Learning Objectives

After you complete your study of this unit, you should be able to:

- Define calibration.
- Explain the role of equipment speed in the calibration of equipment.
- Show that you know how to check for uniform output from multiple nozzles or hoppers.
- Describe how to calculate application rates.
- Name some key factors you must consider when calibrating a sprayer.
- Use nozzle charts, along with facts about the application situation, to choose the correct nozzle tip for each job.
- Use formulas to calibrate sprayers correctly.
- Identify the key factors you must consider when calibrating a granule applicator.
- Use formulas to calibrate granule applicators correctly.
- Use formulas to calibrate other types of application equipment correctly.

Terms To Know

Active ingredients — The chemicals in a pesticide product that control the target pest.
Agitator — Device that stirs or mixes a pesticide in a tank or hopper.
Band spraying — Application of a pesticide to a strip over or along a crop row.
Broadcast spraying — Uniform application of a pesticide over an entire area.
Calibration — The process of measuring and adjusting the amount of pesticide that a particular piece of equipment will apply to a target site.
Carrier — The primary material used to allow a pesticide to be applied effectively; for example, the talc in a dust formulation or the water mixed with a wettable powder before a spray application.
Concentrates — Pesticides that have a high percentage of active ingredient; occasionally applied full strength, but usually diluted before application.
Diluent — Anything used to dilute a pesticide.
Dilute — To make less concentrated.
Directed spraying — Aiming a pesticide at a specific portion of a plant or target site.
Drift — Pesticide movement away from the release site in the air.
Foliage — Primarily the leaves; may include stems of a plant.
Formulation — Pesticide product as sold, usually a mixture of active and inert ingredients.
Fumigant — Pesticide that is a vapor or gas or that forms a vapor or gas when applied and whose pesticidal action occurs in the gaseous state.
gpa — Gallons per acre.
gpm — Gallons per minute.
Labeling — The pesticide product label and other accompanying materials that contain directions that pesticide users are legally required to follow.
mph — Miles per hour.
Porous surfaces — Surfaces that have tiny openings which allow liquid to be absorbed or to pass through.
Release — When a pesticide leaves its container or the equipment or system that is containing it and enters the environment. Release can be intentional, as in an application, or by accident, as in a spill or leak.
Swath width — Side-to-side measurement of the band or strip of pesticide released by the application equipment.
Target — The site or pest toward which control measures are being directed.
Water-based pesticides — Pesticides that use water as the only diluent or carrier.
Calibration is the process of measuring and adjusting the amount of pesticide your equipment will apply to the target area. Equipment that must be calibrated includes mechanical dusters; granule spreaders; hand, backpack, boom, hand-gun, high-pressure, airblast, and most other sprayers; and fumigant applicators.

The many types of application equipment differ in the details of their operation, but you can apply the basic principles of calibration in any situation.

To calibrate accurately, you must be familiar with the operation of your machinery. Follow the manufacturer's directions carefully — they explain how to adjust the equipment. The directions often contain suggestions about such things as the appropriate rate of travel, the range of most efficient pump pressures, approximate settings for achieving various delivery rates, and types of nozzles that can be used.

Pesticide application equipment will not deliver the right amount of pesticide to the target site if it is not working correctly. Before you begin to calibrate the equipment, check it carefully to be sure that all components are clean and in good working order.

Pay particular attention to the parts that regulate the amount of pesticide being released, such as nozzles or hopper openings. If they become clogged, not enough pesticide will be released. If they become worn, too much pesticide may be released.

Calibration does not have to be difficult. Pesticide labeling and Extension Service and professional association recommendations give you much of the information you need in order to calibrate correctly. Calibration requires some simple mathematics; this unit provides some standard formulas to help you.

It is not necessary to memorize the formulas. Instead, make a list of the ones you will need in your work (including the steps to solution) and keep it handy. Review the formula each time you calibrate, just as you refer to the pesticide label each time you use a pesticide. As you work through the formula, use a calculator to reduce the chances of making an error.

The methods described in this unit are not the only ways to calibrate equipment. Your Extension Service can give you information about other equally acceptable methods.
How Precise Must Calibration Be?

When you measure nozzle output, calculate application rate, or do other calibration-related calculations, the acceptable variation is plus or minus 5 percent. For example, if actual measured nozzle output is within 5 percent of the target, or if the actual application rate is within 5 percent of the recommended rate, those results can be considered accurate for calibration purposes.

How do you determine whether your results fall within the acceptable range? If the target number is 15, for example, multiply that by 5 percent (.05). Add the result to 15 to find the largest acceptable number; subtract it from 15 to find the lowest acceptable number:

\[ 15 \times .05 = .75 \]
\[ 15 + .75 = 15.75 \text{ (5% more than 15)} \]
\[ 15 - .75 = 14.25 \text{ (5% less than 15)} \]

Therefore, anything between 14.25 and 15.75 is within the acceptable range.

Speed

For some types of application equipment, the speed at which the equipment moves (or is carried) through the target site is one of the main factors in determining the rate of application. For some other types of equipment, you do not need to consider speed when calibrating.

Equipment With Gravity-Flow Dispersal

Some equipment, such as some granule applicators, use gravity to achieve the flow of pesticide. For hand-operated granule applicators, an adjustable opening at the base of the hopper allows granules to flow onto a disk that rotates when turned by a hand crank. To maintain even distribution of the granules, the operator must turn the crank at an even rate while walking at a steady pace. Calibration is achieved by adjusting the hopper opening and the walking rate.

For machine-mounted gravity-flow applicators, an adjustable opening at the base of each hopper allows the granule to flow into the furrow or band or onto a spinning disk. To calibrate this equipment correctly, you must adjust the flow rate by altering the hopper opening, and you must also establish a precise, even ground speed. If the wheels slip, too much pesticide will be applied in the areas where the slippage occurs. Wheel slippage is especially likely on uneven ground, on wet surfaces, and when the equipment is heavily loaded.

Equipment With Ground-Wheel-Driven Dispersal

If the equipment you have chosen uses the rotation of the equipment’s wheels to maintain the flow of pesticide, calibration may be fairly simple. Some of this equipment, such as some granule spreaders, needs to be calibrated only to adjust the rate of flow or delivery. This equipment releases pesticide only when the wheels are in motion. If the speed of the equipment is kept at an even, moderate pace, the amount of pesticide being released per unit area will be uniform. As with gravity-flow applicators, wheel slippage will cause too much pesticide to be applied in the areas where the slippage occurs.
Equipment With Powered Dispersal

If your equipment has a pump, blower, auger, or other mechanism to disperse the pesticide, you will need to determine the rate of speed best suited for the type of equipment and for the particular requirements of your application job. Such equipment may be either hand-carried or mounted on a vehicle.

In either case, the speed at which the equipment moves through the target site determines the amount of pesticide applied in a given area. Keep the speed as constant as possible both during the calibration process and during the actual application.

For accurate calibration, operate the equipment at the target site or on ground (or other surface) similar to that at the target site. Whether the equipment is hand-carried or mounted on a vehicle, the condition of the ground (surface) that must be crossed is important. A rough and uneven surface generally causes the equipment to be operated at a slower speed.

The equipment manufacturer’s directions may offer a range of appropriate speeds. Your knowledge of conditions in the target site (including the drift hazard), plus your experience with the equipment, will help you determine an appropriate speed.

Measuring Actual Speed

To calibrate accurately, you must know your actual speed. Due to wheel slippage under field conditions, the actual ground speed will differ from the speed indicated by a speedometer.

To measure actual speed, mark off measured distances of 100, 200, or 300 feet in the field where the application is to be done. Then run the equipment over this distance at the operating speed, carefully marking the throttle setting or speedometer reading and recording run times. Be sure the equipment is moving at full operating speed before you reach the starting point. Make at least three runs; use the average time to do your calculations.

Table 1 converts the time measured to speed in miles per hour.

<table>
<thead>
<tr>
<th>Ground speed in miles per hour</th>
<th>Time required in seconds to travel a distance of:</th>
<th>Ground speed in miles per hour</th>
<th>Feet traveled per minute</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>100 feet</td>
<td>200 feet</td>
<td>300 feet</td>
</tr>
<tr>
<td>0.5</td>
<td>136</td>
<td>272</td>
<td>408</td>
</tr>
<tr>
<td>1.0</td>
<td>68</td>
<td>136</td>
<td>204</td>
</tr>
<tr>
<td>1.5</td>
<td>45</td>
<td>91</td>
<td>136</td>
</tr>
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<td>2.0</td>
<td>34</td>
<td>68</td>
<td>192</td>
</tr>
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<td>2.5</td>
<td>27</td>
<td>54</td>
<td>82</td>
</tr>
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<td>3.0</td>
<td>23</td>
<td>45</td>
<td>68</td>
</tr>
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<td>10.0</td>
<td>6.8</td>
<td>14</td>
<td>20</td>
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<td>12.0</td>
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</tr>
<tr>
<td>15.0</td>
<td>4.5</td>
<td>9</td>
<td>13.6</td>
</tr>
<tr>
<td>20.0</td>
<td>3.4</td>
<td>6.8</td>
<td>10.2</td>
</tr>
</tbody>
</table>
Uniform Release

If the application equipment you will be using has more than one nozzle (or more than 1 cluster of nozzles) or hopper, part of the calibration process is to measure the output from each to be sure that they all are releasing the correct amount of pesticide. Check whether the pesticide output from one or more nozzles (or cluster of nozzles) or hoppers is 5 percent more or less than the amount desired. Check for clogging or other obstruction in the openings that are distributing less. Check for leaks or worn parts in the openings that are distributing more. If you find no correctable problem, replace the nozzles or hoppers.

You can check for uniform output in the following two ways. Either method requires that you use containers (jars) to collect the output from each nozzle, nozzle cluster, or hopper.

- Operate the equipment for a set period of time (1 to 5 minutes) and compare the amount of output in each jar to the amount desired, or
- Operate the equipment over a measured area while calibrating the equipment and, at the end of the calibration run, compare the amount of output in each jar to the amount desired.

If all the nozzles or hoppers are intended to release an equal amount of pesticide, just check whether all the containers contain the same amount.

Calibration Methods

No matter what calibration method you use, you will be measuring how much pesticide is being applied in a specific area. Calibration usually requires you to operate the equipment over a pre-measured distance.

It is best to use something other than the actual pesticide when you make test applications during calibration. This is not always possible, because the rate of application depends partly on the properties of the pesticide — such as droplet size, weight, and texture. If the pesticide is a liquid formulation diluted with water, you can use water alone in the test. If the pesticide is a dust, granule, or fumigant, or a liquid diluted with a liquid other than water, you usually must use the actual pesticide in the test.

With some kinds of equipment, the rate of application depends also on the pressure and on the nozzle size or hopper opening. The equipment manufacturer’s directions and pesticide label directions can provide guidelines for these selections.

Do a Test Application

To find out how much pesticide your equipment is applying, make a test run. One way to determine how much was applied during the test run is to:

- Accurately measure the amount in the tank or hopper at the start.
- Operate the equipment over the pre-measured distance while maintaining your chosen speed (if speed affects the delivery rate of the equipment you are using).
- Accurately measure the amount needed to refill the tank or hopper to the pre-application level.

Another way to determine how much was applied during the test run is to:

- Attach collection containers to the nozzles or hoppers.
- Operate the equipment over the pre-measured distance while maintaining your chosen speed (if speed affects the delivery rate of the equipment you are using).
- Measure the amount of material collected. If the equipment has multiple nozzles or hoppers, add together the output of all the collection containers.
Figure the Application Rate

The amount of pesticide applied, divided by the area covered, is the application rate. Sometimes no calculations are needed. If, for example, the label lists the application rate as “per acre” or “per 1,000 linear feet” and you measure the output for exactly 1 acre or exactly 1,000 linear feet, no calculations are necessary because the amount of output you measured is the total amount required.

However, you may not have the time to test your equipment over such a large site. Or, if you are using the actual pesticide in the test, you may not want to risk applying it over a large site without knowing the application rate. Under these conditions, you can test smaller sites and then calculate the application rate.

Small equipment, small target sites

If you are using application equipment that carries a relatively small load (up to a few gallons of liquid or a few pounds of dry pesticide) or if the target site is relatively small (less than an acre or 1,000 linear feet), you can choose a test site that is small.

If the use directions are for 100 linear feet, you might choose a test site of 25 linear feet. If the directions are for 1,000 square feet or for an acre, you might choose a test site of 250 square feet (a 10- by 25-foot rectangle). Measure the amount applied in this smaller site and then multiply to find the rate:
- The amount applied to 25 linear feet, multiplied by 4, equals the rate per 100 linear feet.
- The amount applied to 250 square feet, multiplied by 4, equals the rate per 1,000 square feet.
- The amount applied to 250 square feet, multiplied by 175, equals the rate per acre.

Larger equipment, larger target sites

If you are using application equipment that carries a larger load (more than a few gallons of liquid or a few pounds of dry pesticide) or if the target site is relatively large (greater than an acre or 1,000 linear feet), choose a larger test site. If the test site for these types of equipment or sites is too small, measurements are likely to be inaccurate. Operating a boom or other multi-nozzle or multi-hopper equipment over a site as small as 10 feet by 25 feet, for example, would not allow you to carry or drive the equipment far enough to gauge average speed accurately.

If label directions tell you the amount to apply per 1,000 square feet or per acre, use a test site of at least 1,000 square feet (a 20- by 50-foot rectangle, for example). The output you measure during the test will be the actual application rate for the 1,000 square feet. To find the rate per acre, multiply the test output by 43.56, which is the number of square feet in an acre (43,560) divided by 1,000.

Check Calibration Often

Once you have calibrated your equipment, do not assume that it will continue to deliver the same rate during all future applications. Clogging, corrosion, and wear may change the delivery rate, or the settings may gradually get out of adjustment. Taking the time to check the calibration of your equipment regularly is worth your while.

Be alert for possible calibration problems each time you use your application equipment. During the application, notice whether you are treating the same amount of area per load that you figured. If you find that you are covering more or less area than your figures indicated, stop application and check both your calculations and the equipment. If you have figured wrong or if your application equipment changes its delivery rate, you will be able to correct the mistake before you have a major problem.

Calibrating Sprayers

To calibrate spray equipment, you must determine:
- the appropriate pump pressure,
- the spray volume to be delivered,
- the type of diluent to be used (usually water).
Pump pressure

Pump pressure is controlled by the type of equipment — particularly the type of pump — you have chosen. Each pump is designed to provide a range of optimum pressures. To protect the pump and to ensure steady pressure output, do not operate it at pressures above or below its optimum range. Within the optimum pressure range, you can determine which specific pressure to use by considering such factors as:

- drift hazard (lower pressure produces less drift),
- penetration required (penetration of foliage, animal hairs, soil surfaces, and other barriers requires higher pressure),
- recommendations on the pesticide labeling or from other sources.

Spray volume

The amount of spray volume needed for effective application is often listed in the labeling (or other recommendations). The spray volume is the amount of diluted pesticide mixture to be applied per unit of area. The recommendation may be for a specific volume, such as 20 gallons per acre or 2 1/2 gallons per 1,000 square feet.

In other cases, a wide range of acceptable volumes may be listed; for example, “up to 400 gallons per acre,” or “15 to 40 gallons per acre.” Choose the spray volume most appropriate for your spray job. Base the choice on your experience with the equipment and such factors as:

- the size of the spray tank,
- the availability and cost of water or other label-specified diluent,
- the surface to be treated (dense foliage, animal hairs, and porous surfaces require more volume).

Whatever spray volume you use, remember that you need to calculate the dilution carefully to be sure you are delivering the correct amount of pesticide active ingredient to the target.

Spray volume recommendations usually are given in terms of broadcast spraying. The band rate also may be included. If not, you will have to determine the appropriate rate for band spraying. Divide the band width by the row spacing to determine what proportion of the field area is actually being sprayed. Then multiply by the broadcast rate per acre to determine the gallons per acre (gpa) needed for band spraying.

\[
\frac{\text{Band width} \times \text{broadcast rate}}{\text{Row Spacing}} = \text{Gpa needed for band spraying}
\]

Example:

\[
\frac{\text{Band width (10 in.)} \times \text{broadcast rate (20 gpa)}}{\text{Row spacing (40 in.)}} = \text{Gpa when band-applied(5)}
\]
Type of diluent

The diluent for most spray applications is water. However, your situation may require the use of another diluent. The pesticide labeling usually recommends the diluent to be used with that product. You must know what diluent you will use before you can select the appropriate nozzles for the job.

Because most selection charts provided by nozzle manufacturers are based on spraying with water, the figures will not be correct if you are using another diluent. A table such as Table 2 is often provided to help you adjust the figures to fit your situation.

Multiply the values on the nozzle charts by the conversion factor from the table to determine the correct value for the solution being sprayed.

<table>
<thead>
<tr>
<th>Weight of Solution</th>
<th>Factors</th>
</tr>
</thead>
<tbody>
<tr>
<td>6.6 lbs per gallon - KEROSENE</td>
<td>1.26</td>
</tr>
<tr>
<td>7.0 lbs per gallon</td>
<td>1.09</td>
</tr>
<tr>
<td>8.0 lbs per gallon</td>
<td>1.02</td>
</tr>
<tr>
<td>8.34 lbs per gallon - WATER</td>
<td>1.00</td>
</tr>
<tr>
<td>9.0 lbs per gallon</td>
<td>.96</td>
</tr>
<tr>
<td>10.0 lbs per gallon</td>
<td>.91</td>
</tr>
<tr>
<td>11.0 lbs per gallon</td>
<td>.87</td>
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<tr>
<td>12.0 lbs per gallon</td>
<td>.83</td>
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<tr>
<td>14.0 lbs per gallon</td>
<td>.77</td>
</tr>
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<td>16.0 lbs per gallon</td>
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</tr>
<tr>
<td>18.0 lbs per gallon</td>
<td>.68</td>
</tr>
<tr>
<td>20.0 lbs per gallon</td>
<td>.65</td>
</tr>
</tbody>
</table>

Example:

You have determined that you would be applying 6 gallons per acre if water were the diluent. The solution you are using, which is not water-based, weighs 16 pounds per gallon:

\[ 6 \text{ gpa} \times .72 \text{ (conversion factor from Table 2)} = 4.32 \text{ gpa} \]

Selecting Nozzle Tips and Strainers

Nozzle manufacturers help applicators choose the right tip for each job by providing detailed charts of tip performance. You can match the specific needs of the job to information on the chart to decide what tips and strainers to use.

The charts include the factors you must consider in order to choose the right nozzles — pressure, equipment speed, and spray volume. In general, nozzle selection is based on the gallons per minute (gpm) the nozzles produce. If the chart shows spray volume in terms of both gallons per minute and gallons per acre (gpa), you can choose nozzles without further figuring. Some manufacturers, however, list only gallons per minute. The following formula converts from gallons per acre to gallons per minute:

\[ \frac{\text{Gallons per acre} \times \text{miles per hour (mph)} \times W}{5,940} = \text{Gallons per minute (per nozzle)} \]

(In boom spraying, \( W = \text{nozzle spacing, in inches.} \) In boomless spraying, \( W = \text{sprayed width, in inches.} \))

Example:

\[ \frac{10 \text{ gpa} \times 4 \text{ mph} \times 20'' \text{ nozzle spacing}}{5,940} = 0.13 \text{ gpm} \]

The nozzle charts that accompany this unit are typical of those that manufacturers commonly distribute, but the nozzles named are not actual products.
Boom sprayers deliver the pesticide solution from several nozzles placed along a long pipe or other structure called a boom. The spacing between the nozzles is determined by the row spacing (in band or directed applications) and by individual preferences.

Common nozzle spacings are 20, 30, or 40 inches apart along the boom. Nozzle manufacturers often include a factor for spacing into their charts. If the nozzle spacing on your boom is different from those listed on the charts, you must use a conversion factor. Multiply the gallons per acre figure on the nozzle chart by the appropriate factor from Table 3.

### Table 3. Nozzle Spacing Conversion Factors

<table>
<thead>
<tr>
<th>Other Spacing</th>
<th>8&quot;</th>
<th>10&quot;</th>
<th>12&quot;</th>
<th>14&quot;</th>
<th>16&quot;</th>
<th>18&quot;</th>
<th>22&quot;</th>
<th>24&quot;</th>
<th>30&quot;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conversion Factor</td>
<td>2.5</td>
<td>2.0</td>
<td>1.67</td>
<td>1.43</td>
<td>1.25</td>
<td>1.11</td>
<td>.91</td>
<td>.83</td>
<td>.66</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Other Spacing</th>
<th>28&quot;</th>
<th>30&quot;</th>
<th>32&quot;</th>
<th>34&quot;</th>
<th>36&quot;</th>
<th>38&quot;</th>
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</thead>
<tbody>
<tr>
<td>Conversion Factor</td>
<td>1.43</td>
<td>1.33</td>
<td>1.25</td>
<td>1.18</td>
<td>1.11</td>
<td>1.05</td>
<td>.95</td>
<td>.91</td>
<td>.83</td>
</tr>
</tbody>
</table>

**Example:**

A nozzle selection chart based on 20-inch nozzle spacing shows that the tips you are using would apply 6 gallons per acre. The nozzles are spaced at 16 inches:

\[
6 \text{ gpa} \times 1.25 \text{ (conversion factor from Table 3)} = 7.5 \text{ gpa}
\]

The height of the boom above the soil surface (or above the plants in over-the-top applications) influences the type of nozzle tips you choose for broadcast applications and for some band applications. In directed spraying, the boom height is not a factor in nozzle selection because the nozzles can be positioned to direct the spray at specific parts of the plant.

Boom height is determined by the equipment you have chosen and by crop height or obstacles that may have to be cleared.

**Broadcast boom spraying** is the uniform application of a pesticide over an entire area. To select nozzles for a broadcast boom sprayer, you must know:

- approximate boom height,
- nozzle spacing on the boom,
- pump pressure,
- sprayer speed,
- gallons of spray to be applied per acre.

**Example:**

- Boom height = 22 inches.
- Nozzle spacing = 20 inches.
- Pump pressure = 30 psi.
- Sprayer speed = 4 mph.
- Spray volume = 10 gpa.
Table 4 shows that:
- The 65°-series will accommodate a 22-inch boom height.
- The 20-inch nozzle spacing is factored into the chart.
- Any of the nozzle tips listed will operate at 30 psi.
- The 4 mph tractor speed narrows the choice to nozzle tip number 502, which delivers 9.7 gpa. The chart requires a 100-mesh strainer for that nozzle.

Note that other nozzle tips could be used if you changed the speed and the pump pressure. However, it is usually more economical to purchase tips that allow you to operate your equipment at its optimum pressure and speed.

<table>
<thead>
<tr>
<th>Flat Spray Tip No. and strainer screen size</th>
<th>501 (100 Mesh)</th>
<th>502 (100 Mesh)</th>
<th>503 (50 Mesh)</th>
<th>504 (50 Mesh)</th>
<th>505 (50 Mesh)</th>
<th>506 (50 Mesh)</th>
<th>507 (50 Mesh)</th>
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</thead>
<tbody>
<tr>
<td>Flat Spray Tip No. and strainer screen size</td>
<td>65° Series (For Boom Heights of 21-23 inches)</td>
<td>Gallons Per Acre (25° Nozzle Spacing)</td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pressure in psi</td>
<td>1 Nozzle in gpm</td>
<td>4 mph</td>
<td>5 mph</td>
<td>7.5 mph</td>
<td>10 mph</td>
<td>4 mph</td>
<td>5 mph</td>
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</tr>
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</table>
Band spraying is application of a pesticide to a strip over or along a crop row. Choosing nozzles for a band sprayer is very similar to choosing them for a broadcast sprayer. However, if the labeling lists the spray volume in terms of broadcast spraying, you must first convert that figure to the band rate. Use the formula discussed in the section on “Spray Volume” (page 4-8):

\[
\frac{\text{Band width} \times \text{Broadcast rate}}{\text{Row spacing}} = \text{Gpa needed for band spraying}
\]

Before you select the nozzles for your band sprayer, you must know:
- the boom height (the height of the boom above the surface will determine the nozzle angle needed to achieve the desired band width),
- row spacing (same as nozzle spacing on boom),
- pump pressure,
- sprayer speed,
- spray volume per acre (band rate),
- the desired band width.

**Example:**
- Row spacing = 40 inches.
- Pump pressure = 30 psi.
- Sprayer speed = 5 mph.
- Spray volume for band application = 5 gpa.
- Boom height = 6 inches.
- Band width = 10 inches.

To select a nozzle tip, use Table 5, which is for nozzles spaced at 40-inch intervals. Using the “5 mph” column, look at the gpa output of each nozzle at 30 psi until you find the 5 gpa you need. You will find that the tip numbered 103 with 50-mesh strainers will deliver 5.1 gpa.

To select the correct nozzle angle, use Table 6. It indicates that since you have chosen a 6-inch boom height and need to achieve a 10-inch band width, an 80° fan angle (with the number 103 nozzle tip) is needed.
Directed spraying is aiming a pesticide at a specific portion of a plant. Choosing nozzles for directed spraying is very similar to choosing them for broadcast treatments, except that the number of nozzles per row and the spacing of the rows become the variables. Nozzle manufacturers usually supply special charts for selecting nozzles for directed spraying. You must know:

- row spacing,
- number of nozzles to be used per row,
- pump pressure,
- sprayer speed,
- spray volume per acre.

**Example:**

- Row spacing = 30 inches.
- There are two nozzles per row.
- Pump pressure = 80 psi.
- Sprayer speed = 4 mph.
- Spray volume = 15 gpa.

Using Table 7, you should choose nozzle tip number 3-23.

### Table 7. Hollow Cone Tips

<table>
<thead>
<tr>
<th>Liquid Capacity per nozzle</th>
<th>Gallons Per Acre–30” Row Spacing</th>
<th>Gallons Per Acre–40” Row Spacing</th>
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<td>Tip Pressure in psi</td>
<td>One Nozzle per Row</td>
<td>Two Nozzles per Row</td>
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<td>380</td>
<td>0.08</td>
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<td>60</td>
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<td>400</td>
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</table>

4-13
Boomless sprayers

Boomless sprayers have either a single nozzle or a multiple-tip cluster that produces a swath-like spray pattern. The spray delivery is similar to that laid down by a boom sprayer.

Choosing tips for the cluster nozzles is similar to choosing them for a boom sprayer. You must determine the spray volume per acre you wish to apply. You also must choose the operating pressure and speed at which your sprayer performs best. Then use the charts in the nozzle manufacturer’s catalogs to select the nozzle tips and spraying height that best fit your needs. The number of tips and the spraying height determine the width of the swath you will be spraying with each pass. You will have several nozzles from which to choose. Base your decision on:

- approximate swath width you wish to use (open field indicates wider swath; area with obstacles such as trees or buildings requires a narrower swath),
- drift hazard (higher spray heights and greater swath widths increase drift),
- single- versus double-side spraying.

Remember, the double tips will deliver twice the swath width and twice the output capacity in gallons per minute as single tips. However, at any given speed, the gallons per acre delivered by double tips is approximately the same as gallons delivered by single tips.

Example:

You want to apply 15 gallons per acre. Your sprayer works best at 5 mph and 40 psi. Table 8 indicates that tip C-4 will deliver 14.7 gpa at that speed and pressure. If the nozzle is set at a 36-inch spray height, the effective swath width is 27 feet. There are separate charts available for several different spray heights, which will allow you to choose from several nozzles, depending on the requirements of your job.

### Table 8. Cluster Tips

<table>
<thead>
<tr>
<th>Nozzle Number</th>
<th>Liquid Pressure in psi</th>
<th>Nozzle Capacity in gpm</th>
<th>Swath Width in Feet</th>
<th>(Spraying Height SH = 36&quot;) Gallons per Acre at:</th>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>5 mph</td>
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<td>18½</td>
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Airblast sprayers

Airblast sprayers use large quantities of air and smaller quantities of water to deliver the pesticide to the target. Some sprayers (especially those of small capacity) spray to only one side at a time and so may require two passes per row. Other sprayers direct the spray to both sides and require only one pass between each crop row.

Airblast sprayers usually require a nozzle arrangement that permits a greater percentage of spray to be discharged from the upper half of the manifold. Usual recommendations are to select nozzle tips so that two-thirds (67 percent) of total spray volume discharged is from the top half. For most airblast applications that are broadcast, the nozzles should be selected to direct the largest part of the spray into the upper half of the airstream.

Follow the steps below to determine how many nozzles will be needed to provide coverage of the crop you will be spraying:

1. First, determine the number of nozzles you will be using on each manifold. This number depends on the type of equipment you will be using and the size, shape, and density of crop you will be spraying. The following examples will help you arrange nozzles on your sprayer manifold.

   Two-side delivery in high trees with low branches:
   - upper vanes raised,
   - upper nozzles opened,
   - lower nozzles opened.

   Two-side delivery in medium trees with low branches:
   - external vanes pointed at tree top,
   - upper nozzles closed to prevent deflection by external vanes,
   - lower nozzles opened.

   Two-side delivery in medium trees, pruned high:
   - external vanes pointed at tree top,
   - upper nozzles closed as required to prevent deflection by external vanes,
   - lower nozzles closed.

   One-side delivery for high trees or overly dense foliage:
   - cover closed on the side that will not be used,
   - external vane aimed at tree top,
   - upper nozzles closed as required to prevent deflection by external vane,
   - lower nozzles closed as required, depending upon height of lower branches.

   Two-side delivery — young orchard or grove with widely spaced rows:
   - external vanes lowered in full down position,
   - upper nozzles closed, as required,
   - lower nozzles closed, as required.

2. Divide the desired gallons per minute (gpm) by the number of manifolds your equipment has. Some equipment has one manifold per side; other equipment has two manifolds per side.

3. Divide the number of nozzles you will be using on each manifold by 2. This allows you to determine the discharge rate for the upper half and lower half of the manifold separately. If your equipment has nozzles unevenly spaced along the manifold, consult your equipment manufacturer’s information for the number and placement of nozzles directing spray to the upper half of the tree. Normally the bottom 2, 3, or 4 nozzles cover the lower part of the tree.

4. Multiply the discharge rate per manifold (in gpm) by 0.67 to find the discharge rate for the nozzles in the upper section of each manifold (since 67 percent of the spray should be discharged to the upper half of the tree).
(5) Multiply the discharge rate per manifold (in gpm) by 0.33 to find the discharge rate for the nozzles in the lower section of each manifold.

(6) Divide the gpm for the upper section of the manifold by the number of nozzles in that section to find the gpm you need for each nozzle.

(7) Divide the gpm for the lower section of the manifold by the number of nozzles in that section to find the gpm you need for each nozzle.

(8) Use nozzle manufacturer's charts to select the appropriate nozzles.

(9) Check the total capacity of your nozzle arrangement by using the following formula:

\[
\text{Total capacity per manifold} = \left(\frac{\text{Number of nozzles in upper section} \times \text{Capacity per nozzle}}{2}\right) + \left(\frac{\text{Number of nozzles in lower section} \times \text{Capacity per nozzle}}{2}\right)
\]


Compare this rate with the desired discharge rate.

**Example:**

Your equipment has the capacity to apply 14 gpm spraying two sides at 200 psi with one manifold per side. You need eight nozzles operating on each manifold for best coverage of the trees.

\[
\frac{\text{Total discharge rate (14)}}{\text{Number of manifolds (2)}} = \text{Discharge rate per manifold (7 gpm)}
\]

\[
\frac{\text{Number of nozzles per manifold (8)}}{2} = \text{Number of nozzles in upper (or lower) section (4)}
\]

Discharge rate per manifold (7 gpm) \times 0.67 = 4.7 gpm for upper portion

Discharge rate per manifold (7 gpm) \times 0.33 = 2.3 gpm for lower portion

\[
\frac{\text{Gpm for upper section (4.7)}}{\text{Nozzles in section (4)}} = 1.2 \text{ gpm per nozzle in upper section}
\]

\[
\frac{\text{Gpm for lower section (2.3)}}{\text{Nozzles in section (4)}} = 0.6 \text{ gpm per nozzle in lower section}
\]

The airblast nozzle chart (Table 9) indicates that you can choose nozzles 156-B (1.18 gpm) or 141-A (1.23 gpm) for the upper portion. You probably would select 156-B (a two-hole core or whirler), because it delivers larger droplets, provides longer throw, and yields a narrower spray pattern than the 141-A (a five-hole core or whirler). The nozzle charts also indicate that you can choose either nozzles 139-A (0.55 gpm) or 153-B (0.62 gpm) for the lower portion of the manifold. You probably would select the 153-B, because it delivers a wider angle that will better cover the lower parts of the tree.

Check the total capacity of your nozzle arrangement:

\[
\text{Number of nozzles in upper section (4) \times Capacity per nozzle (1.18) = 4.7 gpm for upper section}
\]

\[
\text{Number of nozzles in lower section (4) \times Capacity per nozzle (0.62) = 2.5 gpm for lower section}
\]

\[
4.7 + 2.5 = \text{Total capacity per manifold (7.2 gpm)}
\]

\[
\text{Capacity per manifold (7.2) \times Number of manifolds (2) = 14.4 gpm.}
\]

This is slightly more than the 14 gpm you need. You may compensate by driving slightly faster.
Note: The exact gpm you are seeking will rarely be on the chart. Try to choose nozzles closest to the gpm you need. For the upper portion, choose a size that delivers slightly more than you need. Then compensate by choosing slightly lower capacity nozzles for the lower portion, or vice versa.

### Table 9. Airblast Nozzles

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<th>140-A</th>
<th>141-A</th>
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<th>143-A</th>
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Note: A-Series Nozzles have five-hole core or whirler.

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<th>153-B</th>
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Note: B-Series Nozzles have two-hole core or whirler.
Spray-gun nozzles

Gun spraying usually is done by hand and is intended to wet surfaces thoroughly with spray material. To choose an appropriate spray gun nozzle, you must know the approximate operating pressure of your sprayer. Some guns are designed for a wide range of pressures (from 30 to 800 psi, for example), but others are built for narrower ranges (up to 200 psi or from 200 to 800 psi, for example). The other variables are the spray angle each nozzle delivers at various pressure settings and the maximum throw of each nozzle at different pressures.

You must decide which nozzle delivers spray at the appropriate angle and throw distances for your particular application job. Choose the tip according to the gallons per minute your sprayer will deliver and the pressure necessary to do the job. Nozzle capacities range from 0.25 gpm to 50 gpm at 30 to 800 psi, with throw distances of up to 60 feet.

Calibration at the Application Site

The first step in calibration is to check two important factors related to the nozzles:
- pressure at the nozzles,
- nozzle flow rates.

Unless these two factors match the figures on the manufacturer’s charts, your equipment will not deliver the specified amount of pesticide.

The nozzle selection charts are based on pressure at the nozzles. To check nozzle pressure, mount a pressure gauge close to the nozzles. Then compare that reading with the pressure reading at the main line pressure gauge. (After the test, remove the pressure gauge near the nozzles and plug the connection.)

Even new nozzles may deliver rates that vary from the manufacturer’s charts; variance in delivery rates can result in underdosing or overdosing. You can check nozzle flow rates by measuring the length of time needed to collect a quart of diluent from each nozzle. Using Table 10, you can convert this information to gallons per minute.

Next, you must test your equipment at the application site to determine whether it is delivering the pesticide at the desired rate. Several methods for testing various types of spray equipment are explained below. If you find that the equipment is not delivering at a

**Table 10. Rates of Flow**

<table>
<thead>
<tr>
<th>gpm</th>
<th>Seconds to collect 1 quart</th>
<th>gpm</th>
<th>Seconds to collect 1 quart</th>
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<tr>
<td>.17</td>
<td>88</td>
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</table>
rate that is within 5 percent of the desired gpm or gpa, you must make adjustments and do another test. Minor adjustments in gallons per acre or gallons per minute can be made in one of three ways:

- **Changing the pump pressure** — Lower pressure means less spray delivered; higher pressure means more spray delivered. (Only minor adjustments should be made, because a large pressure change will change the droplet size significantly.)

- **Changing the sprayer speed** — Slower speed means more spray delivered; faster speed means less spray delivered. This is a practical method for most small changes.

- **Changing nozzle tips** — This is the preferred method for large changes in delivery rate.

---

**Boom sprayer calibration**

Install the nozzle tips in the nozzle bodies on the boom using the spacing and boom height appropriate for the nozzle tips. Align them carefully. Misalignment of nozzle tips is a common cause of uneven coverage. Do not use nozzles of different sizes and spray angles on the same boom except in special multiple-nozzle arrangements designed for directed spraying. Check the boom to be sure it is level. If it is not, the spray pattern will be uneven.

Nozzle manufacturers usually recommend a 30-percent spray pattern overlap in broadcast boom spraying. The height of the boom alters the percentage of overlap of the spray pattern, so use the boom height recommended by the manufacturer. At that height, the spray angle built into the nozzles provides approximately the correct overlap.

In band spraying, the boom height influences the width of the band the nozzle is delivering. Make adjustments in the boom height to achieve the desired band width with the angle of nozzle you have chosen.

Fill the spray tank with the diluent you will be using and run the pump to pressurize the system. Operate the sprayer briefly on a paved surface such as a road or driveway, if possible, and check for:

- correct broadcast overlap or band pattern,
- streaks and uneven patterns caused by worn or partly plugged nozzles.
Make any necessary adjustments and then refill the tank. The next step is to choose a calibration method. There are many different ways to calibrate sprayers. Here are two basic methods:

**Nozzle output method:**

1. Using Table 11 below, select the appropriate distance and mark it off in the field or area you will be spraying. For broadcast applications, use the nozzle spacing to determine the calibration distance. For band or directed applications, use the row spacing.

2. Using the throttle setting and gear you wish to use, bring the sprayer up to speed. With the spraying system shut down, drive the measured distance and note the time in seconds that it takes.

3. With the equipment in neutral, operate the spray system for the measured time and collect the nozzle discharge in a container graduated in ounces. For a broadcast boom with evenly spaced nozzles, catch the output from any nozzle along the boom. If more than one nozzle per row is used, catch the spray from all nozzles directed at a single row.

4. The total discharge measured in ounces is equal to gallons per acre (gpa) applied. With either broadcast boom or band sprayer, the gpa is equal to the output from one nozzle. When more than one nozzle is used per row, the combined amount collected from all nozzles directed at the row is equal to the gpa.

<table>
<thead>
<tr>
<th>Table 11. Calibration Distances</th>
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**Example (Broadcast or Band Application):**

The pressure you have selected is 30 psi. The nozzles are spaced 20 inches apart on the boom.

1. The distance to mark off for 20-inch nozzle spacing is 204 feet.

2. Select the gear and throttle setting, bring the sprayer up to speed, and measure the time needed to cover 204 feet.

3. If it required 20 seconds to travel the 204 feet, set the pressure at 30 psi and catch one nozzle’s output for 20 seconds.

4. Measure the amount collected. The output in ounces is the amount applied in gallons per acre. If the nozzle output is 15 ounces, the sprayer applied 15 gallons per acre.

5. Repeat steps 3 and 4 for each nozzle.

**Example (Directed Spray):**

You want to spray a 32-inch row, using two nozzles per row (one on each side). The pressure to be used is 20 psi.

1. The distance to travel for a 32-inch row is 127 feet.

2. Select speed and drive the 127 feet. Measure the time in seconds.

3. If it took 15 seconds, set the pressure at 20 psi and catch the output from one pair of nozzles for 15 seconds.

4. Measure the quantity from the two tips. The amount measured in ounces represents the gallons per acre applied. If each tip delivers 5 ounces (a total of 10 for the pair), the sprayer output is 10 gallons per acre.

5. Repeat steps 3 and 4 for each pair of nozzles on the boom.
**Volume output method:** Sometimes it is not practical to catch the flow from individual nozzles. Another method of calibration is to measure the volume of spray dispersed from the tank over a measured area. Your test area can be either one acre or part of an acre. Be sure to compare flow rate from individual nozzles along the boom before using this method.

First, you must determine the sprayed width for your boom sprayer.

**The sprayed width for broadcast spraying** is the distance (in feet) between the first and last nozzles on the boom, plus the distance (in feet) between adjacent nozzles.

**Example:**
- Nozzle spacing is 24 inches (2 feet).
- Distance between the first and last nozzles on the boom is 18 feet.

\[ 18 \text{ feet} + 2 \text{ feet} = \text{a 20-foot sprayed width.} \]

**The sprayed width for band spraying** is equal to the number of bands (nozzles) multiplied by the band width (in inches). Divide by 12 to convert to sprayed width in feet.

**Example:**
- Number of bands = 9.
- Band width = 10 inches.

\[ \frac{90 \text{ inches}}{12} = \text{Sprayed width in feet (7.5)} \]

**The sprayed width for directed spraying** is equal to the number of rows sprayed multiplied by the row spacing (in inches). Divide by 12 to convert to sprayed width in feet.

**Example:**
- Number of rows = 7.
- Row spacing = 40 inches.

\[ \frac{280 \text{ inches}}{12} = \text{Sprayed width in feet (23.3)} \]

**Spray-an-acre method** — One type of volume output calibration involves spraying an entire acre:

1. Completely fill the tank with water.
2. Mark off one acre in the field to be sprayed. Use this formula to figure the distance you need to drive to cover one acre:

\[ \text{Distance to drive for one acre} = \frac{43,560}{\text{Sprayed width (in feet)}} \]

3. Spray the measured acre at the speed and pressure appropriate for the nozzles you have selected.
4. Completely refill the spray tank, using a container marked off in gallons. Carefully measure the quantity you add. The amount needed to completely refill the tank is the rate applied per acre.
Spraying less than one acre — Another way to calibrate by the volume output method is to spray an area smaller than an acre:

1. Stake out a test area in the field to be sprayed. The distance should be at least 1,000 feet.
2. Fill the spray tank with water.
3. Spray the measured area using the pressure and speed appropriate for the nozzles. Be sure the sprayer is at the correct speed when you reach the test strip.
4. Refill the tank to the initial level, carefully measuring the quantity you add.
5. Calculate the rate of application. The method of calculation depends on whether you are making a broadcast application or a band application.

To figure the gallons per acre for broadcast spraying, first find the area sprayed in the test run:

\[
\frac{\text{Sprayed width} \times \text{distance in test run}}{\text{Square feet in one acre (43,560)}} = \text{Area sprayed (in acres)}
\]

Then find the gallons per acre being sprayed:

\[
\frac{\text{Gallons used in test run}}{\text{Area (in acres) sprayed in test run}} = \text{Gallons per acre}
\]

**Example:**
- Sprayed width = 20 feet.
- Distance in test run = 1,000 feet.
- Gallons used in test run = 8.
- Spray volume desired = 18 gpa.

\[
\frac{\text{Sprayed width (20 ft.)} \times \text{test run (1,000 ft.)}}{43,560 \text{ sq. ft.}} = \text{Area sprayed (0.46 acre)}
\]

\[
\frac{\text{Gallons used (8)}}{\text{Area sprayed (0.46)}} = 17.4 \text{ gpa}
\]

Since the target rate was 18 gpa, and 5 percent more or less than the recommended rate is acceptable, the equipment is correctly calibrated.

To figure the gallons per acre for band application, find area sprayed in the bands of the test area:

\[
\frac{\text{Sprayed width} \times \text{band width} \times \text{no. of bands} \times \text{length of test run}}{\text{Square feet in one acre (43,560)}} = \text{Area sprayed in bands (in acres)}
\]

Find gallons per acre being sprayed in the bands:

\[
\frac{\text{Gallons used in test run}}{\text{Area sprayed in bands (in acres)}} = \text{Gallons per acre}
\]
When you calculate the spray volume desired for the job, remember to convert from broadcast rate to band rate, if necessary:

\[
\frac{\text{Band width} \times \text{broadcast rate}}{\text{Row spacing}} = \text{Gpa needed for band spraying}
\]

**Example:**
- Sprayed width = 7.5 ft. (nine 10-inch bands).
- Distance in test run = 1,000 ft.
- Gallons used in test run = 1.8
- Spray volume desired = 9 gpa (band rate)

\[
\frac{\text{Sprayed width (7.5 ft.)} \times \text{length of test run (1,000 ft.)}}{43,560} = \text{Area sprayed in bands (0.17 acre)}
\]

\[
\frac{\text{Gallons used (1.8)}}{\text{Area sprayed in bands (0.17)}} = \text{Gallons per acre (10.6)}
\]

This is more than 5 percent greater than the 9 gallons per acre you wish to spray, so you must make adjustments and do another test.

**Boomless sprayer calibration**

Calibrate boomless sprayers using the volume output method. Use either the “spray-an-acre” or “spray-part-of-an-acre” technique to measure boomless sprayer output. The sprayed width is the effective swath width your sprayer produces with the nozzle tips and spray height you have chosen. Nozzle selection charts often specify the effective swath width produced by the nozzles at a given height. An overlap percentage may also be recommended.

If you need to measure the effective swath width, spray water on a dry surface under calm conditions at the operating pressure and nozzle height you have chosen. Measure the sprayed width (in feet). The portion that is completely wet is the effective swath width. The width of the area on the fringe that is not completely wetted is the area you need to overlap on the next pass for complete coverage. Boomless sprayers often require 50-percent overlap.

**High-pressure (hydraulic) sprayer calibration**

High-pressure sprayers sometimes are equipped with booms. Even when a high-pressure sprayer is boomless, it may have nozzles that spray a swath. When used in this way, a high-pressure sprayer is calibrated in the same way as a low-pressure boom or boomless sprayer.

High-pressure sprayers also may be equipped with spray guns for treating livestock, orchards, nurseries, roadsides, or rights-of-way. Once the appropriate spray gun tip has been chosen and the flow rate has been checked, no further calibration is necessary.

**Airblast sprayer calibration**

Since airblast sprayers are often used to apply a highly concentrated spray mixture, you must take great care in calibrating the sprayer. With dilute mixtures, a variation of 3 gallons per minute in spray output has little effect on the amount of active ingredient delivered; however, with more concentrated sprays, the same variation can cause an application rate error of 10-fold or more.

The most common error in airblast sprayer operation is traveling at the wrong speed. A travel rate that is too slow will result in overspraying and the waste of time, fuel, money, and pesticide. Too fast a travel rate will result in inadequate spray coverage, resulting in poor pest control.
Most airblast applications operate best at a maximum speed of 2 mph. In cases of very dense foliage or large trees, select a lower speed (from \( \frac{3}{4} \) to \( 1\frac{1}{2} \) mph). Increased speed reduces the coverage to the tops and centers of trees, even though the liquid delivered per tree or per acre is otherwise adequate.

To determine the optimum ground speed, fill the tank with water and make a test run in the area to be treated. Vary the rate of speed until the spray material is being blown through the trees in the desired pattern. In orchard, nursery, and forestry spraying, the spray must be blown completely through the trees. Field crop, mosquito, and similar applications require uniform penetration across the swath width.

To determine sprayer speed in mph, measure the feet traveled in 1 minute and divide by 88. If the distance between trees is constant, you can count the number of trees passed in 1 minute and use this formula to compute speed:

\[
\frac{\text{Tree spacing (tree center to tree center in feet)}}{88 \text{ feet per minute (conversion factor)}} \times \text{No. of trees passed per minute} = \text{Ground speed in mph}
\]

Choosing the spray volume (discharge rate): Airblast sprayers can deliver highly concentrated chemicals. They can carry the same amount of pesticide to the target that other types of equipment do, while using much less water. The amount of chemical per tankful is 3, 5, or even 10 times the amount used with hydraulic sprayers, but only \( \frac{1}{2} \) to \( \frac{1}{10} \) as many gallons of total spray volume (water and pesticide) are applied. The amount of active ingredient that reaches the target should be the same as with other methods.

Sometimes the labeling or other sources specify the concentration necessary for airblast equipment (3×, 5×, 10×, etc.). Many times, however, the applicator must choose the concentration to apply. Consider these factors in making your choice:

- The savings in water and labor are greatest when converting from dilute to 5× or 10× concentrates.
- Over 10×, the savings are negligible.
- High-concentrate applications (over 5×) require extreme accuracy and ideal spraying conditions.
- Very small changes in rate of speed or nozzle output are magnified by the concentrations of the tank mixture.

Labeling and other recommendations often list spray volume in terms of:

- pints, quarts, gallons, or pounds of spray mixture per tree (dilute or concentrated),
- pints, quarts, gallons, or pounds of spray mixture per acre (dilute or concentrated),
- gallons or pounds per acre of dilute spray (as applied by other equipment).

Depending on the requirements of your job, you may need to convert these spray volume recommendations in order to determine the correct discharge rate (in gallons per minute) for your airblast sprayer. Use the following formulas:

1. **When spray volume is given as gallons or pounds per tree in concentrate and trees are closely spaced so that continuous spraying is feasible:**

   - Determine the gallons of spray to apply to each tree in each pass. Since you spray the tree from both sides:

     \[
     \text{Recommended rate per tree per pass (or side)} = \frac{\text{Recommended rate per tree}}{2 \text{ passes (sides) per tree}}
     \]

     \[
     \text{Rate per pass} = \frac{1}{2} \text{ the recommended rate}
     \]
Determine the gpm you need for your sprayer to deliver the desired rate per tree per pass. At the rate of speed you have selected, determine the number of trees passed per minute (by counting or by using the following formula):

\[
\text{Trees passed per minute} = \frac{\text{Mph} \times 88 \text{ ft. per minute}}{\text{Tree spacing in feet}}
\]

If your sprayer sprays on one side only, then:

\[
\text{Gpm} = \text{Trees passed per minute} \times \text{Spray volume in gallons per tree per pass}
\]

If your sprayer sprays on two sides:

\[
\text{Gpm} = \text{Trees passed per minute} \times 2 \times \text{Spray volume in gallons per tree per pass}
\]

**Example:**

- The labeling calls for 2 pints spray concentrate per tree (2 pints = \(\frac{1}{4}\) or .25 gallons).
- Your spray equipment covers the tree thoroughly at 3 mph and sprays to one side only.
- The trees are spaced at 20-foot centers.

\[
\frac{\text{Recommended rate per tree in gallons (0.25)}}{\text{Passes per tree (2)}} = \text{Gallons per tree per pass (0.125)}
\]

\[
\frac{\text{Mph} (3) \times 88 \text{ ft/min}}{\text{Tree spacing (20 ft.)}} = \text{Trees passed per minute (13.2)}
\]

Trees passed per minute (13.2) \(\times\) Spray volume in gallons (0.125) = 1.65 gpm

(2) **When spray volume is gallons per tree in concentrate, spaces exist between trees, and the airblast sprayer will be used to spot spray each tree:**

- Determine the gallons of spray to apply for each side of each tree (as above).
- Find the time (in minutes) you require to pump the needed number of gallons into each side of each tree using the nozzles on your sprayer. First, fill the tank with water. (If you use less than a full tank, be sure to note the water level so you can refill to the same point later.) Bring blower and pump up to speed and run for 5 minutes. Measure the amount of water needed to refill the tank to the original level.

\[
\text{Gpm} = \frac{\text{Gallons pumped in test}}{\text{Minutes in test}}
\]

If your sprayer delivers large volumes (15 or more gallons) per minute, reduce the test time to 1 or 2 minutes.
- Determine the number of minutes you need to spray each side of the tree:

\[
\text{Minutes per side of tree} = \frac{\text{Gallons per side}}{\text{Gallons per minute}}
\]
Example:
- The labeling calls for 3 gallons of concentrate spray per 50-foot elm tree.
- Your sprayer pumps 50 gallons in 5 minutes.

\[
\frac{3 \text{ gallons}}{2 \text{ sides}} = 1.5 \text{ gallons per side of tree}
\]

\[
\frac{\text{Gallons pumped in test} (50)}{\text{Minutes in test} (5)} = \text{Gpm} (10)
\]

\[
\frac{\text{Gallons per side} (1.5)}{\text{Gallons per minute} (10)} \approx 0.15 \text{ minutes (9 seconds) per side}
\]

(3) When the recommended spray volume is listed as pounds or gallons of dilute spray per acre:
You must convert the volume of dilute spray to volume of concentrate spray. There are two methods:
- volume of concentrate per tree,
- volume of concentrate per acre (the only choice when you will be spraying field crops, turf, or other nontree areas).

To convert recommendations for volume of dilute spray per acre to volume of concentrate per tree:
- Determine the gallons of dilute spray that conventional hydraulic sprayers would apply to each tree.
  Charts are available to guide you, or your experience with hydraulic equipment may help you to make the determination.
- Calculate the application rate per tree.

\[
\frac{\text{Gallons per tree (dilute)}}{\text{Concentration to be used} (\times)} = \text{Gallons per tree (concentrate)}
\]

- Because the tree is sprayed on two sides, figure the gallons to be applied to each side of the tree (gallons per pass).

\[
\frac{\text{Gallons (concentrate) per tree}}{\text{Passes per tree} (2)} = \text{Gallons per pass (concentrate)}
\]

- Determine the rate of speed that is best for your equipment.
- Determine the gpm needed.

For a sprayer directing spray to one side:

\[
\text{Mph} \times 88 \text{ ft/min} \times \frac{\text{gallons per pass per tree}}{\text{Tree spacing}} = \text{Gpm}
\]

For a sprayer directing spray to two sides:

\[
2 \times \text{mph} \times 88 \text{ ft/min} \times \frac{\text{gallons per pass per tree}}{\text{Tree spacing}} = \text{Gpm}
\]
Example:

- Labeling directions call for 1 pound per 100 gallons.
- Dilute spray volume = 12 gallons per tree.
- Concentration = 5x.
- Sprayer speed = 2 mph.
- Sprayer sprays to two sides.
- Tree spacing = 30 feet between centers.

\[
\frac{\text{Gallons per tree (dilute) (12)}}{\text{Concentration (5)}} = 2.4 \text{ gallons per tree}
\]

\[
\frac{\text{Gallons per tree (2.4)}}{\text{Number of passes (2)}} = 1.2 \text{ gallons per pass}
\]

\[
\frac{2 \times \text{mph} (2) \times 88 \times 1.2 \text{ gal/pass}}{\text{Tree spacing (30 ft.)}} = 14 \text{ gpm}
\]

To convert recommendations for volume of dilute spray per acre to volume of concentrate per acre (for tree spraying):

- Find gallons per acre (concentrate) you must apply:

\[
\frac{\text{Gallons per acre (dilute)}}{\text{Concentrate rate to be used}} = \text{Gallons per acre (concentrate)}
\]

- Then determine gpm:

For sprayers applying to one side only:

\[
\text{Gpm} = \frac{\text{Gallons per acre} \times \text{mph} \times \text{tree spacing (ft.)}}{1,000} \text{ (conversion factor)}
\]

For sprayers applying to two sides:

\[
\text{Gpm} = \frac{2 \times \text{gallons per acre} \times \text{mph} \times \text{tree spacing (ft.)}}{1,000} \text{ (conversion factor)}
\]

Example:

You have calculated that 1,760 gallons of dilute spray would be needed per acre, but you wish to apply a 4x concentration. Your sprayer covers evenly at 2 mph and is spraying to two sides. The trees are spaced on 24-foot centers.

\[
\frac{\text{Gallons per acre dilute (1,760)}}{\text{Concentration (4x)}} = 440 \text{ gpa}
\]

\[
\frac{2 \times \text{gpa (440)} \times \text{mph} (2) \times \text{tree spacing (24)}}{1,000} = 42.2 \text{ gpm}
\]
To convert recommendations for volume of dilute spray per acre to volume of concentrate per acre (for field, crop, turf, and other nontree spraying):

- Determine the swath width — follow equipment manufacturer’s recommendations and consider the field conditions (wind speed and direction).
- Determine gallons (concentrate) to be applied per acre.

\[
\frac{\text{Gallons per acre (dilute)}}{\text{Concentrate rate}} = \text{Gallons per acre (concentrate)}
\]

- Determine gpm.

\[
\text{Gpm} = \frac{\text{Gallons per acre} \times \text{mph} \times 88 \text{ ft/min} \times \text{swath width}}{43,560}
\]

**Example:**

- Labeling directions call for 200 gallons per acre dilute spray.
- Sprayer speed = 2.5 mph.
- Concentration = 6x.
- Swath width = 90 feet.

\[
\frac{\text{Gpa dilute (200)}}{\text{Concentration (6)}} = 33.3 \text{ gpa (concentrate)}
\]

\[
\frac{\text{Gpa conc. (33.3) \times \text{mph} (2.5) \times 88 \text{ ft/min} \times \text{swath width (90)}}}{43,560} = 15 \text{ gpm}
\]

### Calibrating Granule Applicators

There are many types of granule application equipment. Gravity-feed applicators may have one long hopper with a sliding gate or auger that regulates the flow to the multiple outlets. The granules drop straight down to the target surface from the outlets, so the swath width is equal to the width of the hopper. Other equipment uses an air blast or whirling disks to distribute the granules in swaths much wider than the machines. To determine the swath width, measure the actual swath on a hard surface.

Band applicators usually are a modification of the gravity-feed equipment. Granules drop through tubes and are released just above the soil to form bands of a specific width. For band applicators, the swath width is the number of bands multiplied by the band width in feet.

Soil injectors are band applicators that release the granules into furrows, which are then covered. Ram-air equipment (agricultural aircraft) uses a combination of air flow and gravity to deliver the granules to the target site.

In all types of granule equipment, the amount of granules applied per unit of area depends on the size of the adjustable opening, the speed at which the equipment travels (or the speed of the hopper agitator), the roughness of the surface of the application site (except for aerial application), and the granular formulation chosen.

Different formulations have different flow rates depending on the size, weight, shape, and texture of the granules. Environmental factors such as temperature and humidity also alter granular flow rates. (The flow rate slows as temperature and humidity rise.)

Because so many variables can affect the delivery rate, calibrate your equipment for each batch of product and for each new field condition.

Granule equipment that has wheel-driven dispersal delivers granules at a rate geared to the turns of the hopper agitator, which is in turn geared to the revolutions of the ground wheels. The faster the equipment is moved, the faster the release of granules. As a result, minor changes in equipment speed do not affect the
amount of granules deposited per unit area. The only way to change the application rate in this type of equipment is by changing the feed gate settings.

Granule equipment with powered dispersal or gravity-flow dispersal distributes the granules at a constant rate independent of the speed of the equipment. The application rate per acre (or other unit area) depends on both the metered opening and the equipment speed. Minor adjustments in flow rates can be made by altering the rate of speed. (Faster speed means fewer granules delivered per area). Make larger adjustments by altering the equipment settings.

Consult the equipment manual for manufacturer’s recommended settings to deliver approximate rates of the granules being applied. If the equipment is motorized, select the speed by using manufacturer’s suggestions and taking into consideration the condition of the application site. Soft, muddy, or uneven surfaces and small areas with many obstacles require slower speeds.

Calibrate your equipment using one of the two methods described below. If the application rate differs more than 5 percent from the desired rate, adjust the equipment and recalibrate.

**Broadcast granule applicators**

Run a precalibration check on the equipment:
- First, fill the hopper to a predetermined height or weight. Settle the material by driving a short distance or by shaking or striking the hopper; then refill the hopper.
- Set the flow rate as recommended by the equipment manual.
- Turn on the applicator and operate on a hard surface to check for uniform distribution along the swath width. If you cover the surface with a tarp before making the test run, you can collect the granules for reuse.

Next, operate the equipment over a measured area to determine whether the equipment is metering granules at the rate per acre you need. You may use either of two methods:
- the calibration pan method,
- the volume output method.

**Calibration pan method**

Multiple-outlet broadcast spreaders, band applicators, and soil injection equipment often can be calibrated by collecting the granules in calibration pans graduated in ounces. If the application rate is given in pounds per 1,000 linear feet of row:
- Mark off 1,000 feet in the field you wish to treat.
- Collect the granules discharged from one tube or opening during the 1,000-foot test run. If the equipment is motorized, bring it up to the speed you have selected before beginning the test run.

*OR*

- Make the test run at the speed you have selected, but do not operate the applicator. Note the time (in seconds) it takes to complete the test run. Then with the equipment standing still, collect the granules discharged for that measured time.
- The amount of granules collected (in ounces or pounds) is the rate per 1,000 linear feet. (If you wish to use only a 100-foot test run, the amount of granules collected multiplied by 10 is the rate per 1,000 linear feet.)

**Volume output method**

The volume output method of calibration can be done in one of two ways:

1. **Treat an acre** at the speed and setting recommended by the equipment manual. To determine the rate of application, measure the amount of granules needed to refill the hopper.

*OR*

2. **Treat less than an acre**. Stake out a test area in the field to be treated. The total test run should be at least 1,000 feet.
Treat the test area at the speed and setting you have chosen.
Refill the hopper and measure the amount added.
Calculate the rate of application:

\[
\frac{\text{Swath width} \times \text{distance in test run (in ft.)}}{\text{Square feet in an acre (43,560)}} = \text{Area (in acres) treated in test run}
\]

\[
\frac{\text{Pounds used in test run}}{\text{Area (in acres) treated in test run}} = \text{Pounds per acre}
\]

**Example:**
- Swath width = 15 feet.
- Test run = 1,000 feet.
- Amount used in test run = 5 pounds.
- Amount needed per acre = 15 pounds.

\[
\frac{\text{Swath width (15 ft.)} \times \text{test run (1,000 ft.)}}{43,560 \text{ sq. ft.}} = \text{Area treated (0.34 acre)}
\]

\[
\frac{\text{Pounds in test run (5)}}{\text{Area treated (0.34)}} = \text{Pounds per acre (14.7)}
\]

That is within 5 percent of the specified rate of 15 pounds per acre, so the equipment is correctly calibrated.

**Band granule applicators**

Use the methods described above to calibrate band applicators. However, if the labeling directions give the rate in **pounds per acre broadcast**, you must use the following formula to determine the rate per acre in bands (just as in band spray applications):

\[
\frac{\text{Band width} \times \text{Pounds per acre (broadcast)}}{\text{Row spacing}} = \text{Pounds per acre (band) applied}
\]

**Example:**
- Labeling rate = 12 pounds per acre (broadcast).
- Band width = 6 inches.
- Row spacing = 30 inches.

\[
\frac{\text{Band width (6 in)} \times 12 \text{ pounds per acre (broadcast)}}{\text{Row spacing (30")}} = 2.4 \text{ pounds per acre (band) applied}
\]

If the labeling directions list **pounds to apply per 1,000 linear feet**, you must use this formula to determine your rate:

\[
\frac{\text{Total pounds used in test run}}{\text{Number of rows in swath}} = \text{Pounds used per row in test run}
\]

\[
\frac{\text{Pounds used per row (in test run) \times 1,000 ft.}}{\text{Distance traveled in test run}} = \text{Pounds per 1,000 linear feet}
\]
Example:
- Number of bands or rows covered in test run = 8.
- Distance traveled in test = 3,000 feet.
- Pounds used in test = 2.3.

\[
\frac{\text{Pounds used in test (2.3)}}{\text{Number of rows (8)}} = \frac{\text{Pounds used per row in test run (.288)}}{\text{Distance traveled in test run (3,000 ft.)}} = \text{Pounds per 1,000 linear ft. (.096 or 1.5 oz.)}
\]

Calibrating Dust Application Equipment
To calibrate dusters for use in ground application, follow the directions given above for calibrating granule application equipment.

Calibrating Soil Fumigation Equipment
Soil fumigation equipment can be calibrated by using the volume output method described for sprayers. Use the following formulas:

\[
\text{Test area sprayed} = \frac{\text{Swath width} \times \text{distance in test run}}{\text{Square feet in an acre (43,560)}}
\]

\[
\text{Gallons per acre} = \frac{\text{Gallons used in test run}}{\text{Area (in acres) sprayed in test run}}
\]

For band applications, the swath width is the band width (in inches) multiplied by the number of bands. Divide by 12 to find the swath width in feet.
Use the following formula if soil fumigant rates are listed as ounces per 100 (or 1,000) linear feet traveled:

\[
\frac{\text{Total ounces used in test run}}{\text{Number of rows in swath}} = \frac{\text{Ounces used per row in test run} \times 100 \text{ (or 1,000) feet}}{\text{Distance traveled in test run}} = \text{Ounces per 100 (or 1,000) feet}
\]

Soil fumigant rates are sometimes listed as feet traveled per pint of fumigant delivered. Then:
- With the system pressurized, keep the unit stationary and operate the pump or pressure system at the equipment manual’s suggested setting.
- Measure how long (in seconds) it takes to collect 1 pint of fumigant from the orifice.
- Determine how fast you need to travel:

\[
\frac{\text{Feet per pint specified on labeling}}{\text{Collection time for one pint}} = \text{Speed (feet per second)}
\]

\[
\frac{\text{Speed (feet per second)}}{1.45 \text{ (conversion factor)}} = \text{Miles per hour}
\]

If the speed is too fast or slow for your ground conditions and equipment, change settings and recalibrate.
Calibrating Airplanes and Helicopters

This equipment is highly specialized and should be calibrated according to equipment manufacturer's instructions or with guidance from Extension Service or other professional personnel. The basic volume output method can also be used for this equipment:

(1) Fill the tank or hopper to a known level.
(2) Apply water (or another nonpesticide test material designed for this purpose) over a known area (acre or part of an acre).
(3) Measure quantity needed to refill tank or hopper.
(4) Figure rate per acre.

Calibrating Aquatic Application Equipment

Aquatic application equipment should be calibrated according to the equipment manufacturer's instructions or with guidance from Extension Service or other professional personnel. The volume output method can be successfully used for aquatic equipment, but you must figure whether to base the rate on:

- water surface area to be treated,
- bottom surface area to be treated, or
- total volume of water to be treated.

Then proceed to:

(1) Fill tank or hopper to known level.
(2) Apply water or another nonpesticide test material to a specific area (acres of surface or bottom area or acre-feet of volume).
(3) Measure quantity needed to refill tank or hopper.
(4) Figure output per area treated (acres or acre-feet).

Test Your Knowledge

Q. What is calibration?
A. Calibration is the process of measuring and adjusting the amount of pesticide that a piece of equipment will apply to a target site.

Q. Why do you need to consider speed when you are calibrating many kinds of equipment?
A. For many types of application equipment, the speed at which the equipment moves through the target site is one of the main factors in calibration. Unless the release of the pesticide is linked to the turning of the equipment’s ground wheels, the speed at which the equipment moves determines the amount of pesticide applied in a given area.
Q. Explain how to determine whether all the nozzles (or hoppers) on a piece of application equipment are releasing approximately the same amount of pesticide.

A. Put a container under each nozzle or hopper to collect the output (1) while the equipment runs for 1 to 5 minutes or (2) while the equipment operates over a measured area. Then check to see if all the containers contain the same amount (within 5 percent).

Q. How do you calculate the application rate — the amount of pesticide the equipment is applying per unit of area?

A. Determine the amount of pesticide that was applied during a test run (either by collecting the pesticide as it is released or by measuring how much is needed to refill the tank or hopper). That amount, divided by the area covered in the test run, is the application rate.

Q. List some important factors to consider when you calibrate a sprayer.

A. Some factors that affect sprayer calibration include equipment speed, pump pressure, spray volume to be delivered, and type of diluent (carrier) to be used.

Q. Using Table 4 in this unit, select the nozzle tips you would use if you were making a broadcast application with a boom sprayer in the following situation:

- boom height = 23 inches
- nozzle spacing = 20 inches
- pump pressure = 50 psi
- speed = 5 mph
- spray volume = 20 gpa.

A. Table 4 shows that nozzle tip number 504, with a 50-mesh strainer, would provide 20 gallons of spray per acre at the chosen speed and pressure.

Q. Using Tables 5 and 6 in this unit, select the nozzle tips and nozzle angle you would select if you were making a band application with a boom sprayer in the following situation:

- row spacing = 40 inches
- speed = 4 mph
- pump pressure = 40 psi
- spray volume for band application = 22 gpa
- band width = 14 inches
- boom height = 7 inches.

A. Table 5 shows that nozzle tip number 107, with a 50-mesh strainer, would provide 22 gallons of spray per acre at the chosen speed and pressure. Table 6 shows that a 95° nozzle angle is needed to provide a 14-inch band width when the boom height is 7 inches.
Q. You are calibrating a boom sprayer to apply 15 gallons per acre in a broadcast application. After a 1,000-foot test run at the chosen speed and pressure, it took 10 gallons of water to refill the sprayer tank to its original level. The sprayer is spraying a 30-foot width.

1) Show how to determine whether the sprayer is delivering the correct amount of pesticide to the target. You will need to calculate the area sprayed in the test run (in acres) and then find the gallons per acre being applied.

2) Is the answer within 5 percent of the 15 gallons per acre you need?

A. (1) \[
\frac{\text{Sprayed width (30 ft.)} \times \text{test run (1,000 ft.)}}{43,560 \text{ sq. ft.}} = \text{Area sprayed (0.69 acre)}
\]

\[
\frac{\text{Gallons used (10)}}{\text{Area sprayed (0.69)}} = 14.49 \text{ gpa}
\]

The sprayer is applying 14.49 gallons per acre.

2) Checking for the 5-percent allowable margin shows that any amount between 14.25 gpa and 15.75 gpa would be acceptable:

15 gpa (desired rate) \times 5\% \times .05 = 0.75
15 - 0.75 = 14.25
15 + 0.75 = 15.75

Since the 14.49 gpa the sprayer is applying falls within this 5-percent range, the sprayer is correctly calibrated.

Q. List some important factors to consider when you calibrate a granule applicator.

A. Some factors that may affect the calibration of granule applicators include the size of the adjustable opening; equipment speed; the roughness of the surface of the application site; the size, weight, shape, and texture of the granules in the formulation; and the temperature and humidity.

Q. You are calibrating a granule applicator to apply granules in six 12-inch bands spaced 30 inches apart. The pesticide labeling lists only a broadcast rate — 13 pounds per acre. After a 3,000-foot test run at the chosen speed, it took 2.1 pounds of formulation to refill the hopper.

1) Calculate the correct band application rate per acre.

2) Show how to determine whether the equipment is delivering the correct amount of pesticide to the target. You will need to calculate the area covered in the test run (in acres) and then find the pounds per acre being applied.

3) Is the answer within 5 percent of the pounds per acre you need?

A. (1) \[
\frac{\text{Band width (12 in.)} \times 13 \text{ lbs per acre (broadcast)}}{\text{Row spacing (30")}} = 5.2 \text{ lbs per acre (band) applied}
\]

2) Determine total swath width of the six 12-inch bands:

\[
\text{Band width in feet (1) \times Number of bands (6) = Swath width (6 feet)}
\]

\[
\frac{\text{Swath width (6 ft.)} \times \text{distance in test run (3,000 ft.)}}{43,560 \text{ sq. ft.}} = \text{Area treated in test (0.41 acre)}
\]

\[
\frac{\text{Pounds used in test run (2.1)}}{\text{Area treated in test run (0.41 acres)}} = \text{Pounds per acre (5.12)}
\]

The equipment is applying 5.12 pounds per acre.
(3) Checking for the 5-percent allowable margin shows that any amount between 4.9 and 5.5 pounds per acre would be acceptable:

\[ 5.2 \text{ pounds per acre (desired rate)} \times 5\% \times 0.05 = 0.26 \]
\[ 5.2 - 0.26 = 4.94 \]
\[ 5.2 + 0.26 = 5.46 \]
Since the 5.12 pounds per acre the equipment is delivering falls within this 5-percent range, the calibration is correct.

Q. You are calibrating your soil fumigation equipment to apply the fumigant at the labeling-recommended rate of 166 feet of row traveled per pint of fumigant delivered. Keeping the unit stationary and operating the system at the manufacturer's recommended pressure, you collected a pint of formulation in 19 seconds. How fast do you need to travel to maintain the recommended rate of application?

A. 
\[ \text{Feet per pint specified on labeling (166)} = \text{Speed (8.74 feet per second)} \]
\[ \text{Collection time for 1 pint (19 seconds)} = \text{Speed (8.74 feet per second)} \times 1.45 \text{ (conversion factor)} = 6.0 \text{ miles per hour} \]
You would need to travel 6 miles per hour to deliver 1 pint of fumigant over a distance of 166 feet of row.