Systems

- Single sprinkler
  - Only one sprinkler that is moved or automatically moves
- Examples:
  - Single lawn sprinkler
  - Large gun on a trailer that is moved or automatically moves (“traveler”)
- Often used for irregularly shaped areas
- Pressure and energy requirements can be high

Traveling Volume Gun Sprinkler Irrigating from Lagoon

Solid Set

- Laterals are permanently placed (enough to irrigate the entire area)
- Laterals are usually buried, with risers or pop-up sprinklers
- Easily automated and popular for turf and some ag/hort applications
- Capital investment can be high

Portable Solid-Set Sprinkler System

Fairway Runoff Research Plots at OSU Turf Research Farm

Periodically Moved Lateral

- Single lateral is moved and used in multiple locations
- Examples:
  - Hand-move
  - Tow-line/skid-tow (lateral is pulled across the field)
  - Side-roll (lateral mounted on wheels that roll to move the lateral)
- Fairly high labor requirement

Side-Roll Sprinkler Lateral in Peanuts

Moving Lateral

- Single lateral moves automatically (mounted on wheeled towers)
- Examples:
  - Center pivots (lateral pivots in a circle)
  - Linear or lateral move systems (lateral moves in a straight line)
- Fairly high capital investment

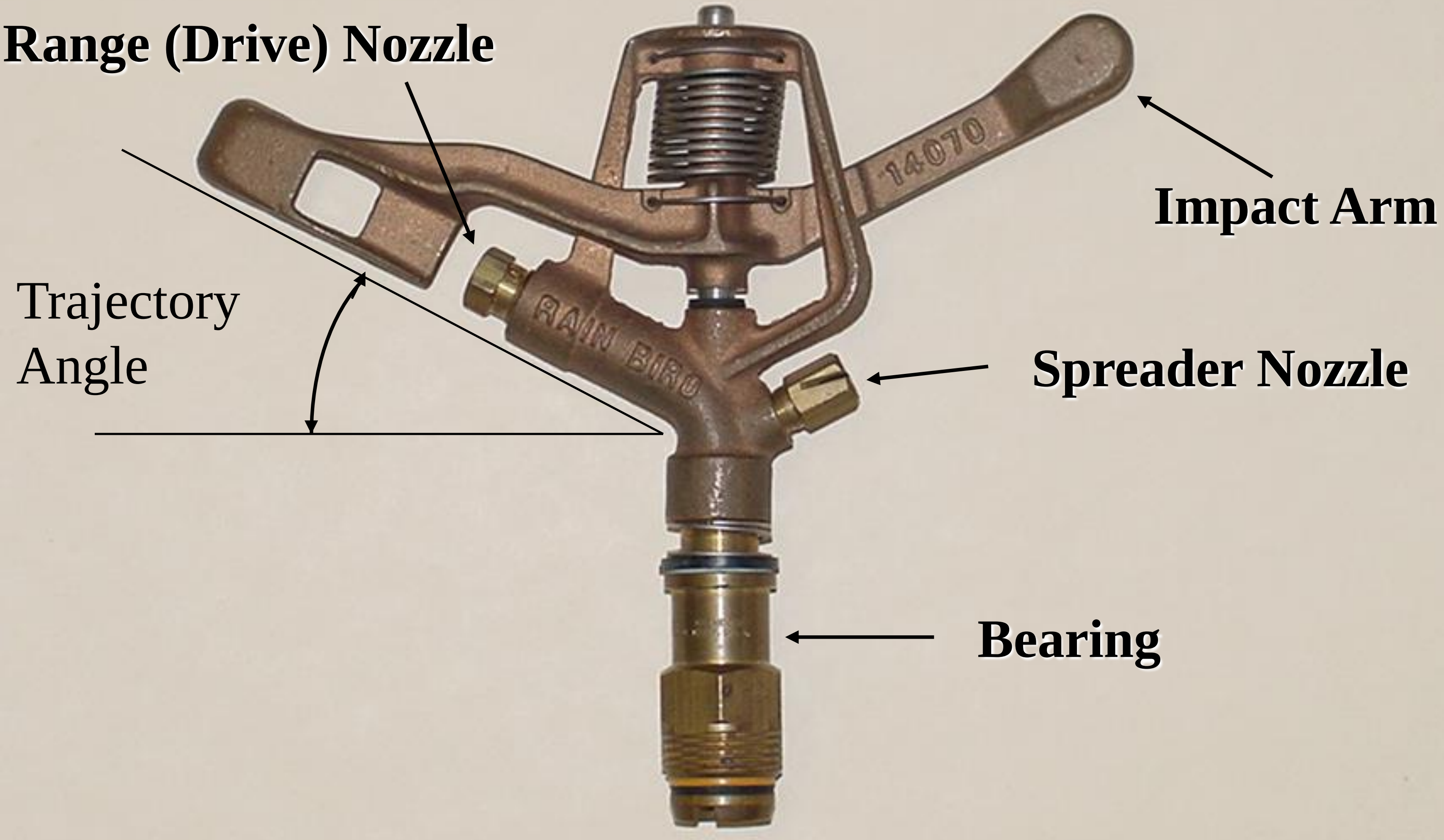
Center Pivot System with Spray Pad Sprinklers

System Components

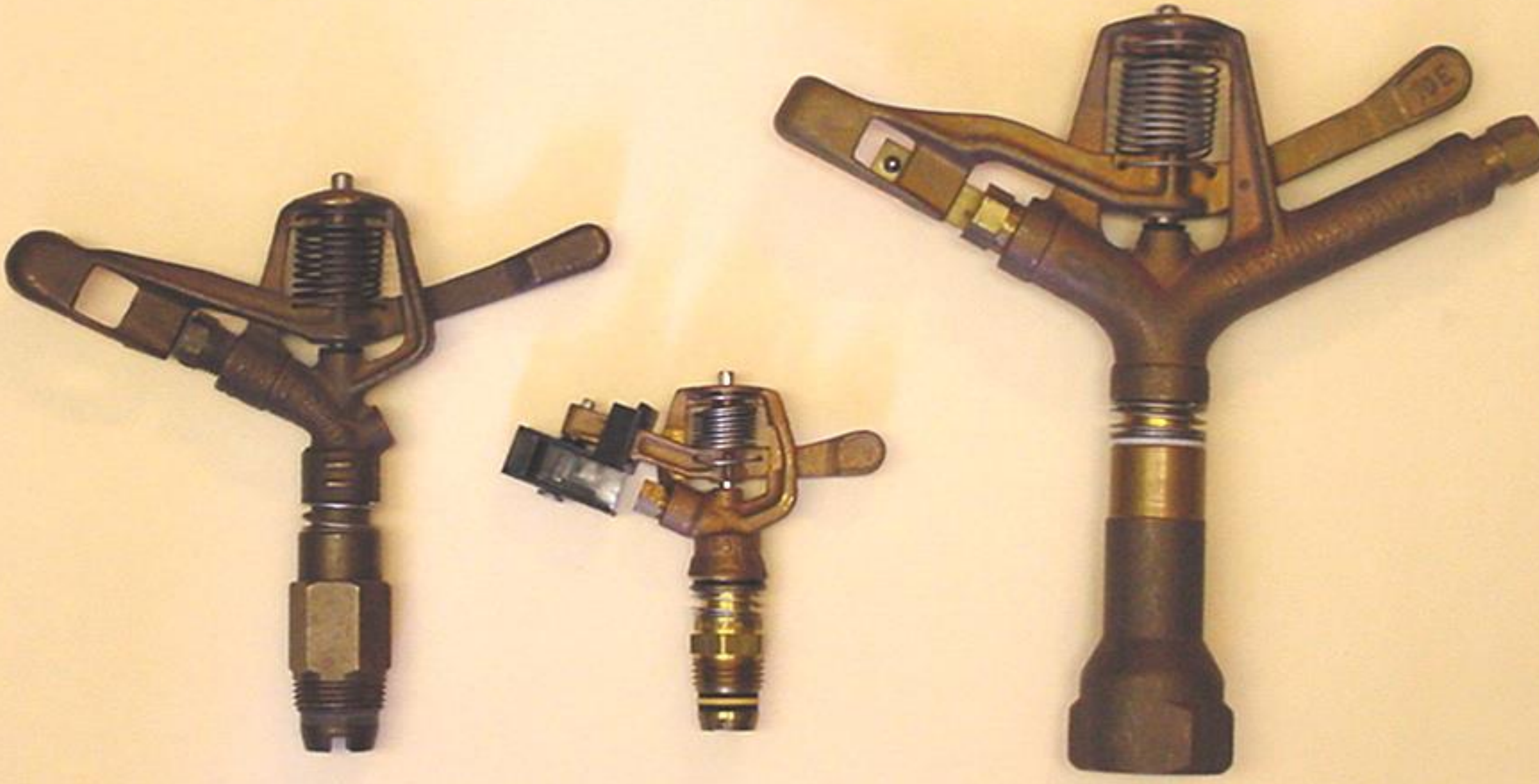
- Sprinklers
  - Devices (usually brass or plastic) with one or more small diameter nozzles
- Impact sprinklers
  - Drive or range nozzle (hits sprinkler arm and throws water out farther)
  - Spreader nozzle (optional; Applies more water close to the sprinkler)
  - Trajectory angles
  - Part-circle sprinklers
  - Used in all types of irrigation, but especially agricultural crops

Impact Sprinklers

Two-nozzle, bronze impact sprinkler



Impact Sprinklers



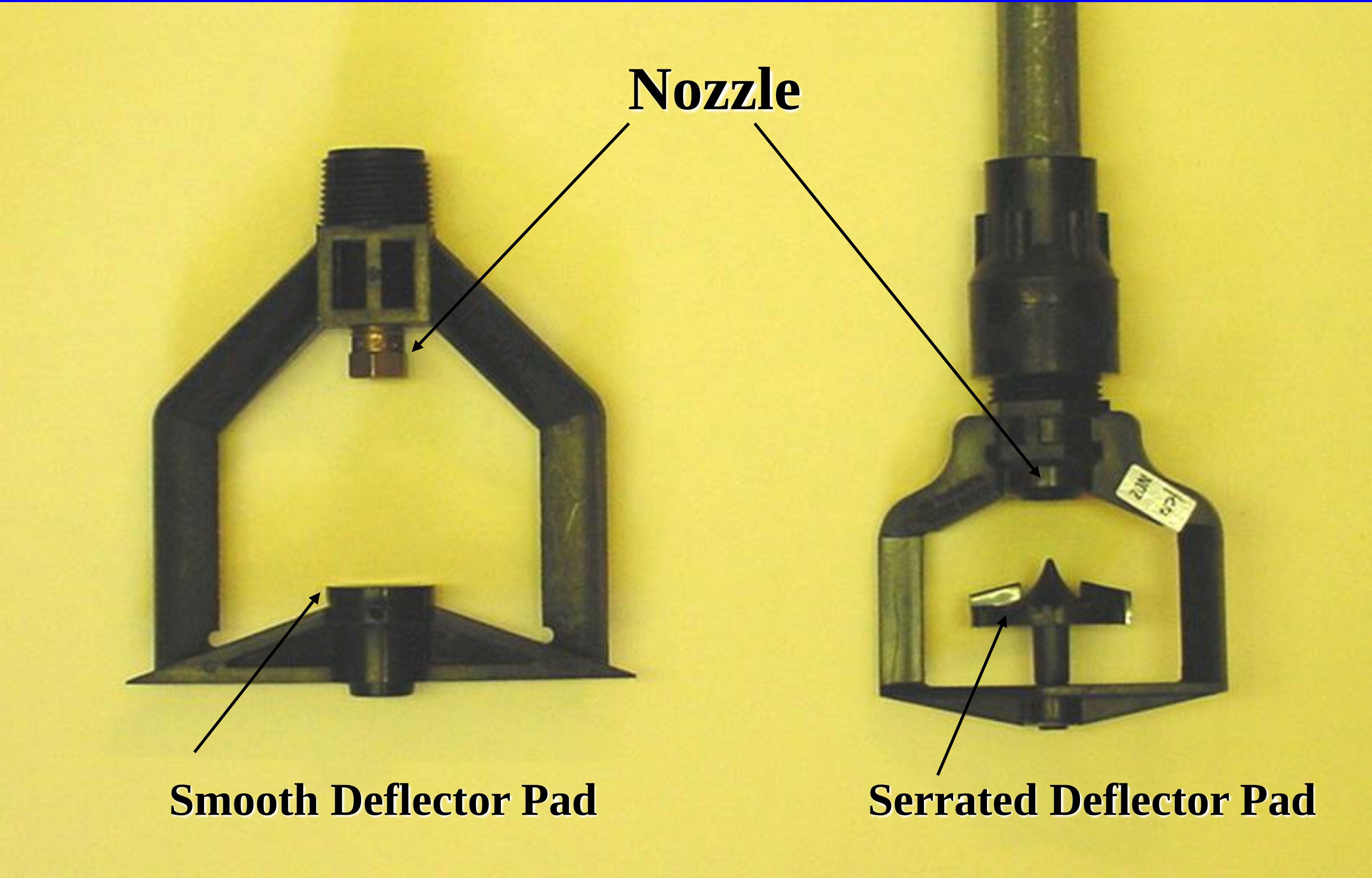
RainBird 30 RainBird 14 RainBird 70

Pop-up, part-circle impact sprinkler head

System Components Cont'd.

- Spray Pad devices
  - Water jet strikes a plate or pad
  - Pad spreads the water and may be smooth or serrated
  - Popular on center pivot and linear move systems

Spray Pad Sprinklers



System Components Cont'd.

- Gear-driven rotors (rotary heads)
  - Energy in the water turns a turbine that rotates the nozzle through a gear train
  - Typically used in large, open turf/landscape areas

Pop-up, turbine rotor with riser extended

Turbine-driven rotor w/ adjustable spray angle

Pop-up, turbine rotor complete with swing arm and tee

System Components Cont'd.

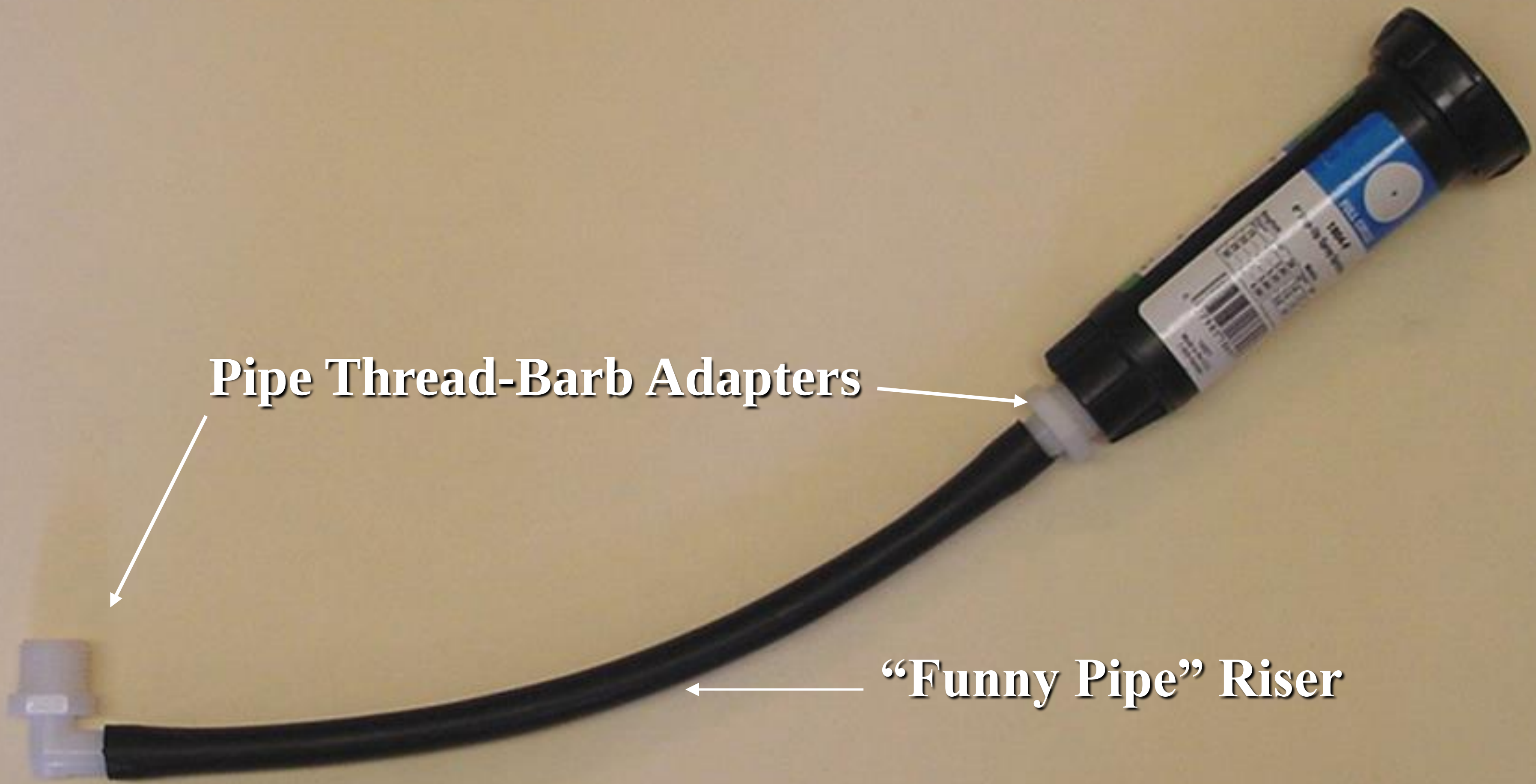
- Spray heads
  - Heads do not rotate
  - Nozzle is shaped to irrigate a certain angle of coverage
  - Typically used for small or irregularly shaped areas
  - Pop-up heads are installed flush with ground and rise when pressurized

Pop-Up Turbine Rotor Sprinklers in Operation

Pop-up spray head with adjustable coverage angle from 1º - 360º

Pop-Up Spray Head

Full-circle, 4-inch, Pop-up spray head w/ Funny Pipe Riser



System Components Cont'd.

- Laterals
  - Pipelines that provide water to the sprinklers
  - May be below, on, or above the ground
- Risers
  - Smaller diameter pipes used to bring water from the lateral to the sprinkler
  - Purposes
  - Raises the sprinkler so that the plants won't interfere with the water jet
  - Reduces turbulence of the water stream as it reaches the sprinkler
- Mainlines and submains
  - Pipelines that supply water to the laterals
  - May serve several laterals simultaneously

Sprinkler Performance

- Discharge
  - Depends on type of sprinkler, nozzle size, and operating pressure

$$q_s = 29.82 C_d D^2 \sqrt{P}$$

  - q_s = discharge (gpm)
  - C_d = discharge coefficient for the nozzle and sprinkler ≈ 0.96
  - D = inside diameter of the nozzle (inches)
  - P = water pressure at the nozzle (psi)

Table 11.1. Discharge (gpm) for straight bore nozzles of various sizes operating for a range of nozzle pressures.

Nozzle Size		NOZZLE PRESSURE, psi															
inches	/64"	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100
3/32	6	1.2	1.39	1.50	1.61	1.71	1.80	1.89									
7/64	7	1.7	1.90	2.05	2.19	2.32	2.45	2.57									
1/8	8	2.2	2.48	2.68	2.86	3.03	3.20	3.35	3.50	3.65	3.78	3.92	4.04				
9/64	9	2.8	3.13	3.39	3.62	3.84	4.05	4.24	4.43	4.61	4.79	4.96	5.12				
5/32	10	3.5	3.9	4.2	4.5	4.7	5.0	5.2	5.5	5.7	5.9	6.1	6.3				
11/64	11	4.3	4.7	5.1	5.4	5.7	6.0	6.3	6.6	6.9	7.2	7.4	7.6				
3/16	12	5.1	5.6	6.0	6.4	6.8	7.2	7.5	7.9	8.2	8.5	8.8	9.1				
13/64	13	6.0	6.5	7.1	7.6	8.0	8.4	8.9	9.2	9.6	10.0	10.3	10.7				
7/32	14	6.9	7.6	8.2	8.8	9.3	9.8	10.3	10.7	11.2	11.6	12.0	12.4				
15/64	15	7.9	8.7	9.4	10.1	10.7	11.2	11.8	12.3	12.8	13.3	13.8	14.2				
1/4	16	9.0	9.9	10.7	11.4	12.1	12.8	13.4	14.0	14.6	15.1	15.7	16.2				
17/64	17	10.	11.2	12.1	12.9	13.7	14.4	15.1	15.8	16.5	17.1	17.7	18.3				
9/32	18	11.	12.5	13.5	14.5	15.4	16.2	17.0	17.7	18.5	19.2	19.8	20.5				
5/16	20	14.	15.5	16.7	17.9	19.0	20.0	21.0	21.9	22.8	23.6	24.5	25.3				
11/32	22	17.	18.7	20.2	21.6	22.9	24.2	25.4	26.5	27.6	28.6	29.6	30.6	31.5	32.4	33.3	34.2
3/8	24	20.	22.3	24.1	25.7	27.3	28.8	30.2	31.5	32.8	34.0	35.2	36.4	37.5	38.6	39.7	40.7
13/32	26	23.	26.2	28.3	30.2	32.0	33.8	35.4	37.0	38.5	40.0	41.4	42.7	44.0	45.3	46.6	47.8
7/16	28	27.	30.3	32.8	35.0	37.2	39.2	41.1	42.9	44.7	46.3	48.0	49.5	51.1	52.6	54.0	55.4
15/32	30	31.	34.8	37.6	40.2	42.7	45.0	47.2	49.3	51.3	53.2	55.1	56.9	58.6	60.3	62.0	63.6
1/2	32	33.	37.0	40.0	42.8	45.3	47.8	50.1	52.4	54.5	56.6	58.5	60.5	62.3	64.1	65.9	67.6
17/32	34	38.	41.8	45.1	48.3	51.2	54.0	56.6	59.1	61.5	63.8	66.1	68.3	70.4	72.4	74.4	76.3
9/16	36	42.	46.9	50.6	54.1	57.4	60.5	63.5	66.3	69.0	71.6	74.1	76.5	78.9	81.2	83.4	85.6
5/8	40	52.	57.9	62.5	66.8	70.9	74.7	78.3	81.8	85.2	88.4	91.5	94.5	97.4	100.	103.	105.
11/16	44	63.	70.0	75.6	80.8	85.7	90.4	94.8	99.0	103.	106.	110.	114.	117.	121.	124.	127.

Sprinkler Performance Cont'd.

- Diameter of Coverage
  - Maximum diameter wetted by the sprinkler at a rate that is significant for the intended use
  - Depends on operating pressure and sprinkler and nozzle design (including trajectory angle)

Table 11.2. Diameter of coverage (feet) for impact sprinklers with straight bore nozzles. †

Nozzle Size		NOZZLE PRESSURE, psi															
inches	/64"	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100
3/32	6	64	66	68	69	70	71	72									
7/64	7	65	67	69	70	71	72	73									
1/8	8	78	79	80	81	82	83	84	85	86	86	87	87				
9/64	9	80	81	82	83	84	85	86	87	88	89	90	91				
5/32	10	82	85	87	88	89	90	91	92	93	94	95	96				
11/64	11	83	88	90	92	93	95	96	97	98	99	100	101				
3/16	12	85	91	94	96	98	100	101	102	103	104	105	106				
13/64	13	91	97	100	103	105	107	109	111	113	114	116	117				
7/32	14	92	99	102	105	108	110	113	115	117	118	120	122				
15/64	15	93	100	104	107	110	112	115	117	119	121	123	125				
1/4	16	94	102	105	109	112	115	118	120	122	124	127	129				
17/64	17	95	103	107	110	114	117	119	122	125	127	129	131				
9/32	18	96	104	108	112	116	119	122	125	127	130	132	134				
5/16	20	121	124	127	130	133	136	140	143	145	147	149	151				
11/32	22	122	128	134	138	142	146	150	154	158	162	164	166	170	172	174	176
3/8	24	124	130	136	142	146	150	154	158	162	166	168	172	174	178	180	182
13/32	26	128	136	144	150	154	158	162	166	168	172	174	178	180	184	186	188
7/16	28	132	138	158	154	158	162	166	172	174	178	180	184	186	190	192	194
15/32	30	132	144	154	160	164	168	172	176	180	182	186	188	192	194	196	198
1/2	32	132	146	156	166	170	174	178	182	186	188	192	194	198	200	202	204
17/32	34	132	146	158	166	176	180	184	188	192	196	198	202	204	208	210	212
9/16	36	132	146	158	172	180	188	192	194	198	202	204	208	210	212	216	218
5/8	40	132	146	158	172	184	190	198	202	204	208	210	214	216	220	222	224
11/16	44	132	146	158	172	184	194	200	208	212	216	218	220	224	226	230	232

† For a brass impact sprinkler where the exit angle of the range nozzzle is 23° above horizontal.

Single Sprinkler

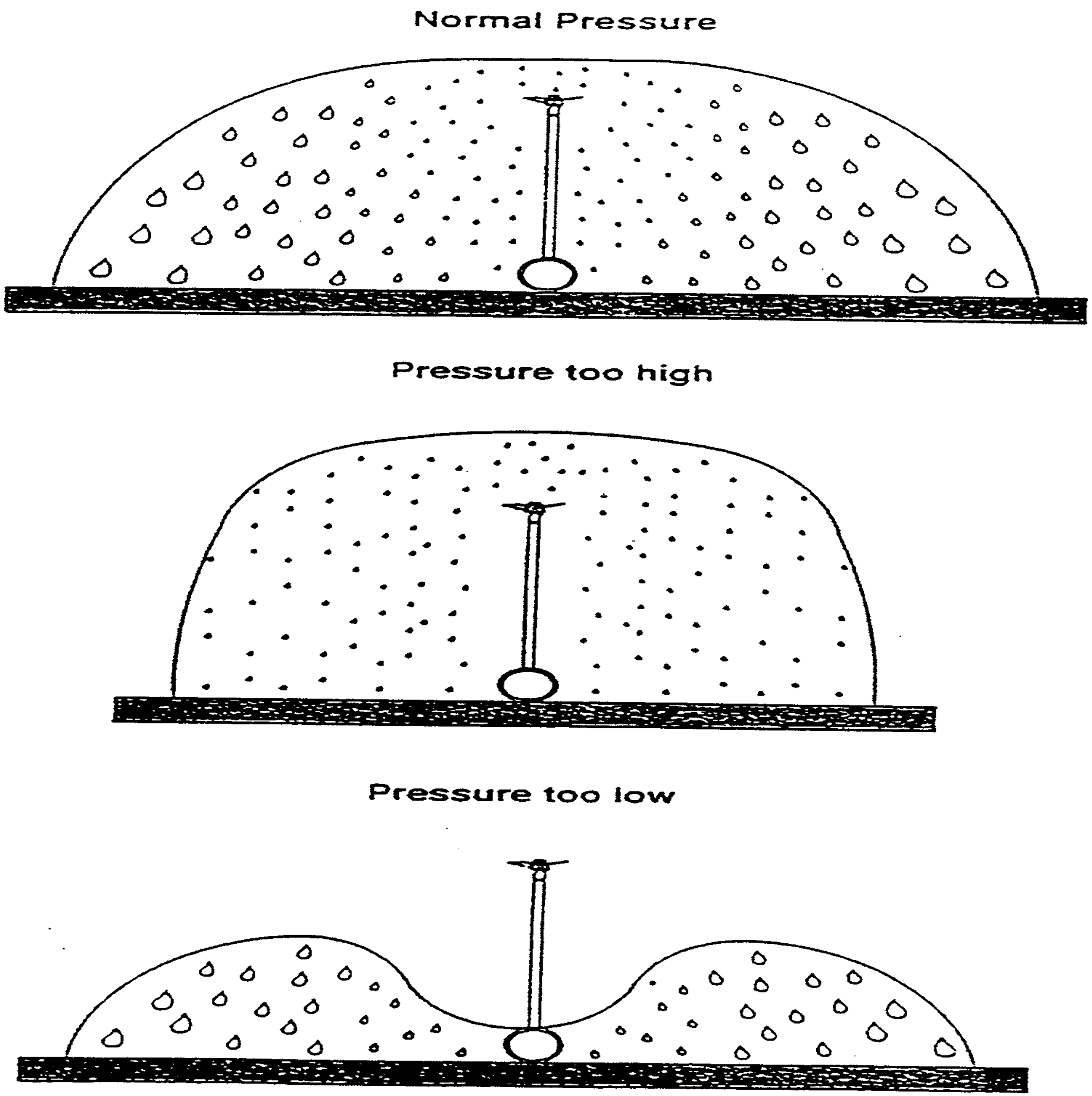
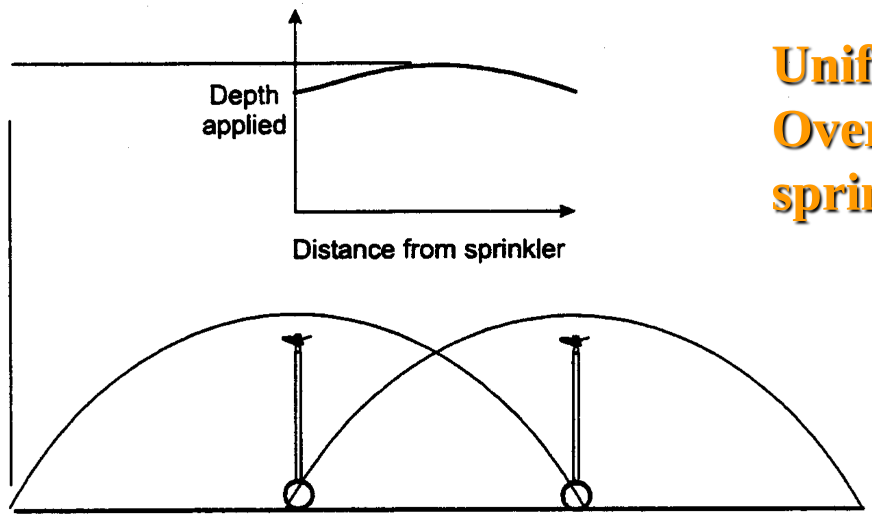


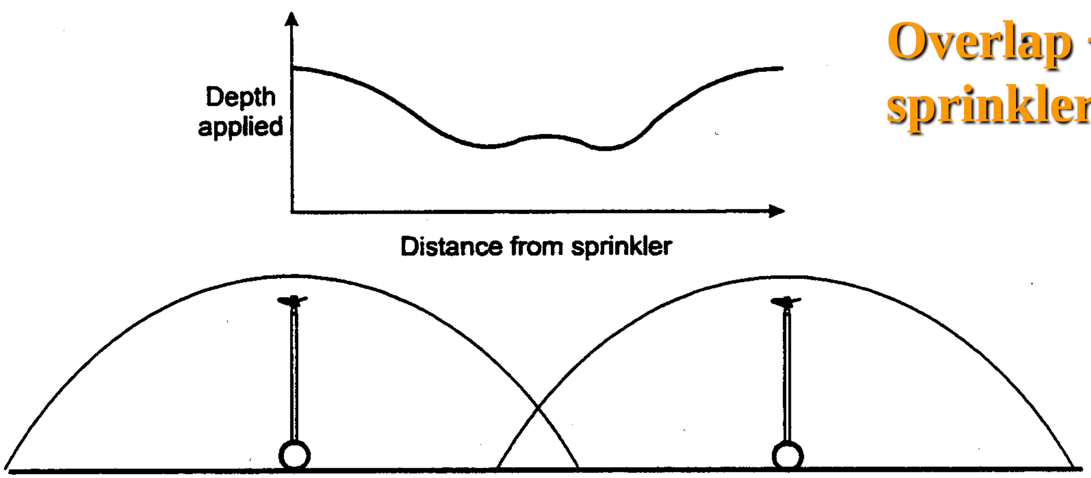
Figure 11.5. Sprinkler distribution for at different operating pressures.

Overlapped Sprinklers



(a)

Uniform Application: Overlap ≥ 50% of sprinkler wetted diameter



(b)

Non-uniform Application: Overlap << 50% of sprinkler wetted diameter

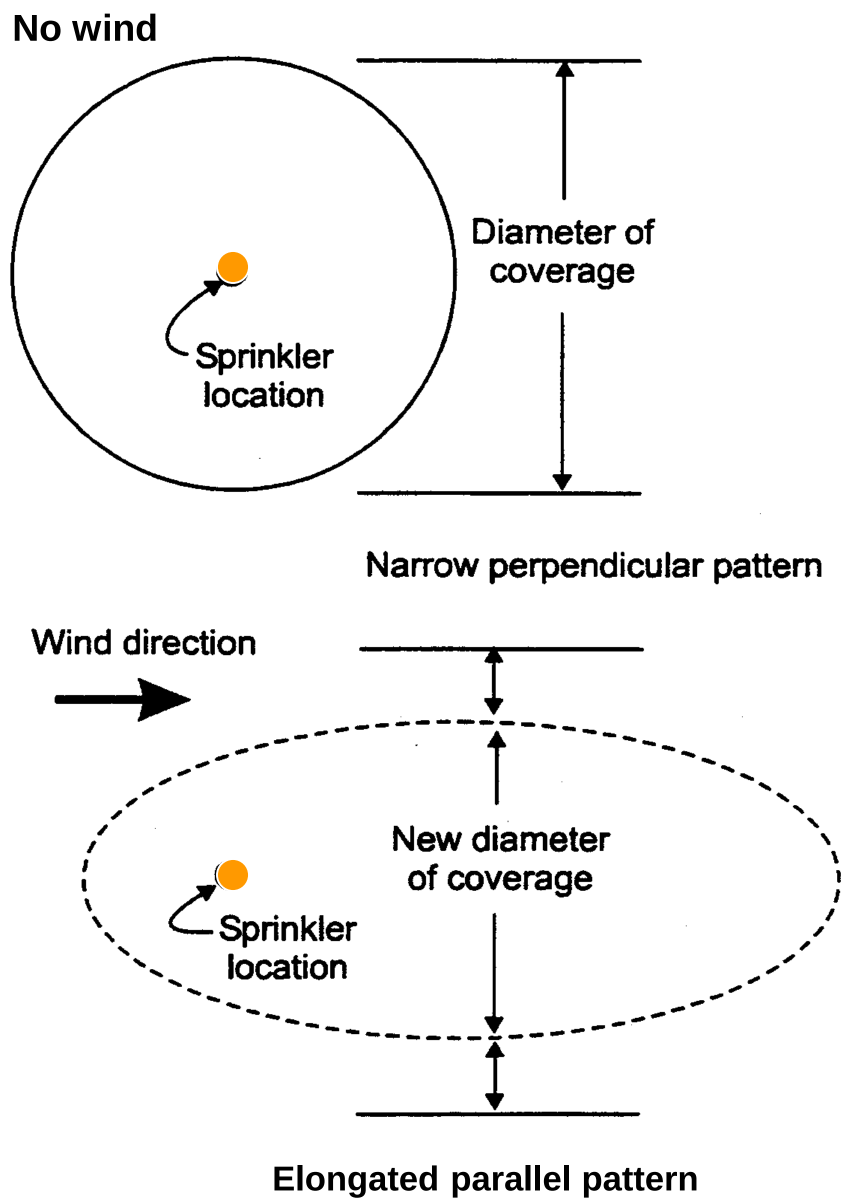


Figure 11.7. Areal view of the effect of wind on the distribution of water from a sprinkler.

Overlapped Sprinklers Contd…

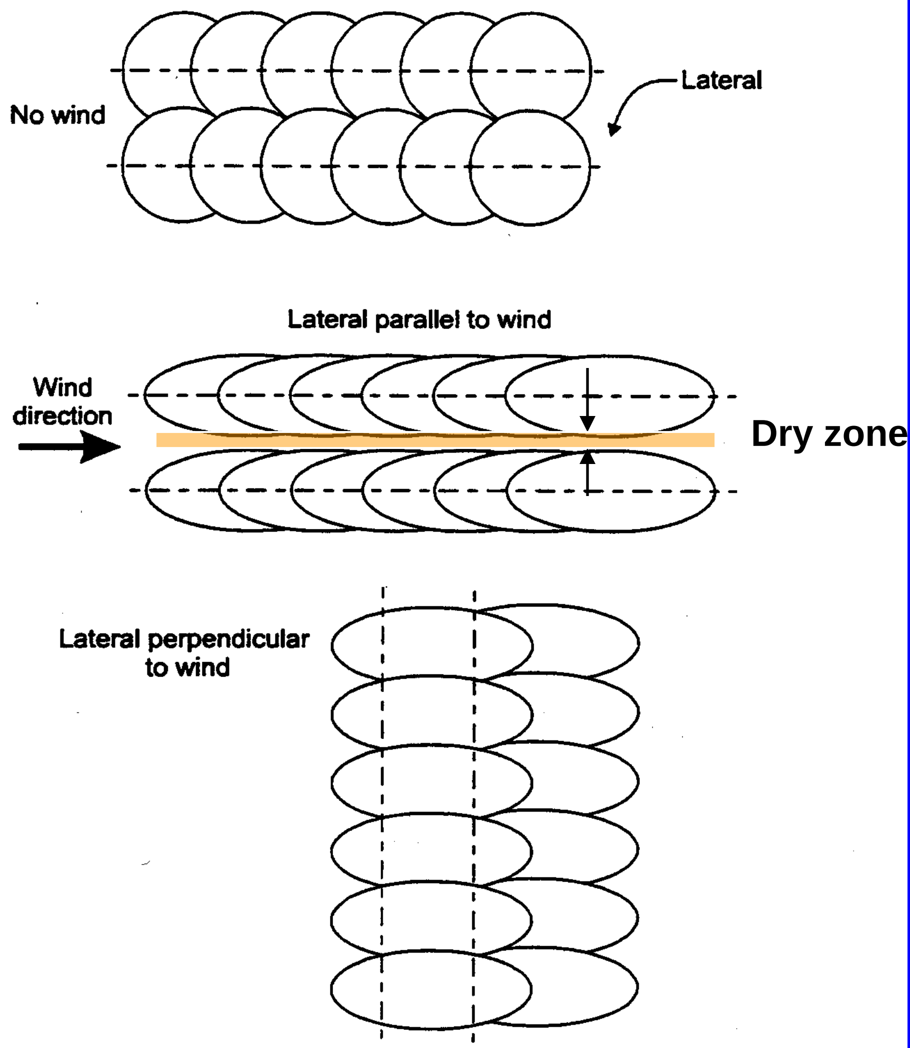


Figure 11.8. Effect of wind on orientation of laterals relative to wind direction.

Maximum Spacing of Sprinklers

Table 11.3. Maximum spacing of sprinklers.

Rectangular Spacing

Average Wind Speed, mph	Maximum Spacing Between Sprinklers on the Lateral	Maximum Spacing Between Laterals Along the Mainline
0-3	50% of Diameter	60% of Diameter
4-7	45% of Diameter	60% of Diameter
8-12	40% of Diameter	60% of Diameter

Square Spacing

Average Wind Speed, mph	Maximum Spacing Between Sprinklers on the Lateral	Maximum Spacing Between Laterals Along the Mainline
0-3	55% of Diameter	---
4-7	50% of Diameter	---
8-12	45% of Diameter	---

Equilateral Triangle Spacing

Average Wind Speed, mph	Maximum Spacing Between Sprinklers on the Lateral	Maximum Spacing Between Laterals Along the Mainline
0-3	60% of Diameter	*
4-7	55% of Diameter	*
8-12	50% of Diameter	*

* For the equilateral triangle pattern, the spacing between laterals is 0.866 x sprinkler spacing.

Application Rate

$$A_r = \frac{d}{t} = \frac{q}{a}$$

- Rectangular sprinkler layout

$$A_r = \frac{96.3 q_s}{S_l S_m}$$

  – A_r = water application rate (inches/hour)
  – q_s = sprinkler discharge rate (gpm)
  – S_l = sprinkler spacing along the lateral (feet)
  – S_m = lateral spacing along the mainline (feet)

- Equilateral triangular layout

$$A_r = \frac{111.2 q_s}{S^2}$$

  - S = spacing between sprinklers (feet)
- Depth of water applied
  - $I_g = A_r T_o$
  - I_g = gross depth of water applied per irrigation (inches)
  - T_o = actual time of operation (hours)

Application Rate & Soil Infiltration Rate

Table 11.4. Maximum recommended precipitation rates for soils (in/h).[1]

Slope, %	Light sandy soils (sands, fine sands) and loamy fine sands)	Medium textured soils (sandy loams, fine sandy loams, and silt loam soils)	Heavy textured soils (silty clay loams, clay loams, and clayey soils)
Soil Surface Not Protected			
0 - 5	0.50 - 0.75	0.25 - 0.50	0.10 - 0.25
6 - 8	0.40 - 0.60	0.20 - 0.40	0.08 - 0.20
9 - 12	0.30 - 0.45	0.15 - 0.30	0.06 - 0.15
13 - 20	0.20 - 0.30	0.10 - 0.20	0.04 - 0.10
> 20	0.10 - 0.20	0.05 - 0.10	0.02 - 0.05
Turfgrass or Heavy Residue Cover			
0 - 5	0.85 - 1.30	0.50 - 0.95	0.15 - 0.35
6 - 8	0.70 - 1.00	0.40 - 0.75	0.10 - 0.25
9 - 12	0.50 - 0.75	0.30 - 0.55	0.10 - 0.20
13 - 20	0.35 - 0.50	0.20 - 0.40	0.05 - 0.15
> 20	0.15 - 0.35	0.10 - 0.20	0.03 - 0.05

[1] Based on recommendations of the Rain Bird Corporation and Pair et. al., 1983.

Sprinkler Example Calculations

A sprinkler system irrigates turf grass on a clay loam soil on a 5% slope in a 10 mph South wind. The sprinklers are 5/32”, single-nozzle sprinklers with a 23° trajectory angle operating at 40 psi. The sprinklers are arranged in a 30 ft x 50 ft rectangular spacing with the laterals running East-West.

a. Is the sprinkler system design satisfactory for these conditions?
b. How many hours should the system operate in one zone?

Sprinkler Example

From Table 11.1: for 5/32” @ 40 psi, q_s=4.5 gpm.

From Table 11.2: for 5/32” @ 40 psi, D_w=88 ft.

From Table 11.3: for 8-12 mph wind, $S_{l\ max}$=40% D_w, $S_{m\ max}$=60% D_w

0.4 x 88=35.2 > S_l =30 ft. And 0.6 x 88=52.8 > S_m =50 ft

S_l and S_m are OK . Note: laterals are perpendicular to wind direction

$$A_r = \frac{96.3 q_s}{S_l S_m}$$

$$A_r = \frac{96.3\ (4.5)}{30 \times 50} = 0.289 \text{ in/hr}$$

From Table 11.4: for Turf, Recommended Max. A_r = 0.15-0.35 in/hr

A_r is within the recommended range and is probably OK.

Sprinkler Example

From Table 2.3: AWC for clay loam= 0.15 in/in

From Table 6.3: R_d for turf grass= 0.5-2.0 ft. Assume R_d= 12 in.

TAW=AWC x R_d = 0.15 x 12 = 1.8 in

For lawn turf assume $f_{d\ max}$= 0.50

AD= TAW x $f_{d\ max}$ = 1.8 x 0.50 = 0.90

To prevent deep percolation loss $d_n \leq AD$

Assume E_a = 80%, so d_n=0.8 d_g , or $d_g = d_n/0.8$ = 0.9/0.8=1.125

From Eq. 11.4 $d_g = A_r$ To, so

To = d_g/A_r = 1.125/0.289= 3.9 hrs.

Hydraulics of Laterals

- Review of friction loss in a lateral:
  - Calculate as though it's a mainline
  - Then multiply by multiple outlet factor (Table 7.3)
  - For a large number of sprinklers, this factor is approximately equal to 0.35
  - This gives <u>total</u> friction loss along the entire lateral length
  - Or use the RainBird Slide Rule to calculate

Pressure Variation Along a Lateral

- General trends
  - Maximum at the inlet and minimum at distal end (assuming level lateral)
  - Linear variation in between? NO!
  - Equations for a level lateral

$$P_i = P_a + \frac{3}{4} P_l$$

$$P_d = P_a - \frac{1}{4} P_l$$

Where:

P_i =inlet pressure

P_a =average pressure

P_d =distal pressure

P_l =pressure loss

Pressure Distribution

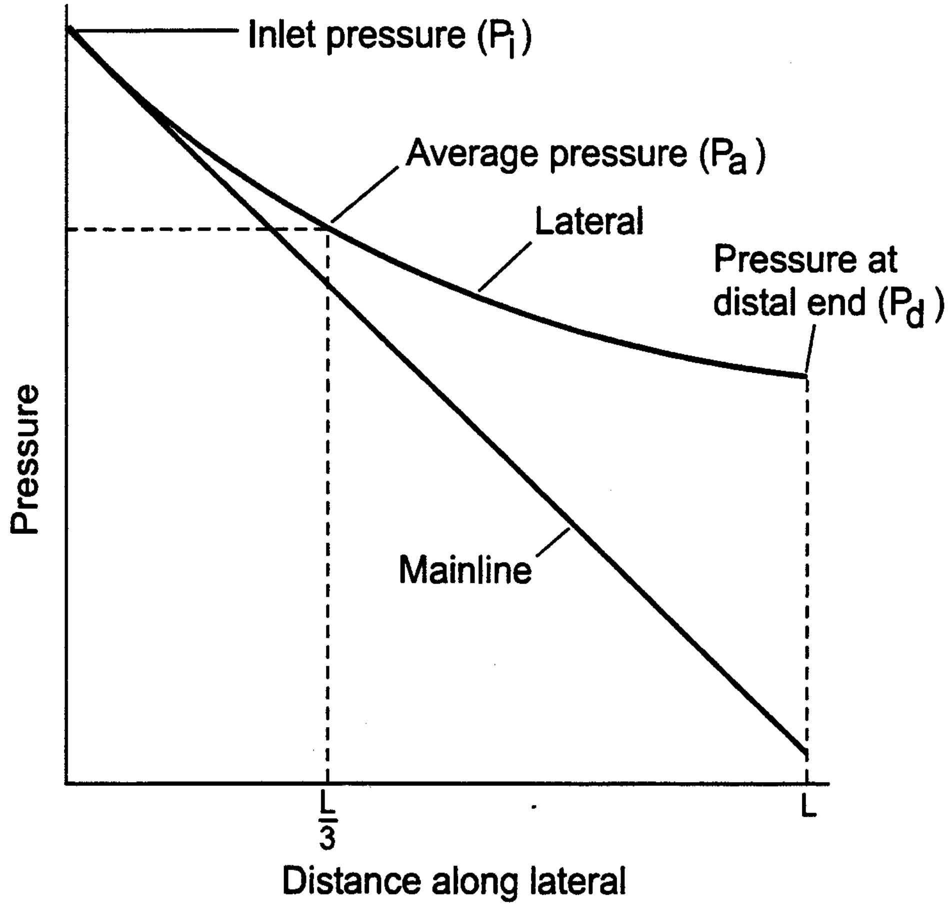


Figure 11.9. Pressure distribution along a lateral placed on a level surface.

Equations for a Sloping Lateral

$$P_i = P_a + \frac{3}{4} P_l - \frac{1}{2} \left(\frac{E_i - E_d}{2.31} \right)$$

$$P_d = P_a - \frac{1}{4} P_l + \frac{1}{2} \left(\frac{E_i - E_d}{2.31} \right)$$

- E's are elevations of the ends of the lateral (in feet)
- Above equations assume half the elevation change occurs upstream of the average pressure point, and half occurs downstream of that point (even if that assumption is not quite true, equations still work pretty well)

Allowable Pressure Variation

- Based on uniformity considerations, recommendation is that $(q_{max} - q_{min})$ not exceed 10% of q_{avg}
- Because of square root relationship between pressure and discharge, this is the same as saying $(P_{max} - P_{min})$ should not exceed 20% of P_{avg}:

$$\text{Maximum } P_l \leq 0.20 \times P_a$$

Example 11.4

<u>Given:</u> A sprinkler lateral was designed for an average pressure of 50 psi and sprinkler heads with one 5/32-inch nozzle in each sprinkler head. The sprinkler lateral is made of 4 inch diameter aluminum pipe with joints 30 feet long. There is one sprinkler outlet at the end of each joint of pipe. The lateral is 1320 feet long.

<u>Find:</u> The pressure at the inlet and distal ends of the lateral if the lateral is on level ground.

The pressure at each end of the lateral if the lateral runs down a uniform 2% grade.

The pressure at each end of the lateral if the lateral runs up a uniform 2% grade.

Which of these systems meet the ASAE criteria for pressure variation in laterals?

<u>Solution:</u> There are 44 sprinklers on the lateral (i.e. 1320 ft / 30 ft per sprinkler). With 5/32-inch nozzles, the average flow is 5 gpm per sprinkler and the total flow for the lateral is 220 gpm.

Aluminum pipe with couplers has a C value of 120 in the Hazen-Williams equation so the friction loss for a mainline with a flow rate of 220 gpm through a 4 inch aluminum pipe is given by:

$$P_m = 4.53 \left(\frac{Q}{C} \right)^{1.852} \frac{L}{D^{4.87}}$$

$$P_m = 4.53 \left(\frac{220\ gpm}{120} \right)^{1.852} \frac{1320\ feet}{(4\ inches)^{4.87}}$$

$$P_m = 21.5\ psi$$

where P_m = the pressure loss in a mainline of constant diameter and flow.

The multiple outlet friction factor (F) for a lateral with 44 sprinkler is abou
0.36 (see Table 8.3) so the friction loss for the lateral is:

$P_l = F\ P_m = 0.36 \times 21.5$ psi = 7.7 psi.

The pressure at the inlet to the lateral for level ground is:

$P_i = P_a + 3/4\ P_l = 50 + 0.75 \times 7.7 = 56$ psi.

The pressure at the distal end of the lateral for level ground is:

$P_d = P_a - 1/4\ P_l = 50 - 0.25 \times 7.7 = 48$ psi.

The pressure variation along the lateral is 7.7 psi compared to the average pressure of 50 psi. The variation is 15.4% of the average pressure and is less than the maximum permissible pressure variation so the lateral meets the ASAE standard.

When the lateral runs down a 2% grade, the elevation change along the lateral is:

$E_i - E_d = 0.02 \times 1320$ feet = 26.4 feet. So the inlet is about 26 feet above the distal end. The pressures at the inlet and distal ends are then:

$P_i = P_a + 3/4\ P_l - 0.5\ (E_i - E_d)/2.31 = 50 + 0.75 \times 7.7 - 0.5 \times 26.4/2.31 = 50.1$ psi

$P_d = P_a - 1/4\ P_l + 0.5\ (E_i - E_d)/2.31 = 50 - 0.25 \times 7.7 + 0.5 \times 26.4/2.31 =$ 53.8 psi

Here the pressure variation is only 3.7 psi, well within the allowable variation. Note that the highest pressure occurs at the distal end of the lateral for this case.

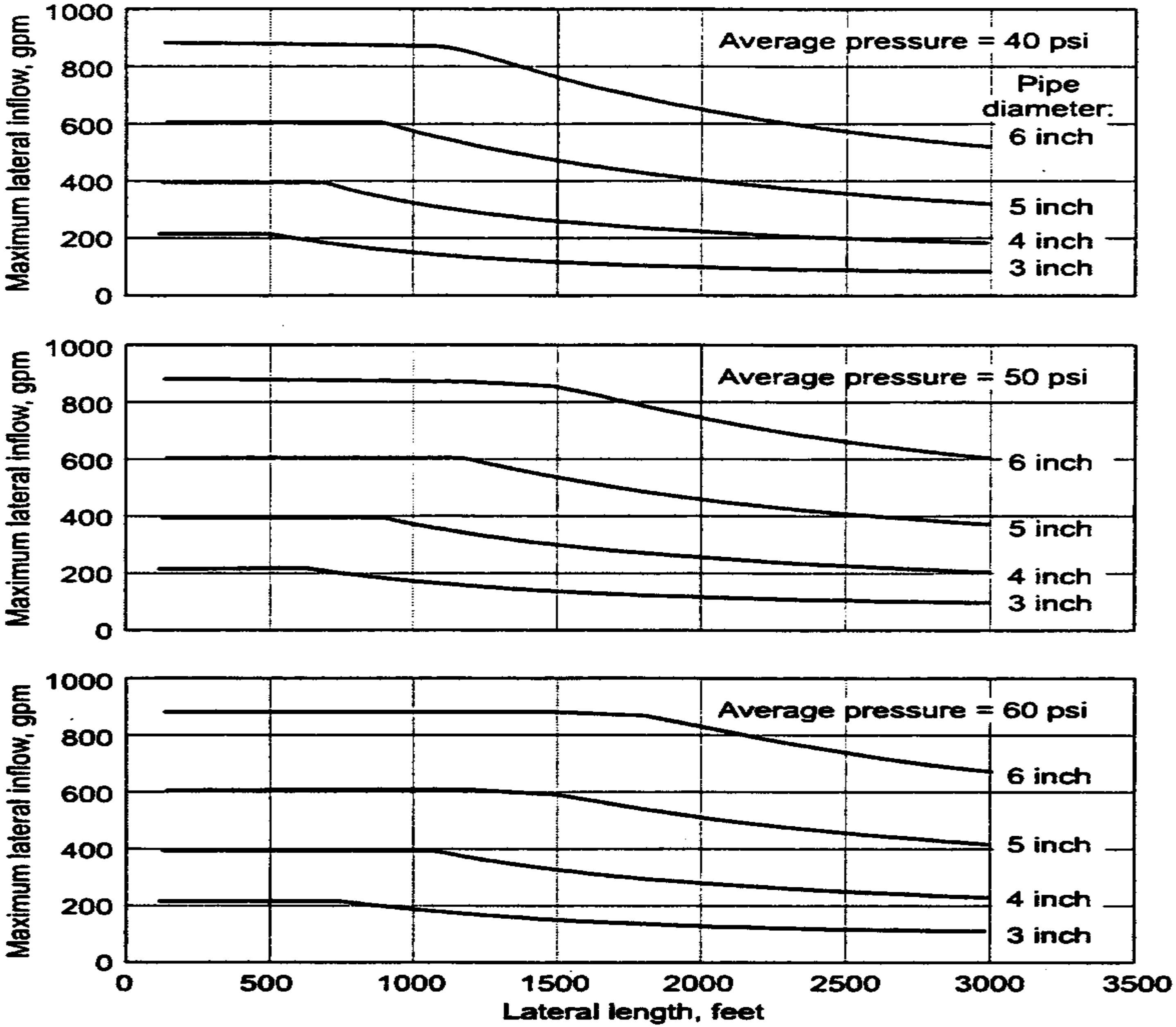
When the lateral runs uphill the elevation of the inlet is now below the distal end so the value of $(E_i - E_d) = -26.4$ feet. Using this value and the method in part b the pressures at the ends of the lateral are:

$P_i = 61.5$ psi and $P_d = 42.4$ psi.

Now the pressure variation is about 19 psi or 38% of the average pressure which is unacceptable according to the standard.

Maximum Lateral Inflow

- Constrained by:
  - Maximum allowable pressure variation (more Q = more P_l)
  - Maximum allowable pipeline velocity (more Q = higher velocity)
- Figure 11.10 -- assumes portable Al pipe and V_{max} of 10 ft/s



Maximum lateral inflow, gpm
1000
800
600
400
200
0
Average pressure = 40 psi
Pipe diameter:
6 inch
5 inch
4 inch
3 inch
Average pressure = 50 psi
6 inch
5 inch
4 inch
3 inch
Average pressure = 60 psi
6 inch
5 inch
4 inch
3 inch
0
500
1000
1500
2000
2500
3000
3500
Lateral length, feet

Example Problem

Determine the maximum sprinkler discharge for a 5-inch aluminum pipe lateral that is 2,000 ft long where the average pressure is 50 psi. Sprinklers are spaced 40 feet along the lateral.

<u>Given:</u>

$P_a = 50$ psi

$D = 5$ inches

$C = 120$ (aluminum pipe with couplers)

$L = 2000$ feet

$S_l = 40$ feet

Find: Q_{max}

q = discharge of individual sprinklers

Solution: From Figure 11.10 the maximum lateral inflow is about 450 gpm.

For a 2,000 ft long lateral, 50 sprinklers would be needed if spaced at a 40 ft spacing.

Thus, each sprinkler could average 9 gpm.

Other Design and Management Considerations

- Sprinkler selection

$$q_s = \frac{Q_c S_l S_m N_s}{43560\, N_l} \left(\frac{T_s}{T_o} \right) \left(\frac{I_i}{I_i - T_d} \right)$$

  - q_s = minimum sprinkler discharge (gpm)
  - Q_c = gross system capacity (gpm/acre)
  - S_l = spacing between sprinklers along the lateral (feet)
  - S_m = spacing between laterals along the mainline (feet)
  - N_s = number of sets required to irrigate the entire area
  - N_l = number of laterals used to irrigate the entire area
  - T_o = time of actual operation per set (hours)
  - T_s = total set time (hours)
  - I_i = irrigation interval (days)
  - T_d = system down time during the irrigation interval (days)

Sprinkler Selection, Cont'd.

$$N_s = \frac{W_f}{S_m}$$

- N_s = number of sets required to irrigate the entire area
- W_f = width of the field or area (feet)
- S_m = spacing between laterals along the mainline (feet)
- Note: Choose a combination of nozzle size and operating pressure to provide the desired q_s

Example Problem

Given: A square field (1200 ft x 1200 ft) is irrigated with a portable set-move sprinkler system. The gross system capacity has been determined to be 6.0 gpm/acre. The spacing of sprinklers is 40 feet along the lateral and 50 feet between lateral sets. The system operates for 10 hours out of a 12 hour set. The field must be irrigated at least once every 10 days and 2 days are needed to move laterals to the beginning side and for equipment maintenance.

Find: Compute the minimum sprinkler discharge required for the system.

Solution: The number of sets in the field will be

$N_s = W_f/S_m = 1200 \text{ ft}/50 \text{ ft} = 24$ sets.

With 12 hour set times, 2 sets can be irrigated daily so 12 days of continual irrigation would be required with one lateral.

We only have 8 days available to irrigate since 2 out of 10 days are used for down time. Therefore, two laterals will be needed ($N_l = 2$).

Each lateral must irrigate 12 sets taking 6 days.

Thus, the irrigation interval can be 8 days.

Then using Equation 11.12:

$$q_s = \left(\frac{Q_c\ S_l\ S_m}{43560}\right)\left(\frac{N_s}{N_l}\right)\left(\frac{T_s}{T_o}\right)\left(\frac{I_i}{I_i - T_d}\right)$$

$$q_s = \left(\frac{6.0\ gpm/acre\ x\ 40\ ft\ x\ 50\ ft}{43560\ ft^2/acre}\right)\left(\frac{24\ sets}{2\ laterals}\right)\ x\ \left(\frac{12\ hr}{10\ hr}\right)\left(\frac{8\ days}{8-2\ days}\right)$$

$$q_s = \frac{6.0\ gpm}{acre}\ x\ \frac{0.55\ \ acres}{sprinkler}\ x\ 1.2\ x1.33$$

$$q_s = 5.3\ \ gpm/sprinkler$$

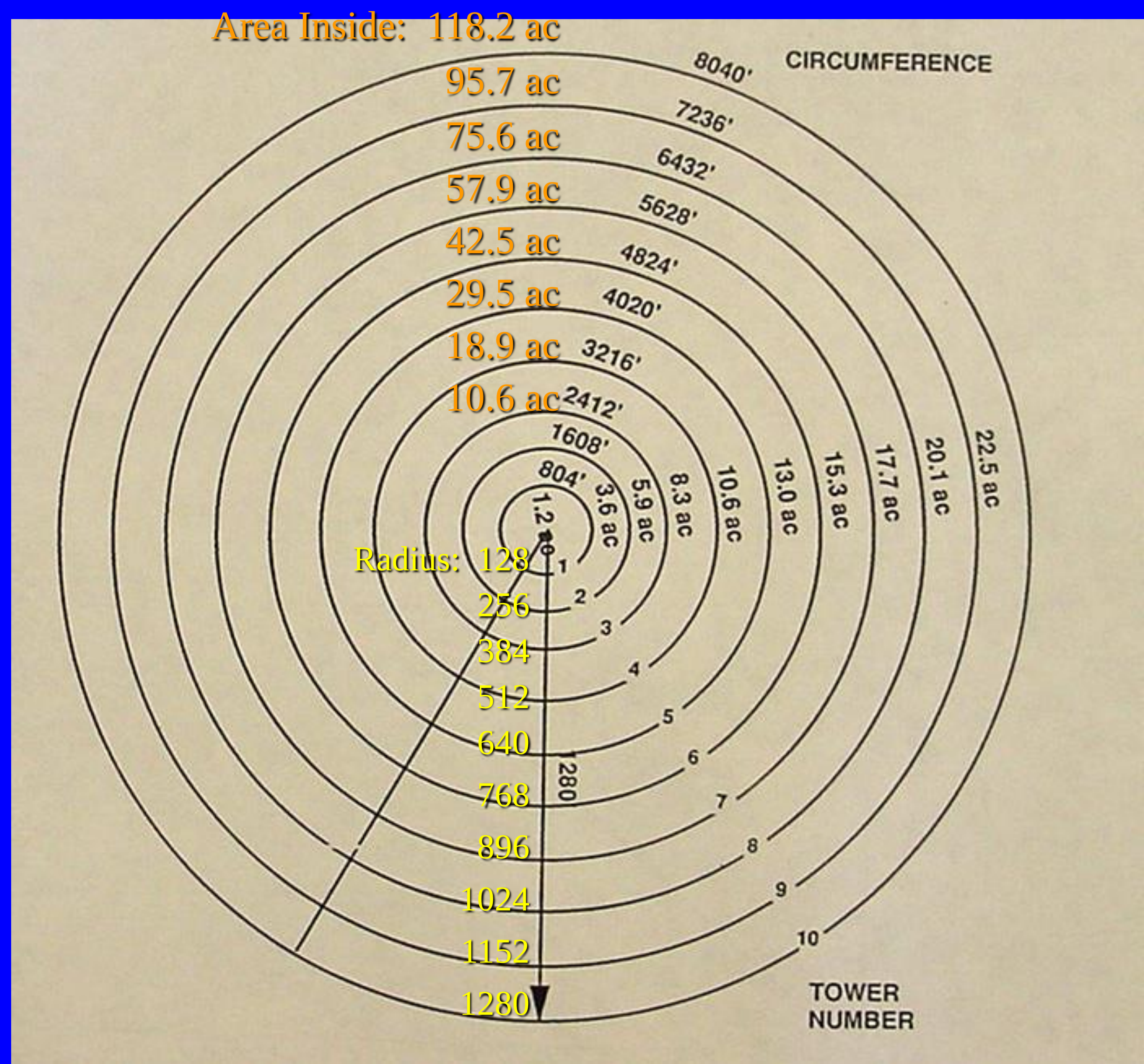
- Required Lateral Inflow

$$Q_l = \frac{q_s L}{S_l}$$

  - Q_l = inflow to the lateral (gpm)
  - L = length of the lateral (feet)
  - Q_l must not exceed maximum allowable based on friction loss or velocity
- System layout
  - Generally best to run the mainline up and down the slope and run the laterals on the contour
  - If laterals must be sloping, best to run them downslope
  - Wind is also a factor (prefer laterals running perpendicular to wind direction; because normally, $S_m > S_l$)

Center Pivot Laterals

- “Multiple outlet factor" is 0.543 (higher than in conventional laterals because more water must be conveyed to the distal end)



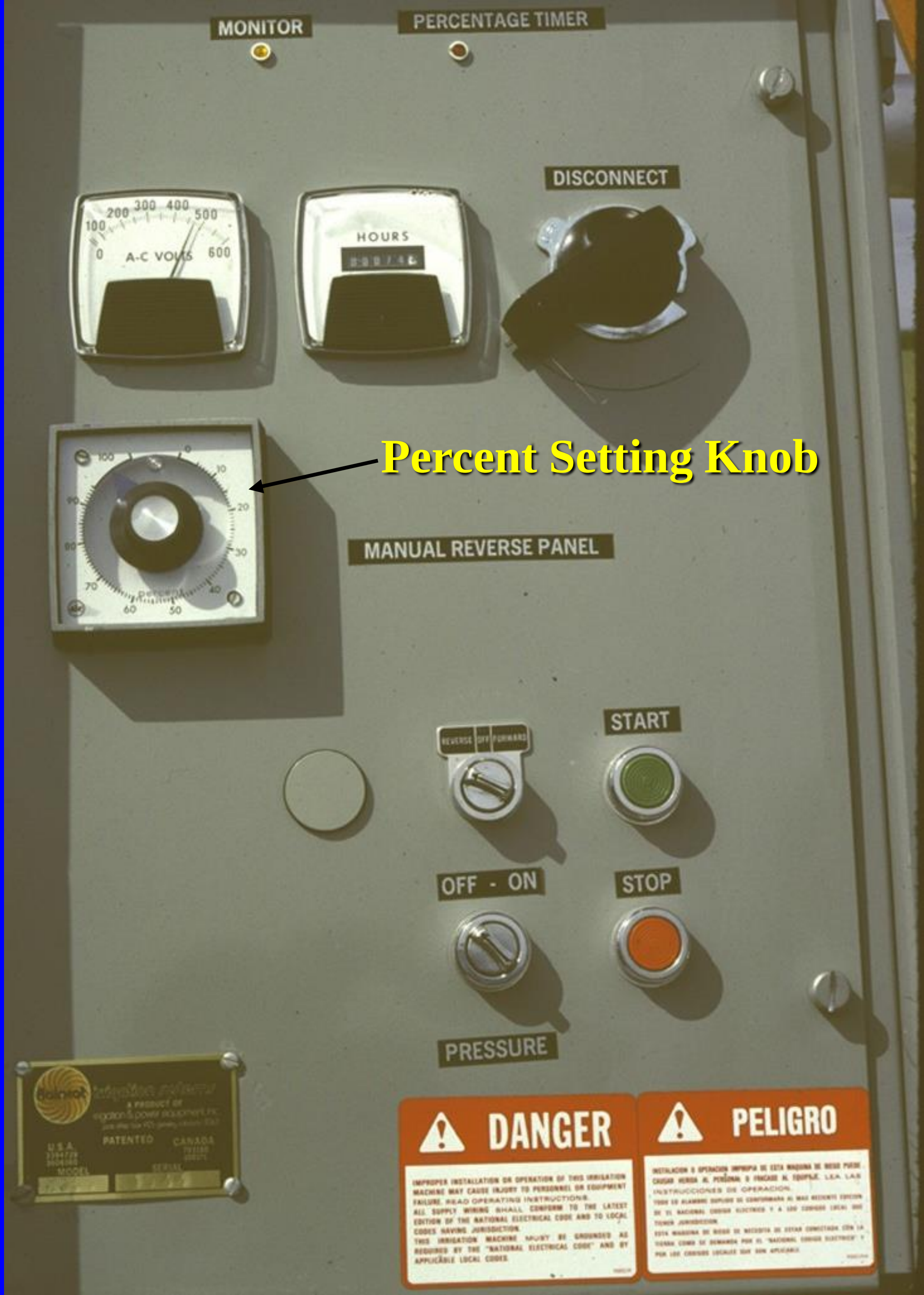
Center Pivot Laterals Cont'd.

- Use the distal sprinkler as the "benchmark" and then calculate the inlet pressure and the pressure distribution along the lateral (as opposed to stationary laterals, where the average pressure was used determine acceptable friction loss and pressure variation)
- But linear move lateral is analyzed like a stationary lateral (area irrigated does not change as you move down the lateral)

Application Depth

The application depth of a continuously moving sprinkler system depends on the water pumping rate, Q; the total acreage irrigated, A; and the time required to cover the area, T_a.

The time to cover the irrigated area is adjusted by the "Percent Setting" of the system. On a center pivot, this sets what percent of the time the tower motor on the outermost tower is running- from 0% to 100%. At 100% a ¼-section pivot takes 22 hrs to cover its 125 acre circle.



Center Pivot Application Depth

Center pivot application rate depends on:

- the area irrigated, A (acres) = $L^2/13866$
  - where (L= lateral length, ft)
- the pumping rate, Q (gpm)
- the actual travel time/revolution, T_a (hours)
  - $T_a = 100\ (T_{min})/P$
    - where T_{min} = minimum travel time (normally 22 hr)
    - where P = percent speed setting, (0% - 100%)

Center Pivot Application Depth

The actual application depth is given by:

$$d = (Q\ T_a) / (453\ A)$$

Example:

A 1300-ft long center pivot has a minimum travel time of 21 hrs at its 100% setting and is supplied with a flow rate of 800 gpm. What is the depth of application at a 20% speed setting?

$A = 1300^2/13866 = 121.9$ acres

$Q = 800$ gpm

$T_a = 100\ (21)/20 = 105$ hrs

d = (800 gpm x 105 hrs)/(453 x 121.9 acres) = 1.52 inches

Lateral Move Application Rate

Lateral system application rate depends on:

- The area irrigated, A (acres) = L D_t/43560
  - where L = lateral length, (ft)
  - where D_t = travel distance of lateral, (ft)
- The actual system flow rate, (gpm)
- The actual travel time T_a (hr) = 100 T_{min}/P
  - $T_a = 100 (T_{min})/P$
    - where T_{min} = minimum time to move distance $D_{t,}$ (hr)
    - where P = percent speed setting, (0% - 100%)

Lateral Move Application Depth

The actual application depth is given by:

$$\mathbf{d = (Q\ T_a) / (453\ A)}$$

Example:

A 1320-ft long lateral move system has a minimum travel time of 14 hrs at the 100% setting over its travel distance of 2640 ft and is supplied with a flow rate of 600 gpm. What is the depth of application at a 17% speed setting?

A= 1320 x 2640/43560 = 80 acres Q = 600 gpm

T_a = 100 (14)/17 = 82.35 hrs

d = (600 gpm x 82.35 hrs)/(453 x 80 acres) = 1.35 inches