Calibrating Manure Application Equipment

If you do not know how much manure is being spread over a given area, you are probably not using the manure most effectively. Calibrating your spreader, however, is a simple, effective way to use the nutrients in manure more effectively. Only by knowing your spreader's application rate can you apply the amount of manure that your crop needs and prevent water quality problems resulting from the overapplication of animal manure.

Applicators can apply manure, bedding, and wastewater at varying rates and patterns, depending on forward travel and/or power takeoff (PTO) speed, gear box settings, gate openings, operating pressures, spread widths, and overlaps.

Solid and semi-solid manure spreaders

To calibrate a spreader for solid manure (20% or more solids), the following materials are needed:

1. Bucket
2. Plastic sheet, tarp, or old bed sheet. An even size–8 ft by 8 ft, 10 ft by 10 ft, or 12 ft by 12 ft–makes calculations easier. A 56-inch by 56-inch sheet, equaling 1/2,000 of an acre, can be used to simplify calculations but exercise caution when determining application rates using a small collection area (1 lb collected equals 1 ton/acre).

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3. Scales

Spreader manufacturers rate solid and semisolid spreaders either in bushels or cubic feet (to get cubic ft, multiply bushels by 1.25). Most spreaders have two rating capacities: (1) struck or level full and (2) heaped. It is difficult to accurately estimate the calibration of solid manure spreaders based on their capacity (volume) because the density of solid and semisolid manures, or their weight per volume of manure (in lbs per cubic ft), varies widely, depending on the type and amount of bedding used as well as its storage method. Therefore, if you estimate spreader application rates as the volume of the manure that the spreader holds, you are overlooking the fact that some manure weighs more than other manure, which can cause significant error when calculating manure application rates.

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Since manures and litters have different densities, an on-farm test should be performed. If a weigh scale for your spreader is not available, determine the load (in tons) of a manure spreader as follows:

1. Weigh an empty 5-gallon bucket.
2. Fill the bucket level full with the material to be spread. Do not pack the material in the bucket but ensure that it settles similar to a loaded spreader.
3. Weigh the bucket again. To calculate the weight of the contents, subtract the empty bucket weight from this weight.
4. To calculate the density (in pounds per cubic ft), multiply the weight of the contents by 1.5.
5. To calculate the tons of material in a spreader load, multiply the manure density by the spreader's cubic ft capacity and divide by 2,000.

$$\text{Spreader load (tons)} = \frac{\text{weight of 5 gal of manure} \times 1.5 \times \text{spreader capacity (ft}^3\text{)}}{2{,}000}$$

Spreader calibration (tarp method). Use the following procedure to calibrate a solid or semi-solid manure spreader with a collection tarp.

1. Locate a large, reasonably smooth flat area where manure can be applied.
2. Weigh the empty bucket and plastic sheet, tarp, or blanket.
3. Spread the plastic sheet, tarp, or blanket smoothly and evenly on the ground.
4. Fill the spreader with manure to the normal operating level. Drive the spreader at the normal application speed toward the sheet spread on the ground, allowing the manure to begin leaving the spreader at an even, normal rate.
5. Drive over the sheet at the normal application speed and settings while continuing to apply manure. If a rear discharge spreader is used, make three passes. First, drive directly over the center of the sheet; then make the other two passes on opposite sides of the center at the normal spreader spacing overlap.
6. Collect all manure spread on the sheet, and place sheet and all in the bucket.

7. Weigh the bucket and manure; then subtract the weight of the empty bucket and ground sheet, giving you the pounds of manure applied to the sheet.
8. To get a reliable average, repeat the procedure three times.
9. Determine the average weight of the three manure applications.
10. Calculate the application rate using the formula below or Table 36-5.

$$\text{Application rate (tons/acre)} = \frac{21.78 \times (\text{manure weight on tarp, lbs})}{(\text{tarp area, ft}^2)}$$

11. Repeat the procedure at different speeds and/or spreader settings until the desired application rate is achieved.

Many times it may be necessary to adjust the application rate. Application rate can easily be changed by increasing or decreasing the speed at which the manure is applied. To perform these calculations, the spreader load (in tons), duration of application (in minutes), and the average width

Table 36-5. Calibration of solid manure spreaders.

Pounds of Manure Applied to Tarp	Tons of Manure Applied/Acre — Tarp Size		
	8 ft × 8 ft	10 ft × 10 ft	12 ft × 12 ft
10	3.40	2.18	1.51
20	6.81	4.36	3.03
30	10.21	6.53	4.54
40	13.61	8.71	6.05
50	17.02	10.89	7.56
100	34.03	21.78	15.13
150	51.05	32.67	22.69
200	68.06	43.56	30.25
250	85.08	54.45	37.81
300	102.09	65.34	45.38
350	119.11	76.23	52.94

PROBLEM 1

Determining application rate (tarp method).
What is the application rate (tons per acre) if you collect 8.5 pounds of manure on a 10-ft by 10-ft tarp during a calibration run?

$$\text{Application rate (tons/acre)} = \frac{8.5 \text{ lbs of manure} \times 21.78}{10 \text{ ft} \times 10 \text{ ft}} = 1.85 \text{ tons/acre}$$

Application rate can easily be changed by increasing or decreasing the speed at which the manure is applied.

Any time you make adjustments, change the rpm, or use thicker manure, you should recalibrate the unit.

(in ft) of a normal application needs to be known. The application rate and travel speed can be found using the following equations:

$$\text{Travel speed (mph)} = \frac{\text{spreader load (tons)} \times 495}{\text{time (min)} \times \text{width (ft)} \times \text{application rate (tons/acre)}}$$

$$\text{Application rate (tons/acre)} = \frac{\text{spreader load (tons)} \times 495}{\text{time (min)} \times \text{width (ft)} \times \text{travel speed (mph)}}$$

When in this type of situation, select the gear in the tractor or truck that most closely matches the required speed (do not adjust PTO speed). If the travel speed is too high or too low, then you need to change the flow rate, altering the time it takes to empty the tank. This is accomplished by changing PTO rpm, by changing valve or gate settings, or by installing an orifice in the flow line. Any time you make adjustments, change the rpm, or use thicker manure, you should recalibrate the unit.

Spreader calibration (scale method). An alternative method of calibrating your spreader is to measure the coverage area during a typical application. Conceptually, this process is less complicated than the previous method explained, but the weight area has several limitations. First, as stated earlier, changes in manure moisture or density must be taken into account. Second, applicators must have access to expensive portable weigh scales or have load cells installed on their spreader to perform calibrations. The scale method is very similar to calibrating a liquid manure spreader, which is discussed in the next section. To calibrate a spreader, divide the weight of the applied manure by the coverage area for a given set of spreader settings, PTO rotations, and travel speed.

Spreader pattern uniformity and determining overlap. To determine the uniformity of spread and the amount of overlap needed, place a line of small, equally spaced (2-4 ft) pans or trays across the spreader path. The pans should be a minimum of 12 inches by 12 inches (or 15 inches in diameter) but no more than 24 inches by 24 inches and 2 inches to 4 inches deep. Make one spreading pass directly over the center pan. Weigh the contents caught in each pan or pour the contents into equal-sized glass cylinders or clear plastic tubes and compare the amount in each.

The effective spread width can be found by locating the point on either side of the path center where manure contents caught in the containers are half of what they are in the center. The distance between these points is the

PROBLEM 2

Adjusting travel speed.

What speed should you drive if you want to apply 4 tons of manure per acre with a 3-ton spreader? Your spreader application width is 20 ft, and your spreader empties in 6 minutes.

$$\text{Travel speed (mph)} = \frac{3 \text{ tons} \times 495}{6 \text{ min} \times 20 \text{ ft} \times 4 \text{ tons/acre}} = 3.1 \text{ mph}$$

effective spreader width. The outer fringes of the coverage area beyond these points should be overlapped on the next path to ensure a uniform rate over the entire field. “Flat-top,” “pyramid,” or “oval” patterns are most desirable and give the most uniform application. “M,” “W,” “steeple,” or “offset” patterns (Figure 36-6) are not satisfactory, and one or more spreader adjustments should be made. Refer to your owner’s manual for recommendations on spreader adjustments.

Liquid manure spreaders

To apply manure at proper rates, liquid tank spreaders must be accurately calibrated. Calibration is the combination of settings and travel speed needed to apply manure at a desired rate and to ensure uniform application. To calibrate a spreader, you must know its capacity, which the manufacturer normally provides in gallons.

Information to collect

1. Tank volume, gallons
2. Gear, rpm, and PTO speed
3. Time, minutes, to unload spreader
4. Time, seconds, to travel 100 ft or speed (in mph) of tractor/truck
5. Spread width, ft
6. Spread length, ft

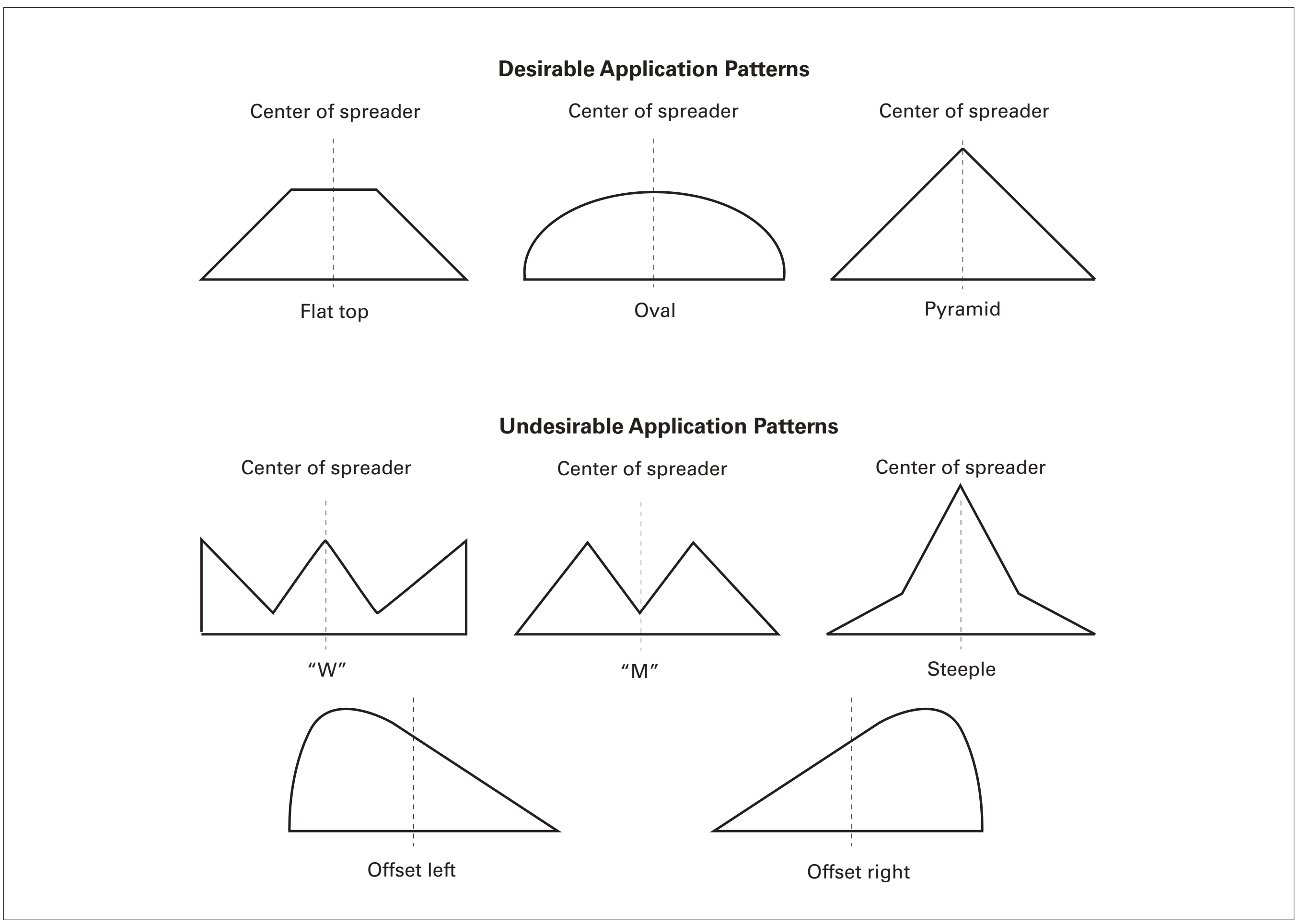

Figure 36-6. Desirable and undesirable application uniformity.

Calibration method: liquid manure spreaders.

1. For ease of measuring, spread at least one full load of manure, preferably in a square or rectangular field pattern, with normal overlaps. Record the time, in minutes, it takes to empty the spreader.
2. Determine the spreader's speed by recording the time it takes the spreader to travel 100 ft. Using the following equation, calculate the travel speed (in mph):

$$\text{Travel speed (mph)} = \frac{68.18}{\text{time (sec) to travel 100 ft}}$$

3. Measure coverage length and width, recognizing that the outer fringe areas of the coverage will receive much lighter applications than the overlapped areas.
4. To measure the coverage length,
   a. Use a measuring wheel or
   b. Tire method
      1. Place a paint mark on a tire visible from tractor cab.
      2. Measure the distance traveled by one wheel rotation.
      3. While spreading, count the number of revolutions to empty the spreader.
      4. To determine the length of spread, multiply distance per revolution by the number of revolutions.
5. To determine the coverage area in acres, multiply the length by the width and divide by 43,560.

$$\text{Coverage area (area of rectangle in ft}^2\text{)} = \text{length (ft)} \times \text{width (ft)}$$

$$\text{Coverage area (acres)} = \frac{\text{length (ft)} \times \text{width (ft)}}{43{,}560\ \text{ft}^2\ \text{per acre}}$$

6. To determine the application rate in gallons per acre, divide the gallons of wastewater in the spreader by the acres covered.

$$\text{Application rate for spreader (gal or tons/acre)} = \frac{\text{spreader load volume (gal or tons)}}{\text{coverage area (acres)}}$$

Reminder: Manufacturers normally provide liquid spreader capacities in gallons. To get tons, multiply by 0.0042.

7. Use the following equation to calculate the travel speed necessary to achieve a desired application rate:

$$\text{Travel speed (mph)} = \frac{\text{capacity (gallons)} \times 495}{\text{unload time (min)} \times \text{width} \times \text{desired rate (gallons/acre)}}$$

8. If a different application rate is desired, repeat Steps 1 through 5.

PROBLEM 3

Load area (honeywagon).
Your manure application method is a tractor-drawn tanker (honeywagon) with a 3,500-gallon capacity. You apply a load to a field and measure the application area as 35 ft wide by 350 ft long. It takes 1.17 minutes (70 seconds) to empty the spreader, and it took the spreader 20 seconds to travel 100 ft. What is the application rate in gallons per acre?

First figure the coverage area:

$$\text{Coverage area (acres)} = \frac{350 \text{ ft} \times 35 \text{ ft}}{43{,}560 \text{ ft}^2/\text{acre}} = 0.28 \text{ acres}$$

Then figure the application rate:

$$\text{Application rate for spreader (gal/acre)} = \frac{3{,}500 \text{ (gallons)}}{0.28 \text{ acres}} = 12{,}500 \text{ gal/acre}$$

Answer: At the current gear and PTO speed, the spreader applies approximately 12,500 gallons per acre.

What speed should you run if you want to apply 25,000 gallons of manure per acre with the 3,500-gallon spreader?

1. How fast was the spreader traveling?

$$\text{Travel speed (mph)} = \frac{68}{\text{time (sec) to travel 100 ft}}$$

$$\text{Travel speed (mph)} = \frac{68}{20 \text{ (sec) to travel 100 ft}} = 3.4 \text{ mph}$$

2. How fast should the spreader be traveling to apply 25,000 gallons per acre?

$$\text{Travel speed (mph)} = \frac{\text{capacity (gallons)} \times 495}{\text{unload time (min)} \times \text{width} \times \text{desired rate (gal/acre)}}$$

$$\text{Travel speed (mph)} = \frac{3{,}500 \text{ (gallons)} \times 495}{1.17 \text{ (min)} \times 35 \text{ ft} \times 25{,}000 \text{ (gal/acre)}} = 1.7 \text{ mph}$$

Answer: The spreader should travel at 1.7 mph to apply the 3,500 gallons at a rate of 25,000 gallons per acre

If you are not using a flow meter, you will have to operate the system for at least one hour before you can get an accurate reading... .

Drag hose injectors. This method calculates the speed required to pull a drag hose application system (Figure 36-2) around the field. If you are not using a flow meter, you will have to operate the system for at least one hour before you can get an accurate reading of the amount of manure you have removed from the storage tank or basin.

To calculate the required speed, you need to know

- The **discharge rate** (gpm) from
  - —A flow meter or
  - —The manufacturer's information or
  - —The amount removed from manure storage
- The desired application **rate,** gallons/acre
- The **width** of application, ft

$$\text{Speed (mph)} = \frac{495 \times \text{volume/min (gpm)}}{\text{application rate (gal/acre)} \times \text{width (ft)}}$$

To match the calculated speed, select the appropriate gear on the field tractor. If the calculated speed is too fast, you could reduce the volume applied per hour by decreasing the power to the main pump. At the same time, you may also have to reduce the nozzle (or orifice) size to keep adequate pressure in the drag hose. Another way to compensate for an excessive calculated tractor speed is to increase the application width by using a boom-style application and no direct injection.

PROBLEM 4

Drag hose boom.
A custom manure applicator measured pumped manure at a rate of 750 gpm. His injector boom is 22 ft wide, and he wants to apply 5,500 gallons per acre.

Using the preceding equation,

$$\text{Speed (mph)} = \frac{495 \times 750 \text{ gpm}}{5{,}500 \text{ gal/acre} \times 22 \text{ ft}}$$

Answer: Speed = 3.1 mph

Spot check applied rate across the width of application. All of the previous options give you the average application across the width. To check the variation across the application width or along the application length, you need to place a series of containers in the application path. Table 36-6 gives you the information to convert the depth of liquid in the *straight-walled* container to the application rate.

Because such small depths are involved, the depth method gives only an approximate application rate. A more accurate method involves weighing the contents of the container and converting this weight to an application rate.

Table 36-6. Liquid manure calibration using a straight-walled pail.

Depth of Manure in Pail, inch	Application Rate, gallons/acre
1/10	2,250
1/8	2,800
1/4	5,650
3/8	8,500
1/2	11,300
5/8	14,150
3/4	17,000
1	22,650

Sprinkler irrigation systems

Operating a sprinkler irrigation system differently than assumed in the design alters the application rate, coverage uniformity, and subsequently, the application uniformity. Operating with excessive pressure results in smaller droplets, greater potential for drift, and also accelerates the wear of the sprinkler nozzle. Pump wear tends to reduce operating pressure and flow, leading to smaller droplets. With continued use, nozzle wear results in an increase in the nozzle opening, which will increase the discharge rate while decreasing the wetted diameter. Clogging of nozzles or crystallization of main lines by struvite can result in increased pump pressure but reduced flow at the gun. Plugged intakes will reduce operating pressure. An operating pressure below design pressure greatly reduces the coverage diameter and application uniformity. Field calibration helps ensure that nutrients from liquid manure or lagoon effluent are applied uniformly and at proper rates.

Operating a sprinkler irrigation system differently than assumed in the design alters the application rate, coverage uniformity, and subsequently, the application uniformity.

The calibration of a hard-hose or cable tow system involves setting out collection containers, operating the system, measuring the amount of wastewater collected in each container, and then computing the average application volume and application uniformity.

By installing an in-line flow meter, suitable for effluent and/or slurry, in the main irrigation line, you can obtain a good estimate of the total volume pumped from the lagoon during each irrigation cycle. As the following formula indicates, the average application depth can be determined by dividing the pumped volume by the application area:

$$\text{Average application depth (inches)} = \frac{\text{volume (gallons)}}{27{,}154\ \text{gal/acre-in} \times \text{application area (acres)}}$$

The average application depth is the average amount applied throughout the field. This method works well for pivot or linear irrigation units but not as well for impact sprinklers or volume guns. Unfortunately, sprinklers do not apply the same depth of water throughout their wetted diameter. Under normal operating conditions, application depth decreases toward the outer perimeter of the wetted diameter. Big gun sprinkler systems typically have overlap based on a design sprinkler spacing of 70% to 80% of the wetted sprinkler diameter to compensate for the declining application along the outer perimeter. When operated at the design pressure, this overlap results in acceptable application uniformity.

When applying wastewater high in nutrients, it is important to determine the application uniformity.

Calibration should be performed during periods of low wind and evaporation.

The wastewater application rate from a stationary impact sprinkler or volume gun depends on the flow rate, wetted diameter, amount of time it operates at a location, and sprinkler location pattern.

When operated improperly, well-designed systems will not provide acceptable application uniformity. For example, if the pressure of an impact sprinkler or volume gun is too low, the application depth will be several times higher near the center of the sprinkler and water will not be thrown as far from the sprinkler as indicated in manufacturers' charts. Even though the average application depth may be acceptable, some areas receive excessively high applications while others receive no application at all.

When applying wastewater high in nutrients, it is important to determine the application uniformity. Collection containers distributed throughout the application area must be used to evaluate application uniformity.

Many types of containers can be used to collect flow and determine the application uniformity. Standard rain gauges work best and are recommended because they already have a graduated scale from which to read the application depth. Gauges with 0.01-inch graduations should be used for measuring application rates and evaluating sprinkler uniformity. Gauges with larger graduation should only be used for estimating application volumes. Pans, plastic buckets, jars, or anything with a uniform opening and cross section can be used, provided the container is deep enough (at least 4 inches deep) to prevent splash and excessive evaporation, and the liquid collected can be easily transferred to a scaled container for measuring. To simplify application depth computations, all containers should be the same size and shape.

All collection containers should be set up at the same height relative to the height of the sprinkler nozzle (discharge elevation). Normally, the top of each container should be no more than 36 inches above the ground. Collectors should be located so there is no interference from the crop. The crop canopy should be trimmed to preclude interference or splash into the collection container.

Calibration should be performed during periods of low wind and evaporation. The best times are before 10 a.m. or after 4 p.m. on days with a light wind (less than 5 mph). On cool, cloudy days the calibration can be performed anytime when wind velocity is less then 5 mph. Impact sprinkler systems should not be calibrated when winds exceed 3 mph.

To minimize evaporation from the rain gauge, the volume (depth) collected during calibration should be read soon after the sprinkler gun cart has moved one wetted radius past the collection gauges. Where a procedure must be performed more than once, containers should be read and values recorded immediately after each setup.

Solid-set sprinkler irrigation systems. The wastewater application rate from a stationary impact sprinkler or volume gun depends on the flow rate, wetted diameter, amount of time it operates at a location, and sprinkler location pattern. To attain acceptable application uniformity with multiple sprinkler setups, the sprinkler spacing should be 50% to 70% of the sprinkler's coverage diameter (Figure 36-7).

Determining application rates.

1. Determine the operating pressure in the field by installing a pressure gauge on the sprinkler riser or mounting a gauge on a volume gun. Verify the nozzle type and size on the sprinkler.
2. Determine the flow rate in gpm from available manufacturer's literature.
3. Determine the coverage diameter in feet from available manufacturer's literature.

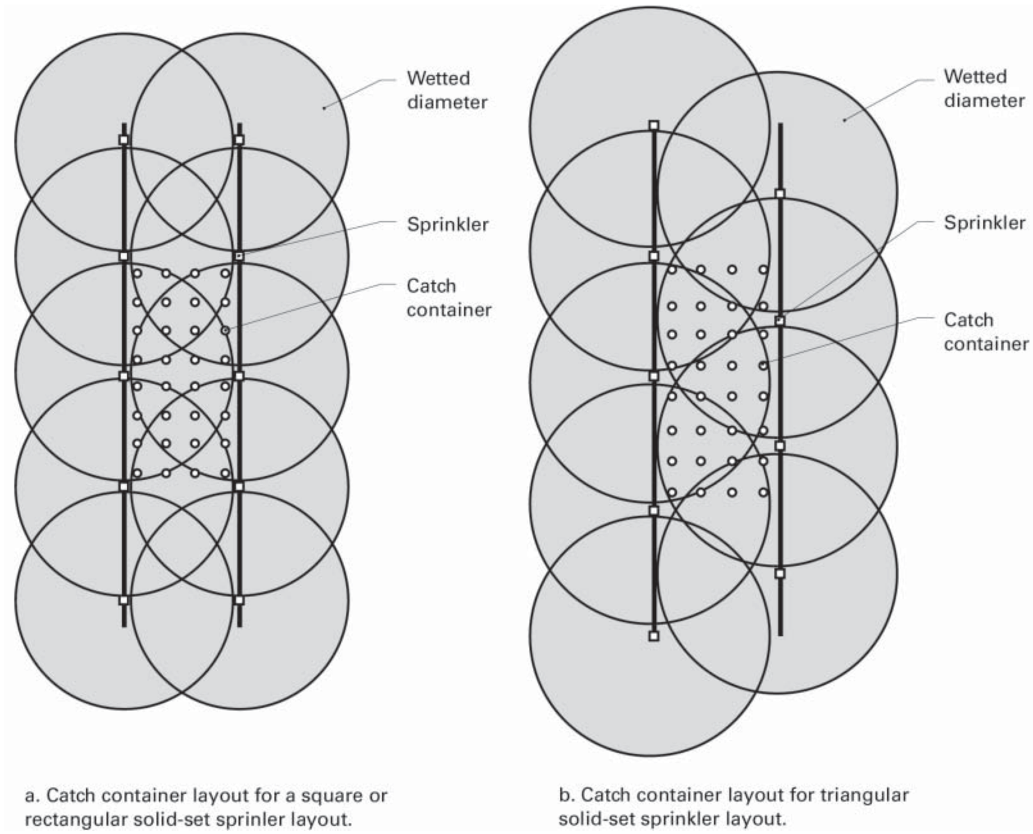

Figure 36-7. System layout for a solid-set irrigation system.
Source: MWPS-30.

4. From Step 2, calculate the required sprinkler spacing (SS) as 50% to 65% of the coverage diameter. Refer to Figure 36-7 for a diagram of a stationary sprinkler setup.

   SS (ft) = wetted diameter × percent overlap (as decimal)

5. Calculate the average application rate, inches/hr.

   $$\text{Average application depth (inches/hr)} = \frac{96.3 \times \text{sprinkler flow rate (gpm)}}{\text{sprinkler spacing (ft)} \times \text{lateral spacing (ft)}}$$

6. Determine the number of inches of wastewater that was applied.

   Application volume (inches) = # of hrs × application rate (inches/hr)

7. The N applied per acre (lb N/ac) is calculated by multiplying the inches of wastewater applied from Step 6 by the pounds of N in a 1,000 gallons of wastewater and then multiplying this result by 27.

   Nitrogen applied (lb N/ac) =
   27 × application volume (inches) × ______ lb N/1,000 gallons

PROBLEM 5

Mr. Smith is using a solid-set volume gun system to apply lagoon effluent to spray for 2 hours. The volume gun was operated at 90 psi with a 0.75-inch nozzle. The manufacturer's specifications for the gun are provided in Table 36-7. Smith wants to set up his sprinklers with a 60% overlap. His effluent was analyzed to have a plant-available nitrogen (PAN) concentration of 3.5 pounds per 1,000 gallons.

Step 1.
Nozzle size = 0.75-inch nozzle, operating pressure = 90 psi

Steps 2 and 3.
From Table 36-7. With a 0.75-inch nozzle at 90 psi, the flow rate is 155 gpm and the wetted diameter estimated as 306 ft.

Step 4.
Required sprinkler spacing, assuming a 60% sprinkler spacing.

SS (ft) = 306 ft x 0.6

SS = 183.6 ft; use 180 ft

Step 5.
Application rate

$$\text{Average application rate (inches/hr)} = \frac{96.3 \times 155\ (\text{gpm})}{180\ (\text{ft}) \times 180\ (\text{ft})}$$

Application rate = 0.46 inches/hr

Step 6.

Application volume (inches) = 2 hrs x 0.46 (inches/hr)

Application volume = 0.92 inches

Step 7.
Amount of PAN applied

Nitrogen applied (lb N/ac) =
27 x 0.92 (inches) x 3.5 lbs PAN/1,000 gallons

Amount of N applied = 86.94 lbs N/ac

Table 36-7. Sprinkler performance chart.

Operating Pressure, psi	0.5 Flow rate, gpm[1]	0.5 Wetted Diameter, ft	0.75 Flow rate, gpm[1]	0.75 Wetted Diameter, ft	1 Flow rate, gpm[1]	1 Wetted Diameter, ft	1.25 Flow rate, gpm[1]	1.25 Wetted Diameter, ft	1.5 Flow rate, gpm[1]	1.5 Wetted Diameter, ft
50	50	205	115	256	204	300	325	353	—	—
60	55	215	126	270	224	316	358	373	515	430
70	60	225	136	283	243	338	385	388	555	450
80	64	235	146	295	258	354	413	403	590	470
90	68	245	155	306	274	362	440	418	625	485
100	72	255	163	316	289	372	463	430	660	500
110	76	265	171	324	304	380	485	440	695	515
120	—	—	—	—	—	—	—	—	725	530
130	—	—	—	—	—	—	—	—	755	540

(Nozzle Size, inches: 0.5, 0.75, 1, 1.25, 1.5)

[1]gpm is gallons per minute.
Note: If your exact numbers are not listed in the table, then estimate your value based on the numbers nearest yours.

Solid-set irrigation calibration method. Rain gauges or other collection containers should be spaced in a grid pattern fully enclosing the "effective" wetted area defined by the sprinkler spacing. The most common spacing pattern for stationary sprinklers is a square spacing where the distance between sprinklers is the same as the spacing between laterals. The spacing between sprinklers and laterals is normally between 50% to 65% of the sprinkler-wetted diameter specified by the manufacturer.

Collection gauges should be placed 1/4 of the lateral line length from the main and no further apart than 1/4 of the wetted sprinkler radius or effective sprinkler spacing. (For example, if the effective spacing is 80 ft, spacing between gauges should be no more than 20 ft).

The grid pattern and number of gauges required to complete the calibration depends on the pattern of operating the irrigation system. The size of the calibration area should be no less than the "effective" area of one sprinkler. When sprinklers are arranged in a rectangular or square pattern with proper overlap, an "effective area" receives flow from four sprinklers. Thus, a minimum of four sprinklers should be included in the calibration.

The reliability of the calibration generally improves as more sprinklers are included in the calibration area. As described in the preceding paragraph, if all sprinklers contributing flow to the calibration area are functioning correctly, it is necessary to include only the minimum number of sprinklers. But, a malfunctioning sprinkler can greatly influence the calibration results. Its effect on the calibration depends on the calibration setup and number of sprinklers being calibrated, the malfunctioning sprinkler's position within the calibration area, the direction of the prevailing wind, and the nature of the malfunction. For these reasons, it is extremely important to observe the performance of every sprinkler contributing to the calibration while the calibration is being performed and to record any obvious performance irregularities. The more sprinklers that can be included in the calibration, the more representative the calibration results will be of the entire field, and the less influence one malfunctioning sprinkler will have on the calibration results.

The grid pattern and number of gauges required to complete the calibration depends on the pattern of operating the irrigation system.

...stationary big guns should not be operated "head to head"... .

To minimize evaporation from the rain gauge, the volume (depth) collected during calibration should be read as soon as a zone or sprinkler is shut off. Where a procedure must be performed more than once, containers should be read and values recorded immediately after each different setup.

Operating patterns affect collection container layout and calibration procedures and results. Typical patterns for stationary sprinklers include

Square sprinkler spacing operated as a block (two or more adjacent laterals operating at the same time)(Figure 36-8). *Volume gun systems:* This procedure should be repeated for each gun or hydrant contributing to the area being calibrated. This operating situation results where one or two guns are moved from hydrant to hydrant throughout the field. Since stationary big guns should not be operated "head to head" (multiple sprinklers operating side-by-side and throwing water on the same area simultaneously), guns must therefore be operated individually for the same amount of time to complete the calibration.

As depicted in Figure 36-8, the calibration area may be positioned or centered between the two laterals. Four sprinklers contribute area in the setup. With no wind effects, all four sprinklers should contribute equal flow to the calibration area (provided all sprinklers are functioning properly). If one of the four sprinklers is functioning improperly, the calibration results are not biased by its position within the calibration area.

An application uniformity greater than 75 is excellent for stationary sprinklers. An application uniformity between 50 to 75 is in the "good" range and is acceptable for wastewater application. Generally, an application uniformity below 50 is not acceptable for wastewater irrigation with stationary sprinklers. If the computed U_c is less than 50, system adjustments are required. Contact your irrigation dealer or technical specialist for assistance.

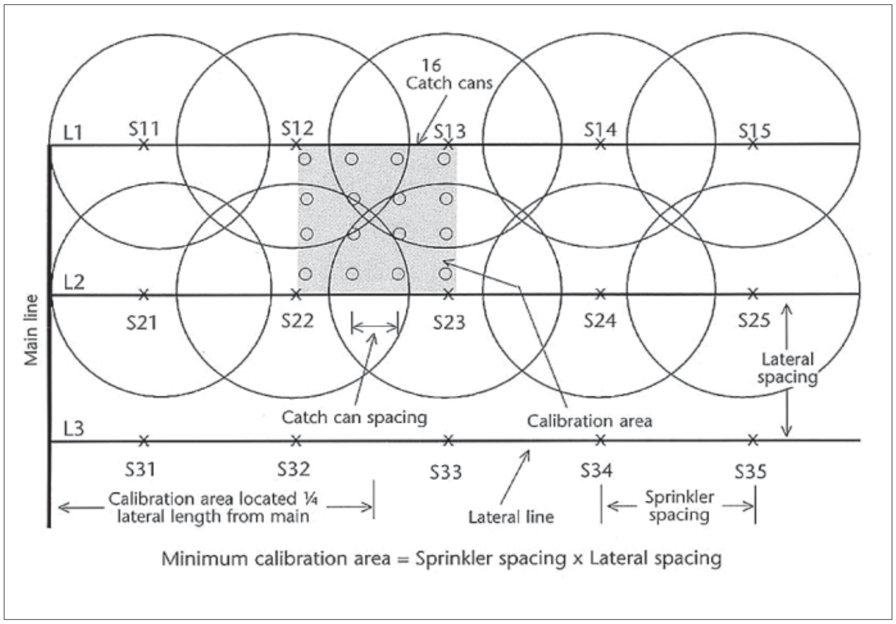

Figure 36-8. Collection container layout to calibrate sprinklers or volume guns in a square sprinkler spacing operating as a block.

PROBLEM 6

Block pattern with two or more laterals operating at the same time (scenario shown in Figure 36-8).

1. Determine the effective sprinkler area. This is the area defined by SS along a lateral multiplied by the spacing between laterals. (Example: 80 ft by 80 ft is typical for a solid-set wastewater system). The effective sprinkler area is the **minimum** area to be included in the calibration area.
   Note: The calibration area can be more than the effective area of one sprinkler.

2. Determine the necessary spacing between collection gauges (1/4 the sprinkler spacing). For an effective SS of 80 ft, the rain gauge spacing should not exceed 20 ft (80 ft/4 = 20 ft). Gauges closest to the sprinklers should be placed a distance of 1/2 the gauge spacing from the sprinkler. For a gauge spacing of 20 ft, the first row of gauges should be 10 ft from the lateral line or sprinklers.

3. Determine the number of gauges required. The minimum number is 16.

   $$\text{Number of gauges} = \frac{\text{calibration area (ft}^2\text{)}}{\text{gauge area (ft}^2\text{)}}$$

   Example:

   Calibration area = 80 ft x 80 ft = 6,400 ft^2

   Gauge area = 20 ft x 20 ft = 400 ft^2

   $$\text{Number of gauges} = \frac{6{,}400\ \text{ft}^2}{400\ \text{ft}^2}$$

4. As Figure 36-8 shows, set out gauges in a rectangular pattern equally spaced at the distance determined in Item 2 (20 ft) within the calibration area.

5. Operate the system for the normal operating time for a full cycle. Record the time of operation (duration in hrs).

6. Immediately record the amounts collected in each gauge.

7. Add the amounts in Item 6 and divide by the number of gauges. This is the average application depth (inches).

   $$\text{Average application depth} = \frac{\text{sum of amounts collected in all gauges}}{\text{number of gauges}}$$

8. Calculate the deviation depth for each gauge. The deviation depth is the difference between each individual gauge value and the average value of all gauges (Item 7). Record the absolute value of each deviation depth (absolute value means the sign of the number [negative sign] is dropped and all values are treated as positive). The symbol for absolute value is a straight thin line. For example, |2| means treat the number 2 as an absolute value. It does not mean the number 121. The symbol is used in formulas in the text.

Deviation depth =

$$|\text{Depth collected in gauge } i - \text{average application depth}|$$

"i" refers to the gauge number

9. To get the average deviation, add the amounts in Item 8 to get the "sum of the deviations" from the average depth and divide by the number of gauges.

Application rate depth =

$$\frac{\text{sum of deviations (add amounts computed in Item 8)}}{\text{number of gauges}}$$

10. The precipitation rate (inches/hour) is computed by dividing the average application depth (inch) by the application time (hours).

$$\text{Precipitation rate} = \frac{\text{average application depth (inch)}}{\text{application time (hrs)}}$$

11. Determine the application uniformity. The application uniformity is often computed using the mathematical formula referred to as the Christiansen Uniformity Coefficient (U_c). It is computed as follows:

$$U_c = \left[1 - \frac{\text{average deviation (Item 9)}}{\text{average depth (Item 7)}}\right] \times 100$$

12. Interpret the calibration results. The higher the index value, the more uniform the application. An index of 100 means that the uniformity is perfect–that the exact same amount was collected in every gauge.

One lateral operating with no overlap between laterals. A typical case when large-volume gun sprinklers are operated in narrow fields or smaller irrigation systems that use single laterals of impact sprinklers (Figure 36-9). The procedure must be repeated for each gun/sprinkler or sprinkler position (hydrant) contributing to the effective area being calibrated. This operating situation results where one or two guns are moved from hydrant to hydrant throughout the field or when a single row of impact sprinklers are operated where they do not overlap another sprinkler. Since stationary big guns should not be operated "head to head" (two or more sprinklers throwing water on the same area simultaneously), two adjacent guns must be operated individually to complete the calibration.

The calibration procedure is similar to those above except outer edges do not receive overlap and must be excluded from the effective area calculations. Collection gauges may be centered between two adjacent sprinklers.

A general rule in irrigation design is to assume that the width of the effective area is between 50% to 65% of the wetted diameter of the sprinkler (often 60% is used). The first calibration approach accepts this design guideline that the effective width of the lateral is 60% of the wetted diameter of one sprinkler. As Figure 36-9 shows, 16 gauges are set out (eight gauges on each side of the lateral) with all 16 gauges positioned within the effective sprinkler width. The outer edges are ignored at the onset of the calibration. Flow from all sprinklers is assumed and then averaged to compute the average application depth for the effective area.

As the same figure also shows, collection gauges are centered between Guns 2 and 3 or Guns 3 and 4. (The actual location depends on the length of the lateral). In this setup, the procedure is performed twice since only two guns or gun locations contribute to the calibration.

An application uniformity greater than 75 is excellent for stationary sprinklers. An application uniformity between 50 to 75 is in the "good" range and is acceptable for wastewater application. Generally, an application uniformity below 50 is not acceptable for wastewater irrigation. If the computed U_c is less than 50, system adjustments are required. Contact your irrigation dealer or technical specialist for assistance.

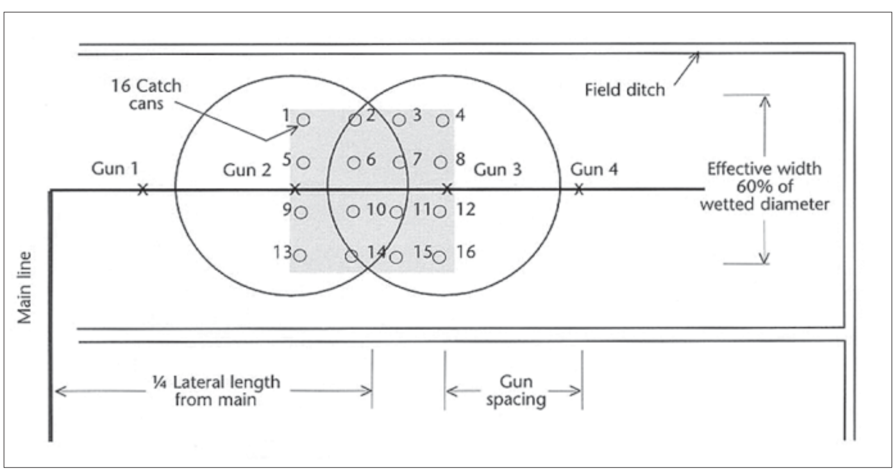

Figure 36-9. Collection container layout to calibrate one lateral of sprinklers or volume guns with no overlap between laterals.

PROBLEM 7

Single lateral or gun sprinkler with no overlap from adjacent laterals (scenario shown in Figure 36-9).

1. Determine the wetted diameter of a sprinkler or field width.
2. Determine the necessary spacing between collection gauges. The spacing in the direction along the lateral should be 1/4 of the effective sprinkler spacing. The gauge spacing perpendicular to the lateral should be 1/8 of the wetted diameter or width of the field.

$$\text{Spacing between collection gauges parallel to lateral} = \frac{\text{effective sprinkler spacing (ft)}}{4}$$

$$\text{Spacing between collection gauges perpendicular to lateral} = \frac{\text{sprinkler-wetted diameter (ft)}}{8}$$

3. Determine the number of gauges required.
   - The minimum number is 32 to perform the procedure in one setup (both sides of lateral at the same time).
   - One side of lateral calibrated at a time requires 16 gauges, procedure performed twice, once on each side of the lateral.

4. As Figure 36-9 shows, set out gauges in a rectangular grid pattern, spaced at the distances determined in Item 2. Be sure to label gauges by rows (rows should be oriented parallel to and outward from the lateral line). The first row of gauges should be located 1/2 of the gauge spacing from the lateral.

5. Operate the system the normal operating time for a full cycle. Record the time of operation (duration in hours).

6. Immediately record the amounts collected in each gauge. If only one side of the lateral is calibrated at a time, after you record the collection amounts, empty and move the collection containers to the other side and repeat Steps 4 through 6 for exactly the same time duration as recorded in Item 5.

7. Add the "nonzero" amounts collected and divide by the number of gauges with a nonzero amount. This is the "preliminary" average application depth (inches) within the "wetted" calibration area.

$$\text{Average application depth} = \frac{\text{sum of nonzero amounts collected}}{\text{number of nonzero gauges}}$$

8. Determine the average application depth by rows parallel to the lateral. Include zero catches in the row computations.

$$\text{Average row application depth} = \frac{\text{sum of collection amounts from all gauges on the row}}{\text{number of row gauges}}$$

9. Identify and delete those rows whose average application depth (Item 8) is less than 1/2 of the preliminary average application depth (Item 7).

10. Determine the effective application width. The boundary is defined as the distance from the lateral to the last row furthest from the lateral that is retained.

11. Determine the average application depth within the effective area. Add amounts from all gauges in rows within the effective width (rows retained in Item 9 and Item 10).

$$\text{Corrected average application depth} = \frac{\text{sum amounts collected in rows within effective width}}{\text{number of gauges within the effective width}}$$

12. Calculate the deviation depth for each gauge. The deviation depth is the difference collected in each usable gauge and the average application depth (Item 11). Record the absolute value of each deviation depth. Absolute value means the sign of the number (negative sign) is dropped and all values are treated as positive. The symbol for absolute value is a thin straight line.

$$\text{Deviation depth} = \left|\text{depth collected at postion i} - \text{average application depth (Item 11)}\right|$$

"i" refers to the gauge position within the effective calibration area

13. Add the amounts in Item 12 to get the "sum of the deviations" from the average depth and divide by the number of gauges.

$$\text{Application deviation depth} = \frac{\text{sum of deviations (add amounts computed in Item 12)}}{\text{number of gauges within the effective width}}$$

14. Using the U_c mathematical formula, determine the application uniformity, which is computed as follows:

$$U_c = \frac{\left[\text{average depth (Item 7)} - \text{average deviation (Item 13)}\right] \times 100}{\text{average depth (Item 7)}}$$

15. Interpret the calibration results. The higher the index value, the more uniform the application. An index of 100 means that the uniformity is perfect–the exact amount was collected in every gauge.

Hard-hose and cable tow traveling guns are calibrated by placing a row (transect) of collection containers or gauges perpendicular to the travel direction… .

A minimum of 16 gauges should be used to calibrate hard-hose travelers… .

Traveling gun systems. Hard-hose and cable tow traveling guns are calibrated by placing a row (transect) of collection containers or gauges perpendicular to the travel direction (Figure 36-10). The outer gauge on each end of the row should extend past the farthest distance the gun will throw wastewater to ensure that the calibration is performed on the "full" wetted diameter of the gun sprinkler. Multiple rows increase calibration accuracy.

Containers should be spaced no further apart than 1/16 of the wetted diameter of the gun sprinkler not to exceed 25 ft. At least 16 gauges should be used in the calibration. A minimum of 16 gauges should be used to calibrate hard-hose travelers except where the wetted diameter from large guns exceeds 400 ft. (The maximum recommended spacing between gauges is 25 ft x 16 = 400 ft.) As Figure 36-10 shows, gauges should be set at least one full wetted diameter of throw from either end of the travel lane.

The system should be operated so the minimum travel distance of the gun cart exceeds the wetted diameter of throw. Application volumes should be read as soon as the last gauges stop being wetted.

Calibration method.

1. Estimate the gun's wetted diameter. Check the actual operating pressure at the sprinkler, and verify the nozzle type and size. Determine the wetted diameter from the manufacturer's charts.
2. Determine the number of collection gauges and spacing between gauges. For a wetted diameter of 320 ft, the rain gauge spacing should not exceed 20 ft (320 ft/16 = 20 ft).
3. Label gauges outward from the gun cart as either left or right (L1, L2, L3, etc; R1, R2, R3, etc.)
4. As labeled and shown in Figure 36-10, set out gauges along a row equally spaced at the distance determined in Item 2 (20 ft). The row should be at least one wetted diameter from either end of the pull. The first gauge on each side of the travel lane should be 1/2 of the gauge spacing from the center of the lane. For a gauge spacing of 20 ft, L1 and R1 should be 10 ft from the center of the lane.

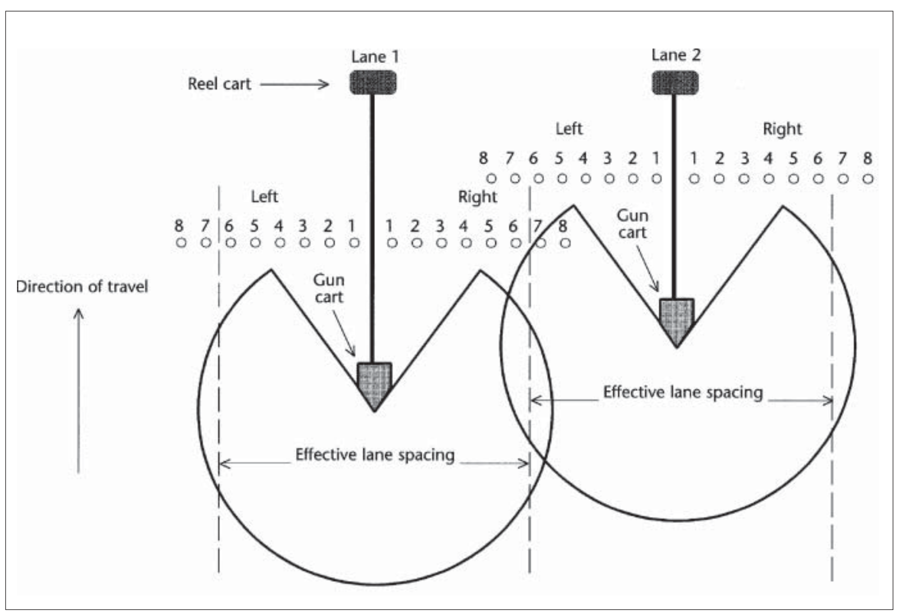

Figure 36-10. Calibration setup for hard-hose travelers.

5. Operate the system until the gun has completely passed all collection containers. Record the “starting” time that wastewater begins to be applied along the row of gauges and the “ending” time when wastewater is no longer being applied anywhere along the row. Also record the distance traveled in feet for the time of operation.
6. Immediately record the amounts collected in each gauge.
7. Identify those gauges that fall outside the effective lane spacing (Figure 36-10). This volume is the overlap volume that is collected when the system is operating on the adjacent lane.
8. Superimpose (left to right and vice versa) the gauges just outside the effective width with the gauges just inside the effective width. Add the volumes together.

   For the layout shown in Figure 36-10, add the volume (depth) collected in gauge R8 (outside the effective lane spacing) to volume (depth) collected in gauge L5 (inside the effective lane spacing). Similarly, R7 is added to L6; L8 is added to R5; and L7 is added to R6. This is now the application volume (depth) within the effective lane spacing adjusted for overlap.

9. Add the amounts collected in all gauges and divide by the number of gauges within the effective area. This is the average application depth (inches) within the effective lane spacing.

$$\text{Average application depth} = \frac{\text{sum of amounts collected in all gauges}}{\text{number of gauges within effective width}}$$

10. Calculate the deviation depth for each gauge. The deviation depth is the difference between each individual gauge value and the average value of all gauges (Item 7). Record the absolute value of each deviation depth. Absolute value means the sign of the number (negative sign) is dropped and all values are treated as positive. The symbol for absolute value is a straight thin line. For example, |2| means treat the number 2 as an absolute value. It does not mean the number 121. The symbol is used in formulas in the text.

$$\text{Deviation depth} = \left|\text{depth collected in gauge i} - \text{average application depth}\right|$$

"i" refers to the gauge number

11. Add the amounts in Item 10 to get the “sum of the deviations” from the average depth and divide by the number of gauges to get the average deviation.

$$\text{Average deviation depth (inches)} = \frac{\text{sum of deviations (add amounts computed in Item 10)}}{\text{number of gauges within effective lane spacing}}$$

12. The precipitation rate (inches/hr) is computed by dividing the average application depth (inch)(Item 9) by the application time (hrs)(Item 5)

$$\text{Precipitation rate (inches/hr)} = \frac{\text{average application depth (inches)}}{\text{application time (hrs)}}$$

13. Compute the average travel speed.

$$\text{Average travel speed} = \frac{\text{distance traveled (ft)}}{\text{time (minutes)}}$$

14. Using the U_c mathematical formula, determine the application uniformity, which is computed as follows:

$$U_c = \frac{[\text{average depth (Item 9)} - \text{average deviation (Item 11)}] \times 100}{\text{average depth (Item 9)}}$$

15. Interpret the calibration results. The higher the index value, the more uniform the application. An index of 100 means that the uniformity is perfect–the exact same amount was collected in every gauge.

For travelers with proper overlap that are operated in light wind, an application uniformity greater than 85 is outstanding and very rare. Only about 10% of travelers operate at such a high level of uniformity.

Application uniformity between 70 to 85 is in the "good" range and is acceptable for wastewater application. Generally, an application uniformity below 70 is considered unacceptable for wastewater irrigation using travelers. If the computed U_c is less than 70, system adjustments are required. Contact your irrigation dealer or technical specialist for assistance.

Center pivot and linear move irrigation systems. As Figure 36-11 illustrates, center pivot and linear move irrigation systems are calibrated by placing a row (transect) of collection containers parallel to the system. Two or more rows increase calibration accuracy.

For center pivot systems with more than three towers, place the first collection container beside the first moving tower (140-180 ft from the boss

For travelers with proper overlap that are operated in light wind, an application uniformity greater than 85 is outstanding and very rare.

...center pivot and linear move irrigation systems are calibrated by placing a row (transect) of collection containers parallel to the system.

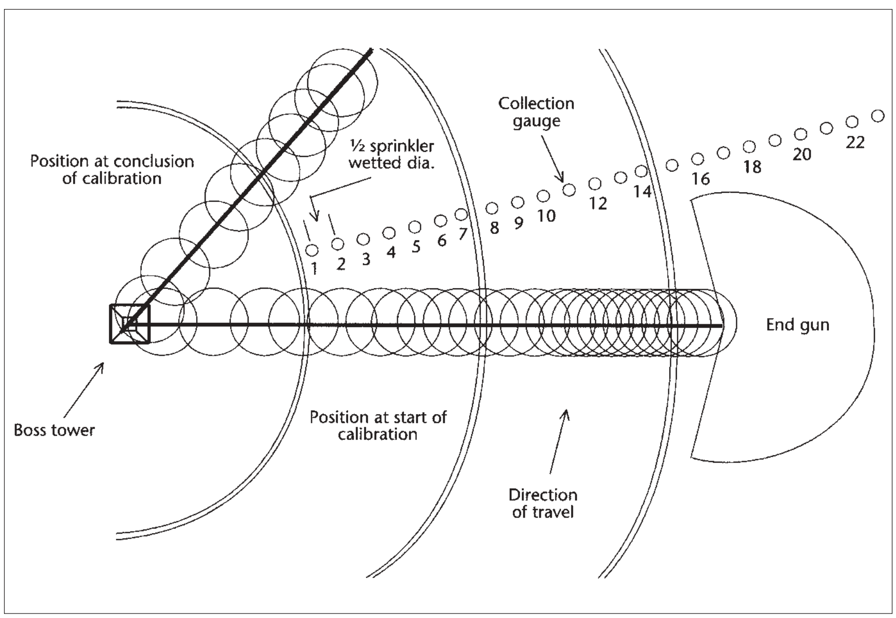

Figure 36-11. Collection container layout for calibration of a center pivot irrigation system.

tower [pivot point]). This setup will miss the area between the boss and first tower, but it is necessary to omit this section through this zone. The area missed will be less than 3 acres and will usually represent less than 10% of a typically sized system. If the system has only one moving tower, place the first container 50 ft from the boss tower. Place equally spaced containers at the end of the system. For lateral move systems, place containers throughout the entire length of the system.

Containers should be spaced no further apart than 1/2 of the wetted diameter of rotary impact sprinklers, or 1/4 of the diameter of gun sprinklers or 50 ft, whichever is less. On systems with spray nozzles, collection containers should be spaced no further than 30 ft. A 20- to 25-ft spacing is generally recommended for all types of sprinklers, which will result in six to eight collection containers between each tower. Collection containers should be placed so they intercept discharge from a range of lateral distances from the sprinkler (midpoint, quarter point, directly under sprinkler, etc.). This goal can be accomplished by selecting a catch can spacing different from a multiple of the sprinkler spacing along the lateral. Where end guns are used, the transect of collection containers should extend beyond the gun's throw.

The system should be operated so the minimum travel distance exceeds the sprinkler wetted diameter for the containers closest to the boss tower. Application volumes should be read as soon as all gauges stop being wetted.

Calibration method.

1. Determine the wetted diameter of the sprinkler, gun, or spray nozzle.
2. Determine the necessary spacing between collection gauges. The spacing should not exceed 50 ft. The recommended spacing is 25 ft or less.
3. Determine the number of gauges required. Label gauges outward from the boss tower.
4. Place gauges along a row as labeled and shown in Figure 36-12, equally spaced at the distance determined in Item 2. The row should be in the direction of system travel and at least 1/2 the sprinkler wetted diameter from the sprinkler nearest the boss tower.
   Note: The alignment of the row relative to the center pivot system does not matter as long as the system operates completely over each collection gauge. For most setups, the gauges closest to the boss tower will control how long the system must be operated to complete the calibration.
5. Operate the system until the sprinkler nearest the boss tower has completely passed the collection containers. Record the time of operation (in minutes) and distance traveled (in ft) at a reference point along the system (usually the last tower).
6. Immediately record the amounts collected in each gauge.
7. Add the amounts in Item 6 and divide by the number of gauges. This is the average application depth (inches).

$$\text{Average application depth} = \frac{\text{sum of amounts collected in all gauges}}{\text{number of gauges}}$$

8. Where an end gun is used, identify those gauges at the outward end where the depth caught is less than 1/2 of the average application depth computed in Item 7. The distance to the last usable gauge is the effective radius of the system from which the effective acreage is computed.

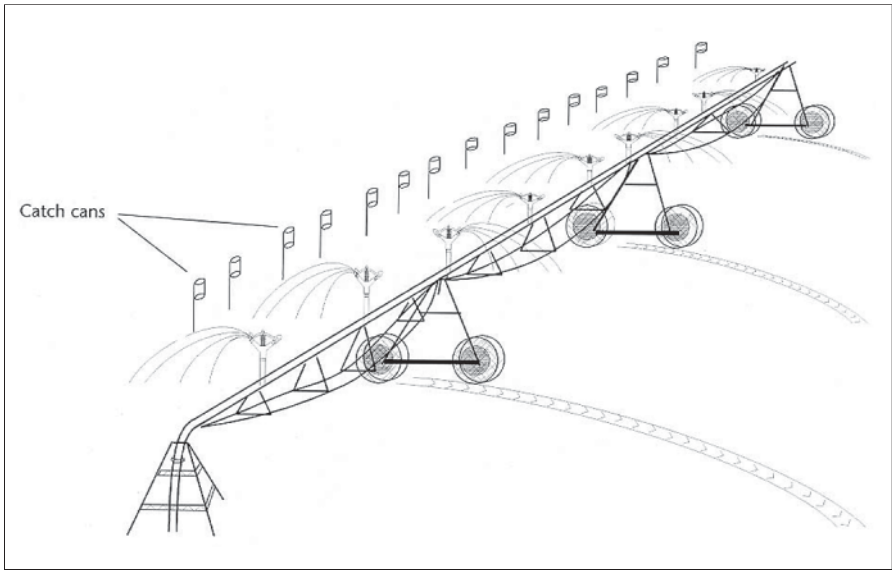

Figure 36-12. Calibration layout for center pivot irrigation systems.

9. Re-compute the average application depth for the "usable" gauges identified in Item 8 that fall within the effective width of the system. (Eliminate gauges on the outer end of the system where the depth caught is less than 1/2 of the average application depth.)
   Note: All gauges interior to the "effective width" of the system are included in the computations regardless of the amount caught in them.
10. Compute the reference travel speed and compare to the manufacturer's chart.

$$\text{Travel speed (ft/minute)} = \frac{\text{distance traveled (ft)}}{\text{time (minutes)}}$$

11. Calculate the deviation depth for each "usable" gauge. The deviation depth is the difference between each individual gauge value and the average value of all gauges (Item 9). Record the absolute value of each deviation depth. (Absolute value means the sign of the number [negative sign] is dropped, and all values are treated as positive). The symbol for absolute value is a straight thin line. For example, |2| means treat the number 2 as an absolute value. It does not mean the number 121. The symbol is used in formulas in the text.

$$\text{Deviation depth} = \left|\text{depth collected in gauge i} - \text{average application depth}\right|$$

"i" refers to the gauge number

12. Add the amounts in Item 11 to get the "sum of the deviations" from the average depth and divide by the number of gauges to get the average deviation.

$$\text{Average deviation depth} = \frac{\text{sum of deviations (add amounts computed in Item 11)}}{\text{number of usable gauges}}$$

13. Using the U_c mathematical formula, determine the application uniformity, which is computed as follows:

$$U_c = \frac{[\text{average depth (Item 7)} - \text{average deviation (Item 12)}] \times 100}{\text{average depth (Item 7)}}$$

14. Interpret the calibration results. The higher the index value, the more uniform the application. An index of 100 means that the uniformity is perfect–the exact same amount was collected in every gauge.

For center pivot and linear move systems operated in light wind, an application uniformity greater than 85 is common. An application uniformity between 70 to 85 is in the "good" range and is acceptable for wastewater application. Generally, an application uniformity below 70 is considered unacceptable for wastewater irrigation using center pivots and linear move systems. If the computed U_c is less than 70, system adjustments are required. Common problems include clogged nozzles, sprinklers not rotating properly, inadequate system pressure, sprinklers installed in the wrong order, end gun not adjusted properly, wrong end gun nozzle, and/or worn nozzles. Contact your irrigation dealer or technical specialist for assistance.

For center pivot and linear move systems operated in light wind, an application uniformity greater than 85 is common.