Learning Objectives

After studying this unit, you will be able to:

• Understand the importance of calibration for chemigators.
• Know what tools you will need for calibration.
• List the six basic steps in calibrating a chemigation system.
• Successfully calibrate your equipment using the steps and examples given.
• Be able to calibrate center pivot, stationary sprinkler, and drip/trickle systems.

 Calibration is essential. It allows you to make sure your equipment delivers the right amount of pesticide uniformly over the target area. In this unit, you will learn how to calibrate your chemigation system, whether it is a center pivot, stationary sprinkler, or drip/trickle type. Since surface/gravity flow systems are not widely used in Hawaii, this manual does not cover calibration techniques for these systems.

 You will understand why you should do your own calibration instead of relying on the manufacturer's data. You will also be able to follow the explanations step-by-step, using the examples in this unit. Most of all, you will understand the importance of calibration to successful chemigation.
Terms to Know

Calibration—The process of determining the correct amount of pesticide to apply to a certain area by measuring and adjusting the delivery rate of your application equipment.

Constant—A number with a fixed value, often used as a conversion factor.

Emitter—An opening, or orifice, on a drip irrigation system through which water emerges.

Irrigation Set—The area to be irrigated at any one time (using a drip/trickle system). The length of time an irrigation system operates (set time).

Lateral(s)—Irrigation pipelines that supply water to sprinklers or emitters. They are parallel to each other and are connected to a main line.

Spray Pattern—The distribution of a liquid from a nozzle.

Viscosity—A measure of the resistance of a liquid to flow. The opposite of viscosity is fluidity, or the lack of flow resistance.

Wetted Radius—The straight-line distance from the center of the pivot to the edge of the area covered by the sprinkler system.
Calibration Basics

Calibrating your chemigation system is critical. Without an accurate calibration, you cannot be sure whether the amount of chemical you are applying is correct. If you apply too much, you may harm the environment. You may also violate the label and run afoul of the law. If you apply too little, you may not control the target pest(s). You must apply an amount of chemical that is equal to or less than the amount given on the label.

Always calibrate the system yourself. The manufacturer’s data provide a good starting point and may help you decrease trial and error. But the conditions at your site will not be the same as those at the factory. Think of calibration as a standardization process. When you calibrate, you identify and correct deviations from a standard. This requires accurate measurements and the right tools.

Tools and Equipment

To calibrate properly, you will need a few basic tools. These include:
- a stopwatch,
- a steel tape measure (at least 100 feet long),
- a pocket calculator, and
- marking flags visible from a distance.

You also need a calibration tube. This is a clear plastic tube such as a large graduated cylinder. Connect the tube to the intake side of the injection pump. It is handy to have fittings and valves that let you switch between the calibration tube and the main supply tank without shutting off the injection pump. The tube makes it easier to check your calibration regularly while chemigating. For more information on calibration tubes, see Unit 4 (Application Systems and Equipment).

System Uniformity

Before you start chemigating, you should check the uniformity of your irrigation system. You need to make sure that the pesticide is distributed evenly over the target area. In the end, a uniform application of chemicals depends on a uniform application of water. See Unit 2 (Before You Chemigate) for a discussion of system uniformity.

Uniformity of the Spray Pattern

You can check the uniformity of a sprinkler system’s spray pattern by using catch cans. Use empty cans of equal size, such as coffee cans. Make sure the catch cans are straight sided and have the same diameter. Follow the steps below to test the distribution pattern of your system.

1. Place the catch cans at equal intervals (about 10 feet apart) along the full length of the irrigation system. Use an open area, and avoid the canopy of the growing crop.
2. Operate your sprinkler system at the same speed and pressure you will use when you apply the pesticide. You should apply about 1/2 inch of water to ensure accuracy.
3. Record the amount of water in each can and its location when the system has passed completely over all the cans.
4. Compare the average amount of water in all cans to the amount actually collected in each can. If you find a large deviation from the average for any of the cans, there may be a problem at that location.
5. Check the nozzles or sprinklers for damage at any point where you find a large deviation from the average amount collected.

NOTE: A large deviation means enough of a difference in distribution of liquid to result in an off-label application of pesticide. Too much pesticide may also cause crop damage in the areas irrigated by the nozzles in question.

For more information on how to determine uniformity, contact your irrigation advisor.

Water Volume

There are several important factors to consider when you select how much water to use during chemigation. These are:
- the capacity and speed of your system,
• the type of chemical you will apply,
• label directions for volume needed per unit area,
• the degree of incorporation into the soil (specified on the label), and
• the rate of infiltration into the soil.

Measurements

Calibration, of course, is all about accurate measurements. The calculations will partly depend on the type of irrigation system you have. If you are using a full-circle center pivot, you need to measure:

• the acreage treated, and
• the rate of coverage.

You do not need to make all your measurements at the time of treatment. It is easiest to measure a field when the crop is small or there is no crop present. You can even measure machine speeds if you have run the machine enough to establish firm wheel paths. When you begin your treatment, set the speed control in exactly the same places as they were when you took the measurements. Avoid slack in the controls by always setting the speed while turning the control knob in the same direction.

Six Basic Steps

Calibration is similar for most types of irrigation systems. There are six basic steps to follow:
1. Determine the size of the treated area.
2. Determine the amount of pesticide to apply per acre.
3. Determine the total amount of pesticide you need (multiply step 1 by step 2).
4. Determine the injection time.
5. Determine the injection rate in gallons per hour (divide step 3 by step 4).
6. Determine the injection pump setting that will deliver the desired injection rate (from step 5).

NOTE. When you calibrate, you should also determine the total fluid output of your irrigation system. This will help you prevent overwatering, deep percolation, and runoff.

We will start with the center pivot system.

Calibrating a Center Pivot System

When you calibrate a center pivot system, you determine how fast the center pivot will cover the field. You then adjust the injection pump to apply the right amount of chemical per acre.

If you are calibrating a full-circle center pivot, leave the end gun either on or off for the entire circle. In this way, you can easily gauge the total wetted area. It is the straight-line distance from the center of the pivot to the edge of the area wetted by the sprinkler system. This is also called the “wetted radius.”

Measurements

To measure the lateral on your system, follow this procedure. Using a steel tape measure, start at the center of the pivot. Keeping the tape taut, extend it on a straight line outward to the edge of the wetted area. Do not let the tape go limp. If you do, it will follow the contour of the surface and will not represent a straight line. If you are careful when measuring lengths, you will keep calibration errors to a minimum.

Be careful if you are using end sprinklers or end guns. High-pressure sprinklers cover about 30 to 50 feet past the end of the pivot while spray sprinklers cover only 10 to 20 feet. If the end sprinkler is a volume sprinkler, do your measurements with the sprinkler shut off. Large sprinklers are prone to wind drift and often have poor distribution patterns. Some experts recommend that they not be used for chemigation with pesticides. In this case, you would not include them when measuring the wetted radius.
Step 1: Determine the Size of the Treated Area

**Full Circle**

Assume that the area you are treating is a full circle. To figure the size of the treated area in square feet, you must know:

- the wetted radius, expressed as “r,” and
- the value of \( \pi \) (3.14), also written as “\( \pi \).”

The wetted radius is the distance (in feet) from the pivot point to the edge of the wetted area.

\( \pi \) is a constant value used to determine the area and volume of circles, spheres, and other curved objects. \( \pi \) is commonly expressed by the Greek letter “\( \pi \).” Its value for the purposes of this manual is 3.14.

Calculate the size of the treated area by using the following formula:

\[
\text{Area treated (in square feet)} = \pi \times r^2
\]

To convert the area from square feet to acres, divide the square footage of the area treated by the number of square feet in 1 acre (43,560).

**Example 1**

Assume the distance from the pivot point to the edge of the wetted area is 1,200 feet. What is the area of the circle you will treat?

\[
\text{Area of the circle} = \pi \times (1,200)^2 = 3.14 \times (1,200)^2 = 4,521,600 \text{ sq ft}
\]

When necessary, convert the area from square feet to acres:

\[
\frac{4,521,600 \text{ sq ft}}{43,560 \text{ sq ft per acre}} = 103.8 \text{ acres}
\]

**Partial Circle**

Sometimes, you may treat a partial circle. In this case, simply multiply the formula above (for a full circle) by the part of the circle that you treat. For example, if you will treat a half-circle, multiply the formula by 1/2.

**Example 2**

Find the area of a half-circle using the example above.

\[
\text{Area of the half-circle} = \frac{4,521,600 \text{ sq ft}}{2} = 2,260,800 \text{ sq ft}
\]

When necessary, convert the area from square feet to acres:

\[
\text{Acreage of the half-circle} = \frac{2,260,800 \text{ sq ft}}{43,560 \text{ sq ft per acre}} = 51.9 \text{ acres}
\]
TREATING CORNERS

To treat corners, you need to know how to calculate the area of a triangle. To do this, you must know:

- the length of the triangle’s longest side (its base), and
- the width of the triangle at its widest point (its height).

Make sure that both dimensions are in the same units, usually feet. Then, multiply the base by the height. Divide the resulting value by two.

\[
\text{Area of the triangular site} = \frac{\text{Base} \times \text{Height}}{2}
\]

**Example 3**

You are planning to treat corners while chemigating a triangular field. The field is 250 feet wide at its widest point (height) and 400 feet along its longest side (base). What is the area of the field?

\[
\text{Area of the triangular field} = \frac{400 \text{ ft} \times 250 \text{ ft}}{2} = 50,000 \text{ sq ft}
\]

When necessary, convert the area in square feet to acres. Divide the square footage of the triangular field by the number of square feet in 1 acre.

\[
\text{Acreage of the triangular field} = \frac{\text{Square footage of the field}}{43,560 \text{ sq ft per acre}} = \frac{50,000 \text{ sq ft}}{43,560 \text{ sq ft per acre}} = 1.15 \text{ acres}
\]

**Step 2: Determine the Amount of Pesticide to Apply per Acre**

The amount of pesticide to apply per acre is the application rate. This rate will appear on the product label. Your advisor may also suggest a specific rate within a specific range in accordance with local conditions.

**Example 4**

The pesticide you have chosen has a label rate of 1.5 pints per acre. When you know the size of the treated area (in acres) and the application rate, you can figure the total amount of pesticide product you will need.

**Step 3: Determine the Total Amount of Pesticide You Need**

To calculate the total amount of pesticide you need, use the following formula:

\[
\text{Total pesticide needed} = \text{Area treated (in acres)} \times \text{Application rate}
\]

**Example 5**

You will treat a full-circle area. Using the examples above, you know that the size of the area is 103.8 acres. The application rate of your pesticide, as given on the label, is 1.5 pints per acre. What is the total amount of pesticide you will need?

\[
\text{Total pesticide needed} = \text{Area treated (in acres)} \times \text{Application rate} = 103.8 \text{ acres} \times 1.5 \text{ pints per acre} = 155.7 \text{ pints}
\]
To convert the amount of pesticide needed from pints to gallons, divide the total number of pints by the number of pints in a gallon (8):

\[
\begin{align*}
\text{gallons} & = \frac{155.7 \text{ pints}}{8 \text{ pints per gallon}} \\
& = 19.5 \text{ gallons}
\end{align*}
\]

*NOTE: See Appendix C, Conversion Factors for Growers, for a list of handy conversion facts. This will help you figure equivalent measures for both liquid and dry pesticides.*

**Step 4: Determine the Injection (Revolution) Time**

One of the most important steps in calibration is determining the injection (revolution) time for your center pivot system. If you are treating a full circle, the injection time is the amount of time that your system takes to complete one revolution. You can calculate this in a few minutes instead of timing one full revolution. Follow the steps below.

1. Measure the distance from the pivot point to the outermost pivot tower or wheel track. Do this even if the owner’s manual for your irrigation system gives the length. When you measure, do not include the overhang.

2. Calculate the circumference of the circle that the tower travels for each revolution of the system. The circumference is the distance around a circle. To do this, use the following formula:

\[
\text{Circumference} = (2 \times \pi) \times r,
\]

where \( \pi = 3.14 \), and
\( r \) = the distance from the pivot point to the outer most pivot tower.

**Example 6**

You want to figure the circumference of the circle that the outermost pivot tower travels in your irrigation system. The distance between the pivot point and the outer tower is 1,200 feet. What is the circumference of the circle?

\[
\text{Circumference} = (2 \times \pi) \times r = (2 \times 3.14) \times 1,200 \text{ ft} = 6,28 \times 1,200 \text{ ft} = 7,536 \text{ ft}
\]

3. Determine the travel (rotational) speed of the tower in feet per minute (fpm). You can do this in two ways:
   - record the time it takes the tower to move a certain distance (at least 50 feet) along the circumference, or
   - measure the distance the tower travels in a certain amount of time (at least 10 minutes). To measure the distance, follow these steps:
     - Flag the position of either wheel on the outer tower when it begins to move.
     - When the flag is set, start the stopwatch.
     - After 10 minutes, flag the location of the same wheel.
     - Measure the distance between the two flags.

**Example 7**

Your outermost pivot tower traveled 55 feet in 10 minutes. What is the travel speed?

\[
\text{Travel speed} = \frac{55 \text{ ft}}{10 \text{ min}} = 5.5 \text{ fpm}
\]

4. Calculate the revolution (injection) time using the following formula:

\[
\text{Revolution time} = \frac{\text{Circumference (ft)}}{\text{Travel speed (fpm)}}
\]

**Example 8**

Using the examples above, figure the revolution time of your center pivot system.

\[
\text{Revolution time} = \frac{7,536 \text{ ft}}{5.5 \text{ fpm}} = 1,370 \text{ min per revolution}
\]
To convert the revolution time from minutes to hours, divide by 60:

\[
\text{Revolution time} = \frac{1,370 \text{ min}}{60 \text{ min per hr}} = 22.8 \text{ hr}
\]

Therefore, your center pivot system makes a complete revolution in 22.8 hours.

More about Travel Speed

When you figure your travel speed, make sure your irrigation system is running “wet.” This means that the pivot is charged with water and is running at the same water pressure that will be used during chemigation. Also, be sure to use the same speed and pressure that you will use when chemigating. Always recalibrate when you change speed settings. Use a stopwatch to check the proportion of 1 minute that the end tower is actually moving. Compare your reading to the percentage timer in the pivot control panel. Remember that alignment issues may cause this to vary somewhat.

Troubleshooting

When you are figuring travel (rotational) speed, remember that a measurement error of only a few feet or a few minutes can cause your actual application rate to be much higher or lower than you planned. This is true because the area treated by a center pivot is so big.

If you change your speed settings, you will need to recalibrate. If the terrain is hilly or rolling, check your speed in several locations and figure the average value. Soil type, soil compaction, slope, and track depth also affect the pivot’s travel speed. It is wise to verify your speed several times during the growing season.

Step 5: Determine the Injection Rate in Gallons per Hour

Once you have completed steps 3 and 4 above, you can easily calculate the injection rate in gallons per hour (gph). Use the following formula:

\[
\text{Injection rate (gph)} = \frac{\text{Total amount of product needed (gal)}}{\text{Injection time (hr)}}
\]

In other words, the injection rate is obtained by dividing step 3 by step 4.

Example 9

Using the examples above, calculate the injection rate of your center pivot system.

\[
\text{Injection rate (gph)} = \frac{19.5 \text{ gal}}{22.8 \text{ hr}} = 0.86 \text{ gph}
\]

You need to know the rate in gph because most injection pumps are rated in these units.

Step 6: Determine the Injection Pump Setting

The last step in calibrating your center pivot sprinkler system is to determine the correct setting for the injection pump. In other words, choose the pump setting that will produce the injection rate determined in step 5. Use the following formula to figure a rough setting:

\[
\text{Pump setting (% of capacity)} = \frac{\text{Injection rate}}{\text{Pump capacity}}
\]

This will give you a setting for an initial calibration. Keep in mind that you will most likely have to adjust this setting. Pump capacity values are usually measured at the factory based on a certain drive shaft speed. This speed may be different from the speed of your drive shaft. In addition, pump wear and differences in pesticide formulations will affect the output.

Example 10

Using the examples above, calculate the initial setting for your injection pump. Suppose that the pump has a capacity of 4 gph.
Therefore, you would use 22% of capacity as your first calibration attempt.

Troubleshooting

After determining the rough pump setting, you should use the calibration tube, on the suction side of the injection pump, to fine tune. Make your adjustments with the pump setting on 1-minute time checks. Make the final check over a longer period, at least 5 minutes. To measure the injection rate over very short periods and with a small volume of material, you will need to measure in milliliters or ounces. This means you need to convert the injection rate from gph to either milliliters per minute (ml per min) or ounces per minute (oz per min), depending on how your calibration tube is marked.

To convert the rate from gph to ml per min, use the following formula:

\[
\text{Milliliters per minute} = \text{gph} \times 63.08,
\]

where 63.08 is a constant.

\[\text{NOTE: 63.08 is determined like this:}\]

\[
\frac{1 \text{ gal}}{1 \text{ hr}} \times \frac{1 \text{ hr}}{60 \text{ min}} \times \frac{3,785 \text{ ml}}{1 \text{ gal}} = 63.08
\]

\[\text{Example 11}\]

Using the examples above, convert the injection rate of your pump from gph to ml per min.

\[
\text{Milliliters per minute} = \text{gph} \times 63.08
\]

\[
= 0.86 \text{ gph} \times 63.08
\]

\[= 54.25 \text{ ml per min}\]

To convert the rate from gph to fl oz per min, use the following formula:

\[
\text{Fluid ounces per minute} = \text{gph} \times 2.13,
\]

where 2.13 is constant.

\[\text{NOTE: 2.13 is determined like this:}\]

\[
\frac{128 \text{ fl oz}}{1 \text{ gal}} \times \frac{1 \text{ hr}}{60 \text{ min}} = \frac{128}{60} = 2.13
\]

\[\text{Example 12}\]

Using the examples above, convert the injection rate of your pump from gph to fl oz per min.

\[
\text{Ounces per minute} = \text{gph} \times 2.13
\]

\[
= 0.86 \text{ gph} \times 2.13
\]

\[= 1.83 \text{ fl oz per min}\]

Compare this rate with your initial pump setting and adjust it accordingly.

Calibrating a Stationary Sprinkler System

Stationary systems—ex. solid set—have one big advantage. They allow you to inject pesticides at any time during irrigation. For example, you could stop injecting an herbicide halfway through an irrigation. This would allow more water to soak the chemical into the soil. You would use a different technique for a foliar insecticide. To keep the chemical from washing off, apply the insecticide at the end of the irrigation.

\[\text{NOTE: If you apply a pesticide during the last part of irrigation, be sure to run your system long enough after injection is complete to flush the chemical from the system. Allow at least 30 minutes.}\]

To calibrate a stationary sprinkler system, follow the same basic steps as for the center pivot and other mobile systems. Begin by figuring the size of the treated area.

Step 1: Determine the Size of the Treated Area

One way to determine the size of the treated area is to figure out how many acres you will irrigate in one set. Follow these steps:
1. Multiply the lateral spacing along the main line by the number and length of the laterals.
2. Convert into acres.

   Calculate the size of the treated area by using the following formula:

\[
\text{Area (square feet)} = \frac{\text{Number of laterals} \times \text{Space between laterals (ft)} \times \text{Length of laterals (ft)}}
\]

To convert the area from square feet to acres, divide the square footage of the area treated by the number of square feet in 1 acre.

**Example 13**

You have placed 10 laterals 40 feet apart. Each lateral is 800 feet long. What is the size of the treated area (in acres)?

\[
\text{Area (square feet)} = \frac{\text{Number of laterals} \times \text{Space between laterals (ft)} \times \text{Length of laterals (ft)}}
\]

\[
= 10 \times 40 \text{ ft} \times 800 \text{ ft}
\]

\[
= 320,000 \text{ sq ft}
\]

Convert the area from square feet to acres:

\[
\text{Acreage of area} = \frac{\text{Square footage of the treated area}}{43,560 \text{ sq ft per acre}}
\]

\[
= \frac{320,000 \text{ sq ft}}{43,560 \text{ sq ft per acre}}
\]

\[
= 7.3 \text{ acres}
\]

**Step 2: Determine the Amount of Pesticide to Apply per Acre**

The amount of pesticide to apply per acre is the application rate. This rate will appear on the product label. Your advisor may also suggest a specific rate within a specific range in accordance with local conditions.

**Example 14**

The pesticide you have chosen has a label rate of 4 pounds of product per acre. When you know the size of the treated area (in acres) and the application rate, you can determine the total amount of pesticide product you will need.

**Step 3: Determine the Total Amount of Pesticide You Need**

To calculate the total amount of pesticide you need, use the following formula:

\[
\text{Total pesticide needed} = \frac{\text{Area treated (in acres)} \times \text{Application rate}}
\]

**Example 15**

Using the examples above, you know that the size of the treated area is 7.3 acres. The application rate of your pesticide, as given on the label, is 4 pounds per acre. What is the total amount of pesticide you will need?

\[
\text{Total pesticide needed} = \frac{\text{Area treated (in acres)} \times \text{Application rate}}
\]

\[
= 7.3 \text{ acres} \times 4 \text{ lb per acre}
\]

\[
= 29.2 \text{ lb}
\]

**Step 4: Determine the Injection Time**

When you use a stationary system, you will usually inject a pesticide during part—not all—of the irrigation set. As noted above, the type of pesticide is a major factor in deciding when to inject it. You must also determine three other factors:

- how long you will be irrigating (irrigation time),
- how long you will be applying the pesticide (injection time), and
- when you will inject the pesticide during the irrigation set.

**Irrigation Time**

To determine the irrigation time, you need to know:

- the water application rate of the system, and
• how much water to apply per acre.

Following are explanations and examples:

**Water Application Rate**

Attach a short piece of hose to the nozzle outlet(s) of several sprinklers along the lateral. For each sprinkler, start your irrigation system and measure the flow for 1 minute. Determine the average sprinkler flow rate in gallons per minute (gpm).

Calculate the water application rate of your system in inches per hour (in per hr) using the following formula:

\[
\text{Water application rate (in per hr)} = \frac{96.3 \times \text{gpm}}{L \times M}
\]

where gpm = Average sprinkler flow rate (gpm),

L = Spacing of sprinklers on lateral (ft),

M = Spacing of laterals on main line (ft), and

96.3 = a constant used as a conversion factor

**Example 16**

Using the procedure described above, you find that your average sprinkler flow rate is 4 gpm. Your sprinklers on the lateral are spaced 40 feet apart. The laterals are also spaced 40 feet apart on the main. What is the water application rate for your irrigation system in inches per hour?

\[
\text{Water application rate (in per hr)} = \frac{96.3 \times 4}{40 \times 40} = \frac{385.2}{1,600} = 0.24 \text{ in per hr}
\]

**How Much Water per Acre**

To figure how much water to apply per acre, first consult the pesticide label. The label will tell you:

• how much pesticide to apply per acre, and

• approximately when to inject the pesticide.

You will also need to know the application efficiency of your irrigation system.

**Troubleshooting**

Your sprinkler system does not distribute water (and pesticide) in a perfectly uniform manner. This means that you need to apply extra water to make sure that every part of the treated area receives at least the minimum amount of water. Consider this when you calculate the irrigation time. The irrigation time, in turn, will help you decide when to inject the pesticide during treatment.

**Example 17**

The label of an herbicide tells you to apply 1 acre-inch of water. It also instructs you to inject the herbicide into your system during the first half of the irrigation. You know that your irrigation system has an application efficiency of 80%. You must determine:

• the total irrigation time, and

• when (and for how long) to inject the herbicide.

First, calculate the gross irrigation amount. Use this formula:

\[
\text{Gross amount} = \frac{\text{Net amount}}{\text{Application efficiency}}
\]

The net amount is 1.0 inch and application efficiency is 80% or 0.80. Therefore:

\[
\text{Gross amount} = \frac{1.0 \text{ in}}{0.80} = 1.25 \text{ in}
\]
Next, figure the total irrigation time. Use this formula:

\[
\text{Irrigation time} = \frac{\text{Gross amount}}{\text{Water application rate}}
\]

Therefore:

\[
\text{Irrigation time} = \frac{1.25 \text{ in}}{0.24 \text{ in per hr}} = 5.2 \text{ hr}
\]

The label directs you to inject the herbicide during the first half of irrigation. Thus, you would inject it during the first 2.6 hours of irrigation:

\[
\text{First half of irrigation time} = \frac{5.2 \text{ hr}}{2} = 2.6 \text{ hr}
\]

**Step 5: Determine the Injection Rate in Gallons per Hour**

Once you have completed steps 3 and 4 above, you can calculate the injection rate in gph. Use the following formula:

\[
\text{Injection rate (gph)} = \frac{\text{Total amount of product needed (gal)}}{\text{Injection time (hr)}}
\]

In other words, the injection rate is obtained by dividing step 3 by step 4.

**Example 18**

Assume your herbicide is a wettable powder. Thus, you will first need to dilute it in water. You want to apply the herbicide during the first 2 hours of the irrigation cycle. Using the examples above, you know that you need a total of 29.2 pounds of product. After it is diluted, you have a total volume of 50 gallons of pesticide/water tank mixture. What is the injection rate?

\[
\text{Injection rate (gph)} = \frac{29.2 \text{ pounds}}{2 \text{ hr}} = 14.6 \text{ gph}
\]

\[
\text{Injection rate (gph)} = \frac{25 \text{ gph}}{50 \text{ gph}} = 50\%
\]

Thus, the injection rate of your stationary sprinkler system is 25 gph.

*NOTE. To convert your injection rate from gph to ml per min or oz per min, follow the procedures outlined in step 6, in “Calibrating a Center Pivot System,” (on page 8).*

**Step 6: Determine the Injection Pump Setting**

The last step in calibrating your stationary sprinkler system is to determine the correct setting for the injection pump. The process is the same as for the center pivot system. Select the pump setting that will produce the injection rate determined in step 5. Use the following formula to determine a rough setting:

\[
\text{Pump setting (\% of capacity)} = \frac{\text{Injection rate}}{\text{Pump capacity}}
\]

As we noted earlier in step 6 in “Calibrating a Center Pivot System” on page 8, this is only a rough estimate. You will probably have to adjust your setting for most accurate results.

**Example 19**

Using the examples above, calculate the initial setting for your injection pump. Assume that the pump has a capacity of 50 gph.

\[
\text{Pump setting (\% of capacity)} = \frac{25 \text{ gph}}{50 \text{ gph}} = 50\%
\]
Therefore, you would use 50% of capacity as your first calibration attempt.

**Calibrating a Drip/Trickle System**

Calibrating a drip/trickle system presents its own challenges. As with a stationary sprinkler system, drip/trickle chemigation often requires injecting pesticide during part of the irrigation set. As discussed above, when you inject the pesticide depends on what type of product you use. Check the product label for instructions. Be sure to run your system for at least 30 minutes after injection is complete to flush all pesticide from the system. You should also run a small-jar compatibility test to ensure that precipitates will not form. See Unit 4 (Application Systems and Equipment) for more information on how to avoid clogging with a drip system.

As with the sprinkler systems, your first step is to determine the size of the field you will treat.

**Step 1: Determine the Size of the Treated Area**

With drip irrigation, you will not treat the entire field where you are chemigating. However, you need to know the size of the field for use in later calculations.

If your field is rectangular, you can calculate the area if you know:
- the length of the field, and
- the width of the field.

Make sure you express both dimensions in the same units, usually feet. Then, multiply length by width to get the total area of the field (in square feet).

\[
\text{Area of a rectangular field} = \text{length} \times \text{width}
\]

**Example 20**

A rectangular field is 250 feet wide and 800 feet long. What is the area of the field? Follow the steps below.
Therefore, you know that the size of the treated field is 4.59 acres.

Step 2: Determine the Amount of Pesticide to Apply per Acre

As noted above, you will not be treating the whole field with your drip/trickle irrigation system. To make calibration easier, consider your chemigation treatment a band application. You will apply only part of the broadcast rate of pesticide to each acre of field. To determine the application rate, use the following formula:

\[
\text{Amount of pesticide needed per acre of field} = \frac{\text{Bandwidth (in)}}{\text{Row spacing (in)}} \times \text{Broadcast rate per acre}
\]

You must know:
• broadcast rate per acre,
• row spacing, and
• bandwidth.

Example 21

You are using a drip/trickle irrigation system in your fields. Your row spacing is 36 inches, and the target area is a 12-inch band along the row. The label of your soil fungicide gives a broadcast rate of 2 quarts of product per acre. How much fungicide will you apply per acre of field?

\[
\begin{align*}
\text{Amount of pesticide needed per acre of field} &= \frac{12 \text{ in}}{36 \text{ in}} \times 2 \text{ qt per acre} \\
&= 0.67 \text{ qt per acre of field}
\end{align*}
\]

Step 3: Determine the Total Amount of Pesticide You Need

To calculate the total amount of pesticide you need, follow the same procedure as for sprinkler irrigation systems. Use the following formula:

\[
\text{Total pesticide needed} = \text{Area treated (in acres)} \times \text{Application rate}
\]

Example 22

You are applying a soil fungicide to your field. Using the examples above, you know that the size of the treated field is 4.59 acres. The application rate is 0.67 quart of product per acre. How much pesticide do you need for the area you plan to treat?

\[
\begin{align*}
\text{Total pesticide needed} &= \text{Area treated (in acres)} \times \text{Application rate} \\
&= 4.59 \text{ acres} \times 0.67 \text{ qt per acre} \\
&= 3.08 \text{ qt}
\end{align*}
\]

Step 4: Determine the Injection Time

As with a stationary sprinkler system, you will inject the pesticide during only part of the irrigation. Therefore, you need to decide when to inject the pesticide into your drip/trickle system and for how long. First, you must determine three factors:
• the flow rate of the emitters (in gph),
• the total amount of water needed, and
• the total irrigation time.

Flow Rate of the Emitters

To determine flow rate in gph, run your irrigation system until it is at full pressure. Then, collect water from 10 randomly selected emitters for 1 minute. Use a measuring cup that can measure tenths of fluid ounces. Determine the average output in ounces per minute for the 10 emitters. Finally, convert this flow rate to gph, using this formula:

\[
\text{Flow rate (gph) per emitter} = \text{Fluid oz per min} \times 0.47,
\]

where 0.47 is a constant used as a conversion factor.
Then, multiply the flow rate by the number of emitters per acre of field. This will tell you how many gallons of water are delivered to each acre of field per hour.

**NOTE:** To find the average, add the total of all items and divide by the number of items.

#### Example 23

After collecting water from 10 emitters along your drip irrigation system for 1 minute, you find that the average output per emitter is 2.13 ounces per minute. There are 1,000 emitters in each acre of your field. What is the flow rate in gph?

Flow rate (gph) per emitter = Fluid oz per min \times 0.47

= 2.13 fl oz per min \times 0.47

= 1.0 gph

**NOTE:** To convert milliliters per minute to gph, multiply the average output per emitter by the constant 0.016.

To find gph per acre of field, multiply the flow rate per emitter by the number of emitters per acre of field:

Flow rate (gph per acre of field) = gph per emitter \times \frac{Number of emitters per acre of field}{1}

= 1.0 \times 1,000

= 1,000 gph

### Total Amount of Water Needed

To determine how much water you will need for your application, check the product label. Then, use this formula:

$$\text{Total water needed (in) per acre} = \frac{\text{Bandwidth}}{\text{Row spacing}} \times \text{Label amount}$$

You also know that there are 27,152 gallons in 1 acre-inch of water. So, to figure the gallons of water needed per acre of field, use the formula below:

$$\text{Total water needed (gal) per acre} = \text{Total water needed (in) per acre} \times 27,152$$

#### Example 24

The label of a fungicide tells you to apply the product near the end of the irrigation in 1/2 acre-inch. Using the examples above, you know that your bandwidth is 12 inches and your row spacing is 36 inches. What is the total amount of water you will need per acre of field (in gallons)?

First, determine the total water needed in inches per acre:

$$\text{Total water needed (in) per acre} = \frac{12 \text{ in}}{36 \text{ in}} \times \frac{1}{2} \text{ acre-inch}$$

= 0.167 in

Now, since you know there are 27,152 gallons in 1 acre-inch of water, you can figure the gallons of water you will need per acre of field:

$$\text{Total water needed (gal) per acre} = 0.167 \text{ in} \times 27,152 \text{ gal}$$

= 4,534 gal

### Total Irrigation Time

Now that you have determined the flow rate of your emitters and the total amount of water you will need, you can calculate the total irrigation time. Use this formula:

$$\text{Total irrigation time (hr)} = \frac{\text{Total water needed (gal) per acre}}{\text{Flow rate (gph)}}$$

#### Example 25

Using the examples above, calculate how long you must irrigate.

$$\text{Total irrigation time (hr)} = \frac{\text{Total water needed (gal) per acre}}{\text{Flow rate (gph)}}$$
To convert the decimal fraction of an hour to minutes, multiply it by 60:

\[
0.534 \text{ hr} \times 60 \text{ min per hr} = 32 \text{ min}
\]

Your total irrigation time, then, is 4 hours 32 minutes.

**Injection Time**

If you know the total irrigation time, you can determine how long you will inject pesticide during the irrigation. Use the label recommendation together with the information you have already gathered.

**Example 26**

Using the examples above, you know that your total irrigation time is 4 hours, 32 minutes per acre of field. The label tells you to inject pesticide near the end of the irrigation. Therefore, you decide to inject pesticide during the last hour of the irrigation.

**Step 5: Determine the Injection Rate in Gallons per Hour**

To determine the injection rate in gph, you can use the information from steps 3 and 4 above. But first, check the product label for directions on diluting the pesticide product in the supply tank. Next, use the following formula:

\[
\text{Injection rate (gph)} = \frac{\text{Total amount of pesticide mix}}{\text{Injection time}}
\]

To figure the total amount of pesticide mix, you need to know four things:

- how much pesticide mix you need,
- the dilution ratio of the pesticide (from the label),
- the total amount of pesticide you need (from step 3), and
- the injection time (from step 4).

**Example 27**

You plan to use a fungicide in your drip irrigation system. The product label says to dilute the fungicide by adding 10 parts of water for every part of product. You decide to add enough water to make 9 gallons (36 quarts) of pesticide mix. Since you need 3.08 quarts of pesticide, you must add at least 30.8 quarts of water to the mix. So, subtract 3.08 from 36 to find the amount of water to add:

\[
36 \text{ qt (total mix)} - 3.08 \text{ qt (total pesticide)} = 32.92 \text{ qt water to add}
\]

Finally,

\[
\text{Injection rate (gph)} = \frac{\text{Total amount of pesticide mix}}{\text{Injection time}}
\]

\[
= \frac{9 \text{ gallons}}{1 \text{ hr}}
\]

\[
= 9 \text{ gph}
\]

**Step 6: Determine the Injection Pump Setting**

The last step in calibrating your drip/trickle irrigation system is to determine the correct setting for the injection pump. The process is the same as for the sprinkler systems. Select the pump setting that will produce the injection rate determined in step 5. Use the following formula to determine a rough setting:

\[
\text{Pump setting (\% of capacity)} = \frac{\text{Injection rate}}{\text{Pump capacity}}
\]

As noted earlier in step 6 in “Calibrating a Center Pivot System” on page 8, this is only a rough estimate. You will probably have to adjust your setting for most accurate results.
Example 28
Using the examples above, calculate the initial setting for your injection pump. Assume that the pump has a capacity of 50 gph.

Therefore, you would use 18% of capacity as your first calibration attempt.

\[
\text{Pump setting (\% of capacity)} = \frac{\text{Injection rate}}{\text{Pump capacity}}
\]

\[
= \frac{9 \text{ gph}}{50 \text{ gph}}
\]

\[
= 18\%
\]

No matter what type of irrigation system you use or where you chemigate, calibration is vital to your success. Keep these pointers in mind:

- Always read the pesticide label thoroughly before you calibrate or chemigate. Follow its application, use, and safety instructions to the letter.

- The density and viscosity of agricultural chemicals varies widely. This means that you must perform your final calibration using the chemical you plan to apply, not water.

- Wear and tear on your equipment and other factors affect the rate of injection. This means you should recalibrate every time you chemigate.
Test Your Knowledge

Q 1. What is calibration?
A. The process of determining the correct amount of pesticide to apply to a certain area by measuring and adjusting the delivery rate of your application equipment.

Q 2. Why is calibration important?
A. It allows you to make sure your equipment delivers the right amount of pesticide uniformly over the target area. Without an accurate calibration, you cannot be sure whether the amount of chemical you are applying is correct.

Q 3. Why should you do your own calibration instead of relying solely on the manufacturer’s data?
A. These data provide a good starting point and may help you decrease trial and error. But the conditions at your site will not be the same as those at the factory. Therefore, you need to calibrate the system yourself.

Q 4. What basic tools do you need for calibration?
A. 1. A stopwatch.
2. A steel tape measure (at least 100 feet long).
3. A pocket calculator.
4. Marking flags visible from a distance.
5. A calibration tube.

Q 5. Describe how to check the uniformity of the spray pattern for a sprinkler system.
A. 1. Use empty, straight-sided cans of equal size, such as coffee cans. Place the catch cans at equal intervals (about 10 feet apart) along the full length of the irrigation system. Use an open area, and avoid the canopy of the growing crop.
2. Operate your sprinkler system at the same speed and pressure you will use when you apply the pesticide. You should apply about 1/2 inch of water to ensure accuracy.
3. Record the amount of water in each can and its location when the system has passed completely over all the cans.
4. Compare the average amount of water in all cans to the amount actually collected in each can. If you find a large deviation from the average for any of the cans, there may be a problem at that location.
5. Check the nozzles or sprinklers for damage at any point where you find a large deviation from the average amount collected.

NOTE: A large deviation means enough of a difference in distribution of liquid to result in an off-label application of pesticide. Too much pesticide may also cause crop damage in the areas irrigated by the nozzles in question.

For more information on how to determine uniformity, contact your irrigation advisor.

Q 6. True or False: For greatest ease and accuracy, you should make all your calibration measurements at the time of pesticide treatment.
A. False. You do not need to make all your measurements at the time of treatment. It is easiest to measure a field when the crop is small or there is no crop present. You can even measure machine speeds if you have run the machine enough to establish firm wheel paths. Be careful, though. When you begin treatment, set the speed control in exactly the same places as they were when you took the measurements.
Q 7. List the six basic steps for calibrating most types of irrigation systems.

A. 1. Determine the size of the treated area.
   2. Determine the amount of pesticide to apply per acre.
   3. Determine the total amount of pesticide you need (multiply step 1 by step 2).
   4. Determine the injection time.
   5. Determine the injection rate in gallons per hour (divide step 3 by step 4).
   6. Determine the injection pump setting that will deliver the desired injection rate (from step 5).

   *NOTE: When you calibrate, you should also determine your total fluid output. This will help you prevent overwatering, deep percolation, and runoff.*

Q 8. What is the “wetted radius” of a center pivot system? How do you measure it?

A. The straight-line distance from the center of the pivot to the edge of the area covered by the sprinkler system. Using a steel tape measure, start at the center of the pivot. Keeping the tape taut, extend it on a straight line outward to the edge of the treated area.

Q 9. The area you are treating with a center pivot system is a full circle. The distance from the pivot point to the edge of the wetted area (radius) is 1,000 feet. What is the acreage of the circle you will treat?

A. First, figure the area of the circle in square feet.
   Then, convert the area from square feet to acres.

\[
\text{Area of the circle} = \pi \times \text{Length of the radius squared} = 3.14 \times (1,000 \text{ ft})^2 = 3,140,000 \text{ sq ft}
\]

\[
\text{Acreage of the circle} = \frac{\text{Square footage of the circular field}}{43,560 \text{ sq ft per acre}} = \frac{3,140,000 \text{ sq ft}}{43,560 \text{ sq ft per acre}} = 72.1 \text{ acres}
\]

Q 10. You plan to treat the corners of a triangular field. The field is 225 feet wide at its widest point (height) and 400 feet along its longest side (base). What is the acreage of the field?

A. First, figure the area of the triangle in square feet.
   Then, convert the area from square feet to acres.

\[
\text{Area of the triangular field} = \frac{\text{base} \times \text{height}}{2} = \frac{400 \text{ ft} \times 225 \text{ ft}}{2} = 45,000 \text{ sq ft}
\]

\[
\text{Acreage of the triangular field} = \frac{\text{Square footage of the field}}{43,560 \text{ sq ft per acre}} = \frac{45,000 \text{ sq ft}}{43,560 \text{ sq ft per acre}} = 1.03 \text{ acres}
\]

Q 11. How do you determine the amount of pesticide to apply per acre (application rate)?

A. From the product label.
Q 12. You are treating a full-circle area with a center pivot system. The size of the treated area is 72.1 acres. The application rate of your pesticide is 1.5 pints per acre. How much total pesticide will you need?

A. Total pesticide needed = Area treated (in acres) x Application rate

\[ = 72.1 \text{ acres} \times 1.5 \text{ pints per acre} \]

\[ = 108.2 \text{ pints} \]

To convert the amount of pesticide needed from pints to gallons, divide the total number of pints by the number of pints in a gallon (8):

\[ \frac{108.2 \text{ pints}}{8 \text{ pints per gallon}} = 13.5 \text{ gallons} \]

Q 13. You want to figure the travel speed of your outermost pivot tower in feet per minute (fpm). You find that the tower travels 50 feet in 10 minutes. What is its travel speed?

A. Travel speed = \[ \frac{50 \text{ ft}}{10 \text{ min}} = 5 \text{ fpm} \]

Q 14. If the circumference of the circle that your outermost pivot tower travels is 7,536 feet and its travel speed is 5 fpm, what is its injection (revolution) time?

A. Revolution time = \[ \frac{\text{Circumference (ft)}}{\text{Travel speed (fpm)}} \]

\[ = \frac{7,536 \text{ ft}}{5.0 \text{ fpm}} \]

\[ = 1,507 \text{ min per revolution} \]

To convert the revolution time from minutes to hours, divide by 60:

Revolution time = \[ \frac{1,507 \text{ min}}{60 \text{ min per hr}} = 25.1 \text{ hr} \]

Therefore, your center pivot system makes a complete revolution in 25.1 hours.

Q 15. Under what condition would you need to recalibrate your equipment?

A. If you change your speed settings.

Q 16. Calculate the injection rate of your center pivot system in gallons per hour (gph). The total amount of product needed is 13.5 gallons, and the injection time is 25.1 hours.

A. Injection rate (gph) = \[ \frac{\text{Total amount of product needed (gal)}}{\text{Injection time (hr)}} \]

\[ = \frac{13.5 \text{ gal}}{25.1 \text{ hr}} = 0.54 \text{ gph} \]

Q 17. Calculate the initial injection pump setting for your center pivot system. The injection rate is 0.54 gph, and the pump has a mid-range capacity of 4 gph.

A. Pump setting (% of capacity) = \[ \frac{\text{Injection rate}}{\text{Pump capacity}} \]

\[ = \frac{0.54 \text{ gph}}{4 \text{ gph}} = 14\% \]

Therefore, you would use 14% of capacity as your first calibration attempt.
Q 18. What advantage do stationary sprinkler systems have? How is this helpful to chemigators?

A. They allow you to inject pesticides at any time during irrigation. For example, you could stop injecting an herbicide halfway through a treatment. This would allow more water to soak the chemical into the soil. To keep a foliar insecticide from washing off, apply it at the end of the irrigation.

Q 19. You are using a stationary sprinkler system to apply pesticide to an area. You have placed 10 laterals 35 feet apart. Each lateral is 800 feet long. What is the acreage of the treated area?

A. First, figure the area of the target site in square feet.

\[
\text{Area (square feet)} = \text{Number of laterals} \times \text{Space between laterals (ft)} \times \text{Length of laterals (ft)}
\]

\[
= 10 \times 35 \text{ ft} \times 800 \text{ ft}
\]

\[
= 280,000 \text{ sq ft}
\]

Then, convert the area from square feet to acres.

\[
\text{Acreage of area} = \frac{\text{Square footage of the treated area}}{43,560 \text{ sq ft per acre}}
\]

\[
= \frac{280,000 \text{ sq ft}}{43,560 \text{ sq ft per acre}}
\]

\[
= 6.4 \text{ acres}
\]

Q 20. Your stationary sprinkler system has an average sprinkler flow rate of 5 gpm. Your sprinklers on the lateral are spaced 40 feet apart. The laterals are also spaced 40 feet apart on the main. What is the water application rate for your irrigation system in inches per hour (in per hr)?

A. Use this formula:

\[
\text{Water application rate (in per hr)} = \frac{96.3 \times \text{gpm}}{L \times M}
\]

where \( gpm = \) Average sprinkler flow rate (gpm),

\( L = \) Spacing of sprinklers on lateral (ft),

\( M = \) Spacing of laterals on main line (ft), and

\( 96.3 = \) a constant used as a conversion factor

So,

\[
\text{Water application rate (in per hr)} = \frac{96.3 \times 5 \text{ gpm}}{40 \text{ ft} \times 40 \text{ ft}}
\]

\[
= \frac{481.5 \text{ gpm}}{1,600 \text{ ft}}
\]

\[
= 0.30 \text{ in per hr}
\]

Q 21. The gross irrigation amount for your stationary sprinkler system is 1.25 inches. If your water application rate is 0.30 inch per hour, what is your total irrigation time?

A. The irrigaion time is calculated as:

\[
\text{Irrigation time} = \frac{\text{Gross amount}}{\text{Water application rate}}
\]

\[
= \frac{1.25 \text{ in}}{0.30 \text{ in per hr}}
\]

\[
= 4.2 \text{ hr}
\]
Q 22. An herbicide label directs you to inject the product during the first half of irrigation, using a stationary sprinkler system. If your total irrigation time is 4.2 hours, when would you inject the herbicide?
A. During the first 2.1 hours of irrigation:

First half of irrigation time = \( \frac{4.2 \text{ hr}}{2} \)

= 2.1 hr

Q 23. The injection rate for your stationary sprinkler system is 24 gph. If your injection pump has a capacity of 50 gph, what is the initial setting for the pump?
A. Pump setting (\% of capacity) = \( \frac{\text{Injection rate}}{\text{Pump capacity}} \)

= \( \frac{24 \text{ gph}}{50 \text{ gph}} \)

= 48%

You would use 48% of capacity as your first calibration attempt.

Q 24. The entire field where you are chemigating with a drip/trickle system is a rectangle. The length of the field is 800 feet, and the width is 350 feet. What is the acreage of the rectangular field?
A. First, figure the area of the rectangle in square feet.

Area of a rectangular field = Length x Width

= 800 ft x 350 ft

= 280,000 sq ft

Then, convert the area from square feet to acres.

Acreage of rectangular field = \( \frac{\text{Square footage of the field}}{43,560 \text{ sq ft per acre}} \)

= \( \frac{280,000 \text{ sq ft}}{43,560 \text{ sq ft per acre}} \)

= 6.4 acres

Q 25. You are treating part of a field using a drip/trickle system. Your row spacing is 36 inches, and the target area is a 12-inch band along the row. The label of your soil fungicide gives a broadcast rate of 2 quarts of product per acre. How much fungicide will you apply per acre of field?
A. Amount of pesticide needed per acre of field = \( \frac{\text{Bandwidth (in)}}{\text{Row spacing (in)}} \times \text{Broadcast rate per acre} \)

= \( \frac{12 \text{ in}}{36 \text{ in}} \times 2 \text{ qt per acre} \)

= 0.67 qt per acre of field

Q 26. After collecting water from 10 emitters along your drip irrigation system for 1 minute, you find that the average output per emitter is 2.13 ounces per minute. Also, 0.47 is a constant used as a conversion factor. What is the flow rate per emitter in gph?
A. Flow rate (gph) per emitter = Fluid oz per min x 0.47

= 2.13 fl oz per min x 0.47

= 1.0 gph

Q 27. The label of a fungicide tells you to apply the product near the end of the irrigation in 1/2 acre-inch. Your bandwidth is 12 inches, and your row spacing is 36 inches. What is the total amount of water you will need per acre of field (in gallons)?
A. First, determine the total water needed in inches per acre.

Total water needed (in) per acre = \( \frac{\text{Bandwidth (in)}}{\text{Row spacing}} \times \text{Label amount} \)
Now, since you know there are 27,152 gallons in 1 acre-inch of water, you can figure the gallons of water you will need per acre of field:

\[
\text{Total water needed (gal) per acre} = \frac{\text{Total water needed (in) per acre}}{27,152}
\]

\[
= \frac{0.167 \text{ in} \times 27,152 \text{ gal}}{}
\]

\[
= 4,534 \text{ gal}
\]

Q 28. The flow rate of your drip system is 1,000 gph per acre of field. The total amount of water needed is 4,534 gallons per acre. What is your total irrigation time?

A.

\[
\text{Total irrigation time (hr)} = \frac{\text{Total water needed (gal)}}{\text{Flow rate (gph)}}
\]

\[
= \frac{4,534 \text{ gal}}{1,000 \text{ gph}}
\]

\[
= 4.534 \text{ hr}
\]

To convert the decimal fraction of an hour to minutes, multiply the decimal by 60:

\[
0.534 \text{ hr} \times 60 \text{ min per hr} = 32 \text{ min}
\]

Your total irrigation time, then, is 4 hours 32 minutes.

Q 29. The injection rate for your drip/trickle system is 8 gph. If your injection pump has a capacity of 50 gph, what is the initial setting for the pump?

A. \[
\text{Pump setting (\% of capacity)} = \frac{\text{Injection rate}}{\text{Pump capacity}}
\]

\[
= \frac{8 \text{ gph}}{50 \text{ gph}}
\]

\[
= 16\%
\]

You would use 16\% of capacity as your first calibration attempt.