CHAPTER 6:

CALIBRATION & MIXING
I. Introduction

Chapter Objectives

By the time you finish this chapter, you will be able to:

- explain why it is important to apply the correct amount of pesticide;
- describe how to determine how much pesticide to apply;
- describe how to figure application rates;
- identify ways that application rates are expressed;
- explain why it is important to calibrate equipment;
- explain which types of pesticides must be diluted before application;
- explain what information you must find in the pesticide labeling or in other recommendations before you can dilute the pesticide correctly;
- explain what information you must know before you can calculate how much of the dilute pesticide mixture to prepare.

Terms to Know

**Active ingredient** — Chemical in pesticide product that controls target pest and has toxicity.

**Diluent** — Anything used to dilute pesticide.

**Calibration** — Measurement and adjustment of your application equipment to ensure it is delivering proper amount of pesticide.

**Dilute** — To make less concentrated.

**Calibration** refers to the adjustment of equipment to ensure that the correct amount of pesticide is applied to a specific area. Failure to properly calibrate equipment is a frequent cause of ineffective pesticide application, when too little is applied, and always carries the potential for illegal residues, when too much pesticide is applied.

To calibrate your equipment, you must first determine the appropriate rate of application. You may have to adjust ground speed or sprayer pressure, change nozzle sizes, or modify application patterns to achieve the desired rate of application. It is important to check equipment periodically, especially nozzles. Nozzles can wear out over a short period of time, resulting in uneven spray patterns. Because operators fail to understand how rapidly equipment may perform inaccurately and become worn, most of them do not calibrate their sprayers often enough.

This chapter discusses the basic principals involved in the calibration of most types of equipment (see Table 6.1 for conversions) and calculations necessary for accurate pesticide application.
## Table 6.1: Useful Conversion Factors for Calibration

<table>
<thead>
<tr>
<th>STANDARD MEASURE</th>
<th>METRIC CONVERSIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>LENGTH</strong></td>
<td></td>
</tr>
<tr>
<td>1 ft = 12 in</td>
<td>1 in = 25.4 mm = 2.54 cm</td>
</tr>
<tr>
<td>1 yd = 3 ft</td>
<td>1 ft = 304.8 mm = 30.48 cm</td>
</tr>
<tr>
<td>1 mi = 5,280 ft</td>
<td>1 yd = 914.4 mm = 91.44 cm = 0.914 m</td>
</tr>
<tr>
<td></td>
<td>1 mi = 1,609 m = 1.61 km</td>
</tr>
<tr>
<td></td>
<td>1 mm = 0.03937 in</td>
</tr>
<tr>
<td></td>
<td>1 cm = 0.394 in = 0.0328 ft</td>
</tr>
<tr>
<td></td>
<td>1 m = 39.37 in = 3.281 ft</td>
</tr>
<tr>
<td></td>
<td>1 km = 3.281 ft = 0.6214 mi</td>
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</tbody>
</table>

| **AREA:**       |                   |
| 1 sq in = 0.007 sq ft | 1 sq in = 6.45 cm$^2$ |
| 1 sq ft = 144 sq in = 0.000023 ac | 1 sq ft = 929 cm$^2$ |
| 1 sq yd = 1,296 sq in = 9 sq ft | 1 sq yd = 8,361 cm$^2$ = 0.8361 m$^2$ |
| 1 ac = 43,560 sq ft = 4,840 sq yd | 1 ac = 4,050 m$^2$ = 0.405 h |
|                  | 1 cm$^2$ = 0.155 sq in |
|                  | 1 m$^2$ = 1,550 sq in = 10.76 sq ft |
|                  | 1 h = 107,600 sq ft = 2.47 ac |

| **VOLUME:**     |                   |
| 1 tsp = 0.17 fl oz | 1 fl oz = 29.5 ml = 0.0295 l |
| 1 tbs = 3 tsp     | 1 pt = 437 ml = 0.437 l |
| 1 fl oz = 2 tbs = 6 tsp | 1 qt = 945 ml = 0.945 l |
| 1 cup = 8 fl oz = 16 tbs | 1 gal = 3,785 ml = 3.785 l |
| 1 pt = 2 cups = 16 fl oz | 1 mL, ml = 0.033 fl oz |
| 1 qt = 2 pt = 32 fl oz | 1 L, l = 33.8 fl oz = 2.112 pt = 1.057 qt = 0.264 gal |
| 1 gal = 4 qt = 8 pt = 128 fl oz = 231 cu in |                   |

| **WEIGHT:**     |                   |
| 1 oz = 0.0625 lb | 1 oz = 28.35 g |
| 1 lb = 16 oz    | 1 lb = 454 g = 0.4536 kg |
| 1 ton = 2,000 lb| 1 ton = 907 kg |
| 1 gallon of water = 8.34 lb | 1 gallon of water = 3.786 kg |
|                  | 1 g = 0.035 oz |
|                  | 1 kg = 35.27 oz = 2.205 lb |

### ABBREVIATIONS

<table>
<thead>
<tr>
<th>ac</th>
<th>=</th>
<th>acre</th>
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</thead>
<tbody>
<tr>
<td>fl oz</td>
<td>=</td>
<td>fluid ounce</td>
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<tr>
<td>ft</td>
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<td>foot</td>
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<tr>
<td>1 h</td>
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<td>10,000 m$^2$</td>
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<td>tbs</td>
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<td>tsp</td>
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<td>teaspoon</td>
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<tr>
<td>yd</td>
<td>=</td>
<td>yard</td>
</tr>
</tbody>
</table>

| cm   | = | centimeter |
| cm$^2$ | = | square centimeter |
| cm$^3$ | = | cubic centimeter |
| g    | = | gram |
| kg   | = | kilogram |
| km   | = | kilometer |
| L, l | = | liter |
| m    | = | meter |
| m$^2$ | = | square meter |
| mL, ml | = | milliliter |
| mm   | = | millimeter |
II. Why Calibration is Essential

Calibration precisely determines the output of the application equipment under controlled conditions. The main reason for calibrating application equipment is to determine how much pesticide to put into the spray tank to ensure that the correct amount of chemical is applied. This is necessary for:

1. effectively controlling pests
2. protecting human health, the environment, and treated surfaces
3. preventing waste of resources
4. complying with the law. It is also important to have control over the volume of water being applied

Effective Pest Control

Manufacturers of pesticides spend millions of dollars researching ways to use their products, including determining the correct amount of pesticide to apply for effective control of pests. Using less than label recommendations may result in inadequate control and could be a waste of time and money. Using too little pesticide can lead to problems such as pest resistance and resurgences, while using too much pesticide may have adverse effects on natural predators, target surfaces, and the environment; excessive use also wastes materials and is illegal.

Human Health Concerns

Pesticides that are applied at rates higher than label recommendations may endanger human health. Illegal residues may occur on produce when a pesticide is over applied; the entire crop may be confiscated to protect consumers if residues are above allowable tolerances. Field workers and application equipment operators can also be exposed if the equipment applies too much pesticide.

Environmental Concerns

Pesticides may cause environmental problems when they are not used properly. Harm to beneficial insects, such as honey bees, and to wildlife must be avoided by carefully calibrating equipment to maintain application rates within label recommendations.

Protection of Treated Surfaces

Certain pesticides are phytotoxic and can be damaging to sprayed surfaces when used at higher than recommended rates. Manufacturers evaluate these potential problems during testing. Applying more than the labeled amount of pesticide may increase risks of damage. Chances of building up excessive residues in the soil or potentially polluting the groundwater are also increased when too much pesticide is used; these problems could limit types of crops that can be grown in that soil.

Preventing Waste of Resources and Disposal Problems

Using the improper amount of pesticide costs time and costs more money. Not only are pesticides expensive, but the fuel, labor, and wear and tear on the equipment are costly, too. Another very important reason to calibrate equipment is to minimize the amount of pesticide remaining in the tank after an application is completed. It can be difficult and expensive to legally dispose of this extra material.

III. Deciding How Much Pesticide to Apply

Study the “Directions for Use” section of the pesticide label for rates you should apply. If the label lists a range of possible amounts, use the least amount of pesticide that will achieve the control of the pest.
Amounts of pesticide to be used are expressed in various ways. Application rates may be expressed in terms of how much pesticide formulation should be applied. The instructions may tell you how much pesticide formulation should be applied to each unit of area or volume in the target site—5 gallons of formulation per acre, or 1 pound of formulation per 100 cubic feet of space, for example. Application rates also may be expressed in terms of how much pesticide formulation should be used per volume of mixture. Labeling might call for 3 tablespoons of product per 5 gallons of water or 1 pint of product per 100 gallons of water.

Sometimes pesticide labeling and other sources express application rates in terms of how much active ingredient should be applied per unit of area or per volume of mixture—1 pint active ingredient per 1,000 square feet, or ½ pound active ingredient per 500 gallons of water, for example. When the application rate is expressed in this way, you can select different formulations and be able to figure how much to dilute each one. However, figuring the correct dilution for active ingredient recommendations is more complicated.

Occasionally the application rate is expressed in terms of a percentage of the final dilution — ½ percent by volume or 1% by weight, for example. Products that have adjuvants often express the application rate in this way. Expressing application rates as a percentage allows the user to calculate the dilution correctly for whatever dilution method is being used for the formulation.

### Mixing, Loading, and Calibration

**Alternatives**

Knowing what amount of the pesticide you must apply is only the first step. Next, you must determine how you will deliver the correct amount to the target site. Depending on the type of formulation you choose and the type of application equipment you will use, you may have to do some combination of three basic tasks—mixing the pesticide, loading it into your equipment, and calibrating the equipment so you will know exactly how much pesticide it is delivering.

1. **Mixing.** Unless the pesticide is a ready-to-use formulation or is designed to be applied full strength, you must carefully combine the right amounts of concentrated pesticide formulation and diluent to make the needed application-strength pesticide mixture.

2. **Loading.** You may need to transfer the pesticide into the equipment before it can be applied.

3. **Calibrating.** For many kinds of applications, you must measure and adjust the amount of pesticide your equipment will apply to the target site.

Each different combination of formulation and equipment type requires you to do a different combination of these tasks to prepare for applying a measured amount of pesticide.

### No Calibration, Mixing, or Loading Needed

Some pesticide formulations are sold at application strength and are already in the equipment needed for application. These include aerosol cans; squeeze-trigger sprayers; delayed-trigger foggers; baits; shaker-can dusters; impregnated collars, bars, strips, and rollers; and wiper bags. The pesticide is applied to the point of runoff, is directed at a specific target, is placed so the target contacts it, or is released to fill an enclosed space. Most of these pesticides are available for use in specialized pest control situations.
Loading Needed, No Mixing or Calibration

Some ready-to-use pesticides are not sold loaded in the pesticide application equipment. The user must load them into the equipment. If the application equipment to be used is a squeeze-trigger sprayer, shaker can duster, a vat for dipping animals or plants, a spray dip vat, a wiper applicator, or some fumigant applicators, no calibration is necessary.

Calibration and Loading Needed, No Mixing

Ready-to-use formulations sometimes must be loaded into equipment that does require calibration. These include most granular and dust formulations, some liquid formulations (especially solutions), and some fumigant formulations. The pesticide is loaded directly into application equipment without any further dilution. The equipment must be calibrated so that the correct amount of pesticide will be released per unit area.

Mixing and Loading Needed, No Calibration

Some concentrated pesticides are diluted and then loaded into equipment that does not require calibration. Many plant and animal dips or spray dips, and tree canopy sprays, are applied by equipment that does not need calibration. The applicator is instructed to “cover the plant, animal, or surface thoroughly” or “apply to the point of runoff.”

Calibration, Mixing, and Loading Needed

Many concentrated pesticides are applied with equipment that must be calibrated. For many certified applicators, this is the option most commonly encountered. The concentrate must be diluted correctly and the equipment must be calibrated correctly. Both steps are crucial to applying the correct amount of pesticide to a target site. If there is an error either in dilution or in calibration, the wrong amount of pesticide will be applied.

Calibrating Your Equipment

Most pesticide applications involve equipment that must be measured and adjusted to release the correct amount of pesticide to the target site. Proper calibration is an essential but often neglected task. To be sure your equipment is releasing the right amount of pesticide, take time to calibrate it carefully and correctly. Recheck it regularly to detect changes caused by wear, corrosion, and aging.

Calibration often requires some simple arithmetic. Usually the equipment manufacturer, the pesticide dealer, the Department of Agriculture, or USDA Cooperative Extension Service will provide some standard formulas to help you. The easiest and most accurate way to do the calculations is with a calculator.

Choose equipment that you know how to use and that is:

- designed for the type of chemical being applied
- appropriate for the size and type of application job

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 and hopper openings. If they become clogged, not enough pesticide will be released. If they become worn, too much pesticide will be released.

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 if you understand the basic principles of calibration, you can apply them in any situation. Study the manufacturer’s instructions carefully—they explain exactly how to adjust the equipment. They often contain suggestions on 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.

**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**

If the equipment you have chosen uses gravity to maintain the flow of pesticide, calibration may be fairly simple. Some 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.

**Equipment with Powered Dispersal**

If your equipment has a pump 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 during the calibration process and during the actual application. For the most accurate calibration, operate the equipment at the target site or on ground similar to that at the target site. Whether the equipment is hand-carried or mounted on a vehicle, the condition of the ground that must be crossed is important. A rough and uneven surface will require 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.

**Uniform Release**

If the application equipment you will be using has more than one nozzle (or more than one 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. Note whether the pesticide output from one or more nozzles (or cluster of nozzles) or hoppers is 5% 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 two ways. Either method requires that you attach containers (jars) to collect the output from each nozzle, nozzle cluster, or hopper. Fill the tank with water only, then 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 to see whether all the jars contain the same amount.
IV. Methods of Equipment Calibration

A few simple tools are needed to calibrate pesticide application equipment. Put these items into a small toolbox and use them only for calibration purposes. Keep your tools clean and in good working condition. Make equipment calibration a professional operation.

NOTE: Pesticide application equipment and the discharge from application equipment being calibrated may contain pesticide residue. Always wear rubber gloves and other protective equipment to prevent pesticide contamination of your eyes, hair, skin, clothing, and shoes.

Tools Needed for Calibration

Stopwatch
A stopwatch is essential for timing travel speed and flow rates. Never rely on a wristwatch unless it has a stopwatch function.

Measuring Tape
A 100-foot moisture- and stretch-resistant measuring tape is used for marking off distance and for measuring spray swath width.

Calibrated Liquid Container
A marked, 1- or 2-quart container, calibrated for liquid ounces, is needed for measuring spray nozzle output.

Scale
A small scale that measures pounds and ounces is needed for weighing granules collected from a granule applicator. A scale that weighs between 5 and 10 pounds is usually adequate.

Pocket Calculator
A pocket calculator is needed for making calculations in the field.

Pressure Gauge
An accurate, calibrated pressure gauge, with fittings compatible with spray nozzle fittings, is helpful for checking boom pressure and for calibrating the sprayer pressure gauge.

Flow Meter
A flow meter, attached to a flexible hose or filling pipe, can be used for measuring the amount of water put into a tank. It can also be used for measuring tank capacity and for determining the amount of liquid used during a calibration run. Both mechanical and electronic flow meters are available. If these are not available, a calibrated five-gallon pail can be used instead.

Flagging Tape
Colored plastic flagging tape is useful for marking off measured distances to determine equipment speed.

Always calibrate with clean water. Different calibration techniques are used for liquid application equipment and dust or granular application equipment.

V. Calibrating Liquid Sprayers

Frequent calibration is necessary to monitor pump and nozzle wear on equipment that applies pesticides that are dissolved or suspended in water. Pump wear may decrease the amount and pressure of fluid output; nozzle wear increases the volume of output, may lower the output pressure,
and may produce a poor spray pattern. Abrasive pesticides, such as wettable powders, increase the rate of wear.

Before making any calibration measurements, be sure to service the sprayer; follow the servicing directions outlined below.

**Servicing Spray Equipment** (see italicized paragraph on page 7, under IV. Methods of Equipment Calibration.)

1. Flush the tank and pumping system with clean water to remove debris and dirt;
2. Clean and replace all filter screens;
3. Check nozzles for wear and replace them if there is any doubt about the wear — all nozzles must be clean;
4. Lubricate all bearings and appropriate moving parts;
5. Inspect hoses for cracks and leaks, and replace them if necessary; and
6. Make sure the pressure gauge is working properly by testing it against another gauge known to be accurate.

Once the sprayer is serviced, begin the calibration process. The final goal is to determine how much area will be covered by each tank of spray when the sprayer is moving at a specific speed and operating at a specific pressure. Four factors must be measured: (1) tank capacity; (2) flow rate; (3) speed of travel; and (4) width of spray swath.

**Tank Capacity**

The capacity of the spray tank or tanks needs to be measured only once, but it must be measured. You must know exactly how much liquid a spray tank holds. Never rely on manufacturer’s ratings, because these could be approximate volumes or may not take into account fittings installed inside the tank or the capacity of spray lines, pump, and filters.

Fill the tank either with a bucket or other container of known volume, or by using a flow meter attached to a hose. Always use clean water. A five-gallon bucket works well for smaller sprayers; the bucket must be filled each time to hold exactly five gallons and must be calibrated and marked accordingly before use.

The spray tank should be perfectly level. Close all valves to prevent water from leaking out. Add water, five gallons at a time, until the tank is nearly filled. Use smaller-volume calibrated containers to top off the tank.

Record the total volume of water required to fill the tank (paint or engrave this figure onto the outside of the tank for permanent reference). The tank’s sight gauge should be calibrated while the tank is being filled by making marks on the tank or gauge as measured volumes of water are put in. If the unit is not equipped with a sight gauge, mark volume increments on a dipstick that can be kept with the tank. Use 1-gallon marks for tanks with a capacity of 10 gallons or less, and increments of 5 or 10 gallons for tanks having a total capacity of fifty gallons or less. Increments of 10 to 20 gallons are used on larger tanks.

Once the gauge or dipstick is calibrated and labeled, it will be possible to determine how much liquid is in the tank when the tank is not entirely full. Tanks must always be level when you read the gauge or dipstick.

A flow meter attached to a filling hose may be used for measuring the volume of larger tanks. Be sure to calibrate and label the gauge or dipstick as the tank is being filled.
Travel Speed

Always measure travel speed under actual working conditions. If you are calibrating an orchard sprayer, use a filled tank in an orchard; similarly, row crop and field sprayers should be calibrated under actual conditions. Tractors travel faster on paved or smooth surfaces than on soft dirt or clods. Never rely on tractor speedometers for mile-per-hour measurements because wheel slippage and variation in tire size due to wear may cause as much as a 30% difference in indicated speed. When calibrating a backpack or hand-held sprayer, walk on terrain similar to the area that will be sprayed.

Using a 100-foot tape, measure off any convenient distance. It can be more or less than 100 feet, but calibration is more accurate if longer distances (between 200 and 300 feet) are used, especially if equipment moves at several miles per hour. Sometimes multiples of 88 feet are chosen because 88 feet is the distance covered in one minute while traveling one mile per hour. In orchards or vineyards, a given number of tree or vine spaces of known length can serve as a convenient reference. Indicate the beginning and end of the measured distance with colored flagging tape.

Have someone drive (or walk, if calibrating a backpack sprayer) the sprayer along the measured distance at the speed of an actual application. Choose a speed within a range appropriate for the application equipment. When using a tractor, note the throttle setting, gear, and revolutions per minute (rpm) of the engine. The use of a positive throttle stop is helpful so the engine can always be returned to the same speed. Be sure actual application speed is reached before crossing the first marker. Use a stopwatch to determine the time, in minutes and seconds, required to traverse the measured distance. For best results, repeat this process two or three times and take an average (See Table 6.2).

Flow Rate

Measure the actual output of the sprayer when nozzles are new, then periodically thereafter to measure nozzle wear. Although manufacturers provide charts showing output of given nozzle sizes at specified sprayer pressures, you should check output under actual conditions of operation. Manufacturer’s charts are most accurate when using new nozzles because used nozzles will be worn and may have different output rates; however, even new nozzles may have slight variations in actual output. Sprayer pressure gauges may not be accurate, adding further error to the output estimate determined from charts.

Liquid sprayer output is usually measured in gallons per minute. Two collection methods, listed below, can be used depending on the type of sprayer being calibrated. Collection method 1 is designed for low-pressure sprayers and small hand-held units; it involves collecting a volume of water emitted out of individual nozzles over a measured period of time. Collection method 2 for large air blast and high-pressure sprayers, measures the total output of the sprayer over a certain period of time.
Table 6.2 Calculating speed of application equipment

1. To convert minutes and seconds into minutes divide the seconds (and any fraction of a second) by 60 and then add this to the number of whole minutes.

**Example:** Your trip took 1 min and 47.5 sec.

\[
\frac{47.5 \text{ sec}}{60 \text{ sec/min}} = 0.79 \text{ min}
\]

\[1 \text{ min} + 0.79 \text{ min} = 1.79 \text{ min}\]

2. Add the converted minutes from each run and divide by the number of runs.

**Example:** The following three runs were made:

<table>
<thead>
<tr>
<th>Run 1</th>
<th>Run 2</th>
<th>Run 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Run 1 = 1 min, 47.5 sec = 1.79 min</td>
<td>Run 2 = 1 min, 39.8 sec = 1.66 min</td>
<td>Run 3 = 1 min, 52.0 sec = 1.87 min</td>
</tr>
</tbody>
</table>

Total = 5.32 min

\[
\frac{5.32 \text{ min}}{3 \text{ runs}} = 1.77 \text{ min/run average time}
\]

3. Divide the measured distance in feet by the average time in minutes to get how many feet were traveled in one minute.

**Example:** The measured distance for this example is 227 feet.

\[
\frac{227 \text{ ft}}{1.77 \text{ min}} = 128.25 \text{ ft/min}
\]

4. Divide the feet-per-minute figure by 88 (the number of feet traveled in 1 minute at 1 mile per hour) to get the speed in miles per hour.

**Example:**

\[
\frac{128.25 \text{ ft/min}}{88 \text{ ft/min/mil/hr}} = 1.46 \text{ mil/hr}
\]
Collection Method I

Low-pressure sprayers, including low-pressure boom sprayers, backpack sprayers, and controlled droplet applicators, can be calibrated by measuring the amount of spray emitted from nozzles. If the sprayer is equipped with more than one nozzle, collect liquid from each to compare their output; this comparison will point out any malfunction or wear. A stopwatch and calibrated container are required for taking measurements. Wear rubber gloves to avoid skin contact with the liquid, and stand upwind from the nozzles to prevent fine mist or spray from contacting your face and clothing. Eye protection prevents spray droplets from contacting your eyes.

For low-pressure power sprayers used in agricultural, right-of-way, and landscape application, fill the tank at least half full with water, start the sprayer, and bring the system up to normal operating pressure. Operate hydraulic agitators if they are to be used during the application, because hydraulic agitators divert some liquid from the nozzles and often lower the pressure in the system. Most power sprayers have a limited operating pressure range depending on the type of pump and type of power unit; never attempt to operate equipment beyond its normal working range because this may cause premature failure of the pump. If the sprayer is powered by a tractor (PTO) be sure that the tractor engine rpm is the same as that determined in the speed calibration; otherwise the pump output pressure will be different. Adjust the pressure to the spray situation and nozzle manufacturer’s recommendations. Be sure appropriate nozzles are installed on the equipment. Check the pressure by attaching a calibrated pressure gauge at either end of the boom, replacing one of the nozzles. Open the valves to all nozzles and note the pressure, make adjustments as necessary, then remove the gauge.

While all nozzles are operating at the proper pressure, collect about fifteen to thirty fluid ounces from each. Use a stopwatch to determine the time in seconds it takes to collect each amount (See Table 6.3).

When calibrating backpack sprayers, pump the unit as you would during an actual application. Collect spray in a calibrated container for a measured period of time. Compressed air sprayers lose pressure during operation, so they must be pumped frequently. To calibrate, fill the tank about half full with water to provide sufficient air to keep the pressure uniform. For some types of controlled droplet applicators, it is possible to disconnect the hose and orifice from above the spinning disc or cup and collect liquid in a calibrated container over a measured period of time; the liquid must flow through the orifice.

Record the volume of liquid collected from each nozzle or orifice and the time in seconds required to collect each amount. Determine the fluid-ounces-per-second output for each nozzle by dividing the volume by the seconds required to collect it. Convert ounces per second into gallons per minute by multiplying the result by the constant 0.4688 (sixty seconds per minute divided by 128 fluid ounces per gallon equals 0.4688) (See Table 6.3).

Output among nozzles will usually vary. The variation between nozzles should not be greater than 5%, and the output of any nozzle should not exceed the manufacturer’s rated output by more than 10%. The percentage of variation can be computed by dividing the actual output by the rated output. Subtract 1.00 from this figure, then multiply by 100 to obtain the variation in percent (See Table 6.3). In the example given in Table 6.3, nozzle numbers 3 and 5 should be replaced. However, whenever any nozzles are replaced, the flow rate of all the nozzles must be rechecked because changing one nozzle may affect the
pressure in the whole system; after changing nozzles, readjust the pressure regulator to maintain the desired pressure.

Spray check devices are calibration aids that provide a visual representation of the spray pattern produced by nozzles on spray booms. This portable device is placed under a boom and the output from several nozzles is collected into a series of evenly spaced cells.

Table 6.3  Calculating gallons-per-minute for low-pressure sprayers

1. Determine the gallons-per-minute output of each nozzle by dividing the fluid ounces collected by the time (in seconds) and multiplying the result by 0.4688.

   **EXAMPLE:**

<table>
<thead>
<tr>
<th>Nozzle</th>
<th>fl oz</th>
<th>sec</th>
<th>=fl oz/sec</th>
<th>x 0.4688</th>
<th>= gpm</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>12.5</td>
<td>23.2</td>
<td>= 0.539</td>
<td>x 0.4688</td>
<td>= 0.253</td>
</tr>
<tr>
<td>2</td>
<td>12.0</td>
<td>22.5</td>
<td>= 0.533</td>
<td>x 0.4688</td>
<td>= 0.250</td>
</tr>
<tr>
<td>3</td>
<td>15.5</td>
<td>24.8</td>
<td>= 0.625</td>
<td>x 0.4688</td>
<td>= 0.293</td>
</tr>
<tr>
<td>4</td>
<td>14.5</td>
<td>26.1</td>
<td>= 0.556</td>
<td>x 0.4688</td>
<td>= 0.261</td>
</tr>
<tr>
<td>5</td>
<td>19.0</td>
<td>27.2</td>
<td>= 0.699</td>
<td>x 0.4688</td>
<td>= 0.328</td>
</tr>
<tr>
<td>6</td>
<td>13.0</td>
<td>23.9</td>
<td>= 0.544</td>
<td>x 0.4688</td>
<td>= 0.255</td>
</tr>
</tbody>
</table>

**Total output = 1.640 gpm**

2. Now compute the percent variation from the rated nozzle output. Divide the actual gallons-per-minute output by the rated output. Subtract 1 from this number and multiply by 100.

   **EXAMPLE:**

<table>
<thead>
<tr>
<th>Nozzle</th>
<th>Actual gpm</th>
<th>Subtract 1.00</th>
<th>Multiply by 100</th>
<th>=Percent variation(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.253/0.250</td>
<td>- 1.00</td>
<td>0.012</td>
<td>x 100 = 1.2</td>
</tr>
<tr>
<td>2</td>
<td>0.250/0.250</td>
<td>- 1.00</td>
<td>0.000</td>
<td>x 100 = 0.0</td>
</tr>
<tr>
<td>3</td>
<td>0.293/0.250</td>
<td>- 1.00</td>
<td>0.172</td>
<td>x 100 = 17.2*</td>
</tr>
<tr>
<td>4</td>
<td>0.261/0.250</td>
<td>- 1.00</td>
<td>0.044</td>
<td>x 100 = 4.4</td>
</tr>
<tr>
<td>5</td>
<td>0.328/0.250</td>
<td>- 1.00</td>
<td>0.312</td>
<td>x 100 = 31.2*</td>
</tr>
<tr>
<td>6</td>
<td>0.255/0.250</td>
<td>- 1.00</td>
<td>0.020</td>
<td>x 100 = 2.0</td>
</tr>
</tbody>
</table>

*Greater than 5% variation needs to be changed.
Collection Method II

Due to the air blast or high pressures of larger sprayers, it is not possible to collect ejected liquid in a container. You must measure the output of the sprayer over a period of time by determining how much water was used.

Start by moving the sprayer to a level surface. Fill the tank full with clean water; the water must be at a level that can be duplicated when refilling. A convenient technique is to fill the tank with clean water to the point where it just begins to overflow. Use low-volume, low-pressure water, such as from a garden hose, for topping off the tank. Check for leaks around tank seals and in hoses. All nozzles must be clean and operating properly or the results will be inaccurate.

Stand upwind and operate the sprayer at its normal operating speed and pressure. Open the valves to all nozzles, starting a stopwatch at the same time. Continue to run the sprayer for several minutes, then close the valves to all nozzles and record the elapsed time.

If the tank has been calibrated and marked, the amount of liquid used will be apparent or can be determined with a calibrated dipstick. Otherwise, use a flow meter attached to a low-pressure hose or a calibrated five-gallon bucket and refill the sprayer to the original level. Record the gallons of water used; this volume is the amount of liquid sprayed during the timed run. Repeat this process two more times to get an average of sprayer output (See Table 6.4).

Width of Spray Swath

The final measurement needed to complete calibrations is the width of the spray swath. For multiple nozzle boom sprayers, the swath width is the width of the boom plus the distance between one pair of nozzles; swath width also can be calculated by multiplying the number of nozzles by the nozzle spacing. When making a pesticide application, position the end nozzle of each subsequent pass to leave a space equal to the nozzle spacing on the boom. Spray boom height must be adjusted so that there is approximately a 30% overlap of spray from adjacent nozzles on the boom. Position nozzles at the exact height they would be during an actual application. Check the spray boom to make sure it is level; an unlevel boom will cause uneven distribution of spray.

When sprays are emitted as separate bands or strips, the swath width is equal to the combined width of each individual band, but does not include the unsprayed spaces between bands.

Swath width for herbicide strip sprays in orchards and vineyards should be measured only to the center of the tree or vine row and should not include overlap. Unless the herbicide is applied to the entire orchard or vineyard floor, the actual sprayed area will be less than the total planted area.

Sometimes nozzles are attached to an inverted U-shaped boom so that pesticides can be applied to the top and both sides of vines or plants in a row. Swath width for this type of equipment is equal to the distance between opposing nozzles.

Pesticides are often injected into the soil through special subsoil chisels spaced along a tractor-mounted tool bar. It is assumed that pesticides are being applied to the entire subsurface area in most soil injection applications; therefore swath width is equal to the number of chisels multiplied by the space between the chisels on the tool bar.

Occasionally pesticides are injected as a band, so swath width is the sum of all the band widths, similar to surface band applications. Measure the swath width of a backpack sprayer used for
ground application from the spray pattern produced on the ground in a test run. Keep the nozzle at the height held during an actual application; maintain this height at all times to prevent variation in swath width. Nozzles of these types of sprayers usually provide a uniform spray pattern, so swaths need to be overlapped only enough to ensure a uniform application pattern. Use the same method to measure the swath width of controlled droplet applicators.

Table 6.4 Calculating gallons per minute for high pressure sprayers

1. Record the elapsed time in minutes during each trial run and the amount of liquid sprayed in gallons.

   Example:

<table>
<thead>
<tr>
<th>Run</th>
<th>Time</th>
<th>Volume</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1 min 45 sec</td>
<td>37.5 gal</td>
</tr>
<tr>
<td>2</td>
<td>1 min 30 sec</td>
<td>33.5 gal</td>
</tr>
<tr>
<td>3</td>
<td>1 min 50 sec</td>
<td>38.0 gal</td>
</tr>
</tbody>
</table>

2. Convert the time from minutes and seconds to minutes by dividing the seconds by 60 and adding this decimal to the minutes.

   Example:

<table>
<thead>
<tr>
<th>Run</th>
<th>min</th>
<th>sec</th>
<th>sec/60</th>
<th>=min</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>45</td>
<td>0.75</td>
<td>1.75</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>30</td>
<td>0.50</td>
<td>1.50</td>
</tr>
<tr>
<td>3</td>
<td>1</td>
<td>50</td>
<td>0.83</td>
<td>1.83</td>
</tr>
</tbody>
</table>

3. Divide the collected gallons for each run by the minutes to find gallons per minute.

   Example:

<table>
<thead>
<tr>
<th>Run</th>
<th>gal/min</th>
<th>= gpm</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>37.5/1.75</td>
<td>21.4</td>
</tr>
<tr>
<td>2</td>
<td>33.5/1.50</td>
<td>22.3</td>
</tr>
<tr>
<td>3</td>
<td>38.0/1.83</td>
<td>20.8</td>
</tr>
</tbody>
</table>

4. Add all the gallons-per-minute figures and divide this total by the number of runs (3 in this example) to get the average gallons-per-minute output.

   Example:

<table>
<thead>
<tr>
<th>Run</th>
<th>gpm</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>21.4</td>
</tr>
<tr>
<td>2</td>
<td>22.3</td>
</tr>
<tr>
<td>3</td>
<td>20.8</td>
</tr>
</tbody>
</table>

   Total = 64.5 gpm

   64.5/3 = 21.5 gpm average output
Determining the Amount of Pesticide to Use

Use the tank volume, the speed of the applicator, the flow rate of the sprayer, and the spray swath width to calculate the total area that can be covered with each tank of material. Knowing this value allows you to determine how much pesticide to put into the tank. Two calculation methods may be used, one for pesticides applied by the acre and the other for applications, such as landscape treatments or sprays in confined areas, made by the square foot. Table 6.5 gives an example of pesticides applied by the acre.

Changing Sprayer Output

Once a sprayer has been calibrated, its output rate is determined for a specific speed. There may be times when this output rate needs to be changed to accommodate variations in foliage, plant spacing, other aspects of the treatment area, or requirements to travel at a faster or slower speed. Also, the spray output will change as nozzles or pumps begin to wear. Several adjustments can be made, either alone or in combination, to effectively increase or decrease sprayer output within a limited range.

Table 6.5 How much pesticide to put into the spray tank
(Pesticides applied on a per-acre basis)

1. Divide the spray swath width (in feet) by 43,560 (the number of square feet in one acre) and multiply the result by the travel speed in feet per minute. To find the area in acres that can be treated in one minute, assume the swath width is 12 feet, the travel speed 128.25 feet per minute, and the delivery rate 1.525 gallons per minute.

   \[
   \text{Example:} \quad \frac{12 \text{ ft}}{43,560 \text{ sq ft/ac}} \times 128.25 \text{ ft/min} = 0.0353 \text{ ac/min}
   \]

   In this example, when a swath 12 feet wide is being sprayed, 0.0353 acres are covered in one minute.

2. Divide the gallons-per-minute figure by the acres-per-minute figure to find the gallons of liquid being applied per acre.

   \[
   \text{Example:} \quad \frac{1.525 \text{ gal/min}}{0.0353 \text{ ac/min}} = 43.2 \text{ gal/ac}
   \]

3. Divide the actual measured volume of the spray tank by the gallons-per-acre figure. To find how much pesticide to put in the tank, assume the tank holds 252.5 gallons when filled:

   \[
   \text{Example:} \quad \frac{252.5 \text{ gal/tank}}{43.2 \text{ gal/ac}} = 5.84 \text{ ac/tank}
   \]
4. Multiply the acres-per-tank figure by the recommended rate per acre of pesticide (check the pesticide label for this information) to find how much pesticide to put in the tank.

**Example:**

<table>
<thead>
<tr>
<th>Pesticide label says</th>
<th>Acres per tank</th>
<th>Amount of pesticide to put in tank</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.5 lb/ac</td>
<td>( \times 5.84 )</td>
<td>= 8.76 lb</td>
</tr>
<tr>
<td>3 qt/ac</td>
<td>( \times 5.84 )</td>
<td>=17.52 qt</td>
</tr>
<tr>
<td>2 gal/ac</td>
<td>( \times 5.84 )</td>
<td>=11.68 gal</td>
</tr>
<tr>
<td>1 pt/ac</td>
<td>( \times 5.84 )</td>
<td>= 5.84 pt</td>
</tr>
</tbody>
</table>

**Changing Speed**

The simplest way to alter the volume of spray being applied to an area is by changing the travel speed of the sprayer (Figure 6.1). A slower speed results in more liquid being applied, while a faster speed reduces the application rate. Such adjustments may be needed when swath width changes slightly, such as in orchards or vineyards where plant spacing may differ from block to block.

Changing the travel speed eliminates the need for altering the concentration of chemical in the spray tank, although there are limits to the amount of speed change that can be made. Operating application equipment too fast is a common error and will result in poor coverage. Operating it too slow results in runoff, waste, and an increase in application time and cost.

![Figure 6.1](image)  
_Altering the volume applied by changing travel speed._

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Changing Output Pressure

As nozzles begin to wear, the spray volume will increase. When a pump becomes worn it becomes less efficient and the nozzle output drops off. Adjusting the pressure regulator to increase or decrease output pressure will change the spray volume slightly. Increasing pressure increases the output, while decreasing pressure lowers it. However, in order to double the output volume it is necessary to increase the pressure by a factor of four; this is usually beyond the capabilities of the spraying system because the amount of adjustment that can be made is limited by the working pressure range of the sprayer pump. Whenever pressure in the system is changed, the nozzle output must be remeasured and the calibration calculations reworked. Increasing pressure breaks spray up into finer droplets, while lowering pressure too much may reduce the effectiveness of nozzles by altering the spray pattern.

Changing Nozzle Size

The most effective way to change the output of a sprayer is to install different sized nozzles. Larger nozzles increase volume, while smaller ones reduce spray output. Changing nozzles usually alters the pressure of the system and requires an adjustment of the pressure regulator. The volume output of disc core nozzles may be adjusted by changing either the disc or the core, or by replacing both. Be aware that changes in either the core or disc will also change the droplet size and spray pattern. Use tables included in nozzle manufacturers’ catalogs as a guide for estimating output of different combinations. Whenever any nozzles are changed, recalibrate the sprayer and refigure its new total output.

VI. Calibrating Dry Applicators

The techniques for calibrating dry applicators are similar in many ways to those used for liquids. However, granule applicators must be calibrated for each type of granular pesticide being applied and for each change in weather or field conditions. Granules vary in size and shape from one pesticide to the next, influencing their flow from the applicator hopper. Temperature and humidity, as well as field conditions, also influence granule flow.

Before beginning to calibrate a dry applicator, be sure that it is clean and all parts are working properly; most equipment requires periodic lubrication. Always wear rubber gloves to prevent contact with residues on the equipment. Calibration of granule applicators involves using actual pesticides, so special precautions must be taken. Some formulations are dusty, and you may need a respirator.

Three factors need to be measured when calibrating a dry applicator: (1) travel speed; (2) rate of output; and (3) swath width.

Travel Speed

Determine travel speed in feet per minute in the same way you would using liquid applicators (See Table 6.2). Applicator hoppers should be filled so that speed can be measured under actual operating conditions.

Rate of Output

To determine the rate of output, fill the hopper or hoppers with the granular formulation to be used. Most granule applicator hoppers have ports with adjustable openings for granules to
pass through; refer to charts supplied by the manufacturer to determine the approximate opening for the rate and speed you will be using. Once the approximate opening is set, use one of the following methods to determine the actual output rate:

1. **Measure the quantity of granules applied to a known area.** Collecting and weighing the granules actually applied to a measured area is often the easiest way to calibrate a granule applicator and should be used when working with broadcast applicators. Spread out a plastic tarp of known size on the ground, then operate the broadcast applicator at a known speed across the tarp. Place the granules collected by the tarp into a container and weigh them (Table 6.6).

2. **Collect a measured amount of granules over a known period of time.** Collecting and weighing granules over a known period of time is similar to calibrating a liquid boom sprayer with multiple nozzles; this method is used for granule applicators with multiple ports. While operating the applicator at a normal speed, collect granules from each port in a container; record the time required to collect each sample. Weigh samples separately (See Table 6.7).

3. **Refill the hopper after a measured period of time.** This method may be used with hand-operated equipment or when small quantities are being applied, but is most useful when multiple applicators are used together on a boom. Fill the hopper or hoppers to a known level and operate the equipment for a measured period of time. When finished, weigh the granules required to refill the hoppers to their original levels (See Table 6.8).

### Table 6.6 Calculating granule output rate by measuring the quantity applied to a known area

1. Spread a plastic tarp that is at least 10 feet by 10 feet on the ground. Multiply the length by the width to determine the area of the tarp.
   **Example:**
   
   Tarp size = 10 ft by 12 ft
   Tarp area: 10 ft × 12 ft = 120 sq ft

2. Fill the hopper or hoppers of the granule applicator, adjust the output ports to the recommended opening, and travel across the tarp at a known speed while granules are being broadcast.

3. Measure the swath width of the granules that were applied and compute the area of the swath. If the swath is wider than the tarp, the area figure to be used is equal to the area of the tarp. If the swath is narrower than the tarp, multiply the swath width by the length of the tarp.

4. Transfer all the granules on the tarp to a container and weigh them.

5. Multiply the weight of the granules collected (in pounds) by the area (acre, 1,000 square feet, or 100 square feet) given on the label. (An acre is 43,560 square feet.) Divide the result by the area of the swath.
   **Example:**
   Assume the swath width of granules being applied equals 15 feet. Therefore use the tarp area of 120 square feet in the calculations. (If the swath width was less than the tarp width, for example 8 feet, the area would then be 8 feet × 12 feet = 96 square feet.) Multiply the weight (in pounds) by the labeled area and divide the result by the tarp or swath area:
Weight = 8 oz ÷ 16 oz/lb = 0.5 lb

\[
0.5 \text{ lb} \times 43,560 \text{ sq ft/acre} = 181.5 \text{ lb/acre}
\]

In this illustration, the granule applicator is broadcasting 181.5 pounds of material per acre. If the label calls for a greater amount, open the port more or slow the speed of travel of the applicator. If the label calls for a lesser amount, close the port some or speed up the rate of travel. Once an adjustment has been made, repeat the calibration.

**Table 6.7 Calculating granule output rate by collecting a measured amount over a known period of time**

1. Adjust the hopper opening according to manufacturer’s instructions suggested for your required application rate. If no information is available, begin with an intermediate setting.

2. Operate the equipment at the speed of an actual application. Collect granules in a clean container, such as a pan or bag, before they drop to the ground. Use a stopwatch to determine the time required to collect each volume. If granules are dispersed through more than one opening, collect and time the output from each. Because some units drop granules onto a spinning disc for dispersal, it may be necessary to disable the disc by disconnecting the drive chain or belt to prevent granule loss during collection. For smaller units, collect the discharge in a bag placed over the outlet. Be sure granules move away from the port quickly enough to prevent clogging.

3. Weigh the output from each port separately to detect any variability; if necessary, adjust ports to equalize flow rates. Collections should be weighed in ounces.

4. Divide each weight in ounces by the collection time in minutes and multiply by 0.0625 to get the output in pounds per hour for each port.
**Example:**
The following is an example of an output collected from a granule applicator with six ports, although the same calculations would apply if only one port were used. Hopper openings were adjusted following manufacturer’s recommendations for an application of 200 pounds per acre:

<table>
<thead>
<tr>
<th>Port</th>
<th>oz</th>
<th>min</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>29.5</td>
<td>0.25</td>
</tr>
<tr>
<td>2</td>
<td>33.0</td>
<td>0.28</td>
</tr>
<tr>
<td>3</td>
<td>31.5</td>
<td>0.26</td>
</tr>
<tr>
<td>4</td>
<td>29.0</td>
<td>0.25</td>
</tr>
<tr>
<td>5</td>
<td>33.0</td>
<td>0.27</td>
</tr>
<tr>
<td>6</td>
<td>30.0</td>
<td>0.26</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Port</th>
<th>oz (\div) min</th>
<th>oz/min</th>
<th>(\times) 0.0625</th>
<th>= lb/min</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>29.5/0.25</td>
<td>= 118.0</td>
<td>(\times) 0.0625</td>
<td>= 7.375</td>
</tr>
<tr>
<td>2</td>
<td>33.0/0.28</td>
<td>= 117.9</td>
<td>(\times) 0.0625</td>
<td>= 7.369</td>
</tr>
<tr>
<td>3</td>
<td>31.5/0.26</td>
<td>= 121.2</td>
<td>(\times) 0.0625</td>
<td>= 7.575</td>
</tr>
<tr>
<td>4</td>
<td>29.0/0.25</td>
<td>= 116.0</td>
<td>(\times) 0.0625</td>
<td>= 7.250</td>
</tr>
<tr>
<td>5</td>
<td>33.0/0.27</td>
<td>= 122.2</td>
<td>(\times) 0.0625</td>
<td>= 7.638</td>
</tr>
<tr>
<td>6</td>
<td>30.0/0.26</td>
<td>= 115.4</td>
<td>(\times) 0.0625</td>
<td>= 7.213</td>
</tr>
</tbody>
</table>

**Total output (lbs/min)** 44.42

5. Add the individual outputs of each port in pounds per minute to get total pounds-per-minute output. In this example, the total output is 44.42 pounds per minute.

6. Use the technique shown in Table 6.8 to calculate the rate per acre or other unit of area.

**6.8 Calculate the rate of output by refilling the hopper after a measured period of time**

1. Fill the hopper or hoppers to a known level with granules.

2. Operate the equipment for a measured period of time at a known speed.

3. Weigh the amount of granules required to refill the hopper or hoppers to their original level. If multiple hoppers are being used, be sure each is applying approximately the same amount of granules. If a significant variation exists, adjust the ports and repeat steps 1 through 3.

**Example:**
In this example, six applicators were used together on a boom. They have been adjusted so that they all apply approximately the same amount of granules:
Chapter 6 Calibration & Mixing

Swath Width

To measure the swath width of granules dispersed by the applicator, operate the equipment under actual field conditions. Whenever possible, place cans, trays, or other containers at even intervals across the width of the application swath to collect granules. Weigh the granules collected in each container separately to determine the distribution pattern. Some spreaders can be operated over a strip of black cloth or plastic to provide a rapid visual assessment of granule distribution and swath width.

Granule applicators that apply bands or inject granules into the soil do not have devices to disperse granules from side to side. Swath width is determined by adding the widths of individual bands.

Application Rate

Motorized and hand-operated applicators apply granules at a fixed output, independent of ground speed. If ground speed increases, the effect will be to reduce the amount of granules applied per unit of area; conversely, when ground speed decreases, more material is applied. Application rate with this type of equipment can, therefore, be adjusted not only by the size of the port opening, but also by the speed of travel. The output of ground - wheel-driven granule applicators, however, varies according to the ground speed. If ground speed increases, the applicator runs faster and the output rate is greater. When the ground speed slows, output decreases. The result of this automatic change in output is that the equipment will apply the same amount of material per acre or other unit of area, no matter what speed it is driven (the equipment will have minimum and maximum operating speeds determined by the manufacturer). Use Table 6.9 to calculate the actual rate of granules applied per acre or other unit of area. The application rate also can be adjusted by increasing or decreasing the size the port openings or by changing drive gears or sprockets to change the speed ratio of the metering mechanism to the ground wheel.

### Table 6.9

<table>
<thead>
<tr>
<th>Hopper</th>
<th>Operating time (min)</th>
<th>Weight of granules (lbs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2.5</td>
<td>6.2</td>
</tr>
<tr>
<td>2</td>
<td>2.5</td>
<td>6.1</td>
</tr>
<tr>
<td>3</td>
<td>2.5</td>
<td>6.1</td>
</tr>
<tr>
<td>4</td>
<td>2.5</td>
<td>6.3</td>
</tr>
<tr>
<td>5</td>
<td>2.5</td>
<td>6.1</td>
</tr>
<tr>
<td>6</td>
<td>2.5</td>
<td>5.9</td>
</tr>
</tbody>
</table>

**Total output (lbs) 36.7**

4. Divide the total weight from all hoppers by the time they were operated to convert the output to pounds per minute.

**Example:**

\[
\frac{36.7 \text{ lbs}}{2.5 \text{ min}} = 14.68 \text{ lbs/min}
\]

5. Use the technique shown in Table 6.9 to calculate the rate per acre or other unit of area.
VII. Calculations for Active Ingredients, Percent Solutions, and Parts-per-Million Solutions

Not all pesticide recommendations call for dry or liquid formulated amounts of pesticide per unit of area. Sometimes recommendations require the pesticide to be applied in pounds of active ingredient (A.I.) per unit of area, to be mixed as a percent solution, or to be diluted to parts per million (ppm) solution. Before adding pesticide to the spray tank, read and understand the dilution instructions on the label.

Active Ingredient Calculations

Table 6.9 Calculating rate-per-acre or other unit of area

1. Divide the swath width by 43,560 (the number of square feet in an acre) and multiplying the result by the speed of travel. In this example, the swath width is 30 feet and the application speed is 352 feet per minute (4 miles per hour).

   Example:

   \[
   \frac{30 \text{ ft (swath)}}{43,560 \text{ sq ft/ac}} \times 352 \text{ ft/min} = 0.2242 \text{ ac/min}
   \]

2. Divide the output rate of the granule applicator in pounds per minute by the acres-per-minute calculated in step 1 to get the pounds of formulated pesticide being applied per acre. This example uses 44.42 pounds per minute as the output rate.

   Example:

   \[
   \frac{44.42 \text{ lb/min}}{0.2242 \text{ ac/min}} = 183.6 \text{ lb/ac}
   \]

Table 6.10 Calculating active ingredient with liquid formulations

Assume that a sprayer has been calibrated and sprays 7.5 acres per tank. You have a recommendation to apply 1.5 pounds A.I. of chlorothalonil per acre to control rust on snap beans, and have been supplied with a liquid formulation containing 4.17 pounds (a.i.) of chlorothalonil per gallon.
1. Divide the pounds of A.I. per gallon by the recommended pounds of A.I. per acre to get the number of acres that can be treated with 1 gallon of formulation.

**Example:**

\[
\frac{4.17 \text{ lb A.I. per gal}}{1.5 \text{ lb A.I. per ac}} = 2.78 \text{ ac/gal}
\]

2. Divide the known acre capacity of your tank by the acres per gallon to get the number of gallons of formulation to put into the tank.

**Example:**

\[
\frac{7.5 \text{ ac/tank}}{2.78 \text{ ac/gal}} = 2.7 \text{ gal/tank}
\]

Thus 2.7 gallons of formulated chlorothalonil should be put into the tank for spraying 7.5 acres of crop.

The A.I. of any pesticide will be listed on its label. Labels of liquid pesticides give the percentage by weight of active ingredient and also tell how many pounds of active ingredient are in 1 gallon of formulation; labels of dry formulations list the percentage by weight of active ingredient (Tables 6.11, 6.12).

**Table 6.11 Calculating active ingredient with powder formulations**

Assume that the calibrated sprayer you are using covers 7.5 acres per tank, and you have a recommendation to apply 1.5 pounds A.I. of chlorothalonil per acre for fungus control on melons. You are provided with a wettable powder formulation that, according to the label, contains 75% chlorothalonil.

1. Divide the percent A.I. (to convert it to a decimal) by 100 (or simply move the decimal point two places to the left).

**Example:**

\[
75\% = 0.75 \text{ A.I./lb formulation}
\]

2. Divide the recommended amount of A.I. by the amount of A.I. in the formulation.

**Example:**

\[
\frac{1.5 \text{ lb A.I./ac}}{0.75 \text{ lb A.I./lb formulation}} = 2 \text{ lb formulation/ac}
\]

3. Multiply the pounds of formulation per acre by the number of acres per tank to find out how much formulation to put into the tank.

**Example:**

\[
2 \text{ lb formulation/ac} \times 7.5 \text{ ac/tank} = 15 \text{ lb/tank}
\]
Table 6.12 Calculating active ingredient with granular formulations

Convert the percent A.I. into a decimal and divide this into the recommended application rate. Assume you are given a recommendation for application of 0.50 lb A.I. of ethoprop per 1,000 square feet for control of nematodes. You are provided with a granular formulation containing 10% active ingredient (0.1 pound of A.I. per pound of formulation).

**Example:**

\[
\frac{0.5 \text{ lb A.I./1,000 sq ft}}{0.1 \text{ lb A.I./lb formulation}} = 5 \text{ lb formulation/1,000 sq ft}
\]

Calibrate the granule applicator so that it applies formulation at the calculated rate; here, 5 pounds of formulated ethoprop per 1,000 square feet.

**Percent Solutions**

Sometimes label recommendations require that the pesticide be mixed as a percent solution. The active ingredient is mixed to get a known concentration, regardless of the volume per unit area of spray put out by the sprayer. Percent solutions are mixed on a weight/weight basis (w/w), meaning pounds of A.I. per pound of water (See Tables 6.13 and 6.14).

Table 6.13 Calculating a percent solution with a liquid formulation

Assume you have measured the volume of the spray tank and find that it holds 264.5 gallons of water. You are given a recommendation to apply a 1% solution of glyphosate for control of aquatic weeds, using a high-pressure sprayer with a hand-held spray nozzle. The formulation of glyphosate that you are to use contains 5.4 pounds of active ingredient per gallon. To prepare a percent solution using liquid formulations, you need to know the volume of the spray tank, the weight of active ingredient per gallon of formulation, and the weight of a gallon of water. The weight of a gallon of water is a constant, being approximately 8.34 pounds.

1. To find the total weight of the liquid in the filled tank by multiplying 264.5 gallons by 8.34 pounds per gallon:

   **Example:**

   \[
   264.5 \text{ gal} \times 8.34 \text{ lb/gal} = 2,205.93 \text{ lb}
   \]

2. Multiply the total weight of liquid by the percent of solution, expressed as a decimal, to determine the weight of A.I. required to mix the desired solution:

   **Example:**

   \[
   2,205.93 \text{ lb} \times 0.01 = 22.06 \text{ lb}
   \]

3. Divide the required weight of A.I. by the weight of A.I. in the formulation. The result is the number of gallons of liquid formulation that should be added to the tank to achieve the desired percent solution:

   \[
   \frac{22.06 \text{ lb}}{5.4 \text{ lb/gal}} = 4.10 \text{ gal}
   \]
EXAMPLE:

\[
\frac{22.06 \text{ lb A.I.}}{5.4 \text{ lb A.I./gal}} = 4.1 \text{ gal formulation}
\]

In this example, one tank of liquid should contain 4.1 gallons of glyphosate formulation. The total volume of water combined with the glyphosate formulation should equal 264.5 gallons, the capacity of the tank. You would therefore use 260.4 gallons of water and 4.1 gallons of formulated glyphosate.

NOTE: These calculations give a close approximation of the amount of liquid formulation to add to the tank to achieve a known percent solution. The mathematics for a more exact figure are more complex and unnecessary for this example.

**Table 6.14 Calculating a percent solution with a dry formulation**

Assume your dry formulation is 75% A.I.; 1 pound of dry formulation would contain 0.75 pound of pesticide active ingredient. You need to mix a 1% spray solution of this formulation in 264.5 gallon tank.

1. Multiply the tank capacity in gallons by 8.34 pounds per gallon to find the total weight (in pounds) of the liquid in the filled tank.

   **EXAMPLE:**

   \[264.5 \text{ gal} \times 8.34 \text{ lb/gal} = 2,205.93 \text{ lb}\]

2. Multiply the total weight of liquid by the percent of the desired solution, expressed as a decimal to determine the weight of A.I. required to mix the desired solution.

   **EXAMPLE:**

   \[2,205.93 \text{ lb} \times 0.01 = 22.06 \text{ lb}\]

3. Divide the weight of A.I. (in pounds) by the decimal equivalent of the percent of A.I. in the formulation to get the number of pounds of formulation that should be added to the tank to achieve the desired percent solution.

   **EXAMPLE:**

   \[\frac{22.06 \text{ lb A.I.}}{0.75 \text{ A.I./formulation}} = 29.41 \text{ lb formulation}\]

Add 29.41 pounds of wettable powder to 264.5 gallons of water to achieve a 1 percent solution.
Parts-Per-Million Solutions

Certain pesticides need to be mixed in parts-per-million (ppm) concentrations, which are essentially the same as percent solutions. For example, a 100 ppm solution is equal to a 0.01 percent solution (See Table 6.15). The ppm designation represents the parts of active ingredient of pesticide per million parts of water; ppm dilutions are a common way of measuring very diluted concentrations of pesticides (See Tables 6.16 and 6.17).

Table 6.15 Parts Per Million (ppm)

<table>
<thead>
<tr>
<th>ppm</th>
<th>Decimal</th>
<th>Percent Solution</th>
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</thead>
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<tr>
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<td>0.0001</td>
</tr>
<tr>
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</tr>
<tr>
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<td>1.0</td>
<td>100.0</td>
</tr>
</tbody>
</table>

Table 6.16 Calculating a parts-per-million dilution for dry formulations

Assume you are given a recommendation requiring a 100 ppm concentration of streptomycin to be mixed in a 500-gallon tank. Streptomycin is used for control of angular leaf blight on cotton. The formulation you have is a water soluble powder, containing 17% A.I.

1. Multiply (in pounds) the tank capacity in gallons by 8.34 pounder per gallon to find the total weight of the liquid in the filled tank.

   \[\text{Example:}\]
   
   \[500 \text{ gal} \times 8.34 \text{ lb/gal} = 4,170 \text{ lb/tank}\]

2. Calculate how many pounds of A.I. are required for a pound of spray solution.

   \[\text{Example:}\]
   
   \[100 \text{ ppm} = \frac{100 \text{ parts A.I.}}{1,000,000 \text{ lb solution}} = 0.0001 \text{ a.i./lb solution}\]

   It will require 0.0001 pounds of A.I. for each pound of solution to achieve a 100 ppm mixture.
3. Calculate how many pounds of A.I. are required for a tank solution, using the weight of the liquid in the tank:

**Example:**

\[ 4,170 \text{ lb/tank} \times 0.0001 \text{ lb A.I.} = 0.417 \text{ lb A.I./tank} \]

4. Divide the weight of A.I. by the decimal equivalent of the percent of A.I. in the formulation. The result is the number of pounds of formulation that should be added to 500 gallons of water to achieve a 100 ppm solution.

**Example:**

\[ \frac{0.417 \text{ lb A.I.}}{0.17 \text{ lb A.I./lb formulation}} = 2.45 \text{ lb formulation} \]

**Table 6.17 Calculating a parts-per-million dilution for liquid formulations**

1. Multiply (in pounds) the tank’s capacity in gallons by 8.34 pounds per gallon. Assume a pesticide contains 5.4 pounds of A.I. in one gallon of formulation. You are required to prepare a 100 ppm concentration in a 500 gallon tank.

**Example:**

\[ 500 \text{ gal/tank} \times 8.34 \text{ lb/gal} = 4,170 \text{ lb/tank} \]

2. Calculate how many pounds of A.I. are required for a pound of spray solution.

**Example:**

\[ \frac{100 \text{ ppm}}{1,000,000 \text{ lb/soluton}} = 0.0001 \text{ a.i./lb solution} \]

It will require 0.0001 pounds of A.I. for each pound of solution to achieve a 100 ppm mixture.

3. Determine how many pounds of A.I. are required for a tank of solution, using the weight of the liquid in the tank:

**Example:**

\[ 4,170 \text{ lb/tank} \times 0.0001 \text{ lb A.I.} = 0.417 \text{ lb A.I./tank} \]

4. Divide the required weight of A.I. by the pounds of A.I. per gallon to get how many gallons of formulation should be added to the tank. Because this will probably be a small number, multiply the number of gallons by 128 ounces per gallon to convert to ounces.
EXAMPLE:

\[ \frac{0.417 \text{ lb A.I.}}{\text{tank}} \div \frac{5.4 \text{ lb A.I.}}{\text{gal}} = 0.0772 \text{ gal/tank} \]

\[ 0.0772 \text{ gal/tank} \times 128 \text{ fl oz/gal} = 9.88 \text{ fl oz/tank} \]

Adding 9.88 fluid ounces of this formulated pesticide to 500 gallons of water will result in a 100 ppm solution.

VIII. Summary

Calibration is essential for good pest control. By calibrating equipment we maintain effective pest control, protect our health and the environment, prevent waste of resources and maintain compliance with state and federal laws. Calibration makes sense.

References


University of California Publication: *How Much Chemical Do You Put in the Tank?* Publication 2718.
Chapter Six
Calibration & Mixing — Question and Answer Review

1. Q. When you have the right mixture in your spray tank, can you still apply the wrong amount of pesticide?

A. Yes. Noncalibrated application equipment will apply the pesticide at an unknown rate. Unless calibrated, the equipment could be under- or overapplying the pesticide.

2. Q. What is the delivery rate?

A. **Delivery rate** is the total amount of pesticide delivered on the target over a period of time.

3. Q. Once your sprayer is calibrated, does it remain the same or should you recheck it often?

A. It must be rechecked often. For example, nozzles can wear or become plugged, thus changing the delivery rate.

4. Q. If your sprayer is delivering less spray per acre than you want, how would you usually change the rate?

A. Change pump pressure, speed, or nozzles.

5. Q. What must you measure to calibrate granular application equipment?

A. You must measure the amount of granules spread over a known area.

6. Q. Must you calibrate granular application equipment each time you change granules? Applicators? Why?

A. Yes to both questions, because each granule flows differently, and, in hand models, each applicator may walk or crank at a different speed.

7. Q. What facts must you know for the “gallons per acre — known area” method of sprayer calibration?

A. The number of square feet in an acre, the speed of your sprayer, the width of your spray boom, and the delivery rate of your sprayer.

8. Q. Thirty-two ounces of water were collected from one spray nozzle in 30 seconds. What is the nozzle delivery rate in gallons per minute (GPM)? (ex. 6.4)
A. Delivery rate = \( \frac{32 \text{ ounces (wet)}}{30 \text{ seconds}} \times \frac{1 \text{ gallon}}{128 \text{ ounces}} \times \frac{60 \text{ seconds}}{1 \text{ minute}} = 0.5 \text{ GPM} \)

9. Q. Why is it so important to add the correct amount of pesticide to the mix?

A. Too little may result in poor results; too much may result in crop injury, illegal residues, or unnecessary expense.

10. Q. If your recommendations call for 3 pounds of wettable powder per 100 gallons of an emulsifiable concentrate, how much do you put in a 450-gallon tank? Show your calculations.

A. Answer: 13.5 pounds. There are 4.5 times as much water in the 450-gallon tank as in the 100-gallon tank, so \( 4.5 \times 3 \text{ pounds} = 13.5 \text{ pounds} \).

11. Q. How much do you put in an 80 gallon tank at 3 pounds per 100 gallons?

A. Answer: 2.4 pounds. 80 gallons is \( \frac{80}{100} \) of 100 gallons = \( \frac{4}{5} \). \( \frac{4}{5} \times 3 \text{ pounds} = 2.4 \text{ pounds} \).

12. Q. If the label says to mix 3 pints per 100 gallons of an emulsifiable concentrate, how much do you put in a 300 gallon tank? How much in a 50 gallon tank?

A. Answer: Nine (9) pints, or 1 gallon and 1 pint in 300 gallons. \( 3 \times 3 \text{ pints} = 9 \text{ pints} \).
Answer: 1 1/2 pints in 50 gallons. \( 1/2 \times 3 \text{ pints} = 1 1/2 \text{ pints} \).

13. Q. If two pints of EC are recommended per 100 gallons of water, how many teaspoons of EC would you add to one gallon? (1 pt. = 32 tsp.)

A. Answer: 2 teaspoons. \( \frac{1}{100} \times 2 \text{ pints} \times 16 \text{ fluid ounces} = 0.32 \text{ fluid ounces} \text{ or a little less than 2 teaspoons} \).

14. Q. How much does 100 gallons of water weigh?

A. Answer: 100 \( \times 8.34 \text{ lbs per gallon} = 834 \text{ pounds} \).

15. Q. How many gallons of 25% emulsifiable concentrate would you add to a 50 gallon tank to get a 1% mixture? (ex. 6.13)

A. Answer: 2 gallons.

\[ 0.1 \times 50 \text{ gallons} \times 8.34 \text{ pounds per gallon} = 4.17 \text{ pounds active ingredient in 50 gallons of 1% solution} \]

\[ 0.25 \times 1 \text{ gallon} \times 8.34 \text{ pounds per gallon} = 2.085 \text{ pounds active ingredient per gallon of 25% EC} \]

\[ 4.17 \div 2.085 = 2 \text{ gallons 25% EC to make 50 gallons of 1% solution} \]
16. Q. How many pounds of 25% wettable powder must you add to 100 gallons of water to get a 1% active ingredients mixture? (ex. 6.14)

   A. Answer: 33.36 pounds or almost 33 pounds 6 ounces.
   \[
   0.01 \times 100 \text{ gallons} \times 8.34 \text{ pounds per gallon} = 8.34 \text{ pounds active ingredient in 100 gallons of 1% solution.}
   \]
   \[
   0.25 \times 1 \text{ pound} = 0.25 \text{ pounds active ingredient per pound of 25% WP}
   \]
   \[
   8.34 \div 0.25 = 33.36 \text{ pounds 25% WP to make 100 gallons of 1% solution.}
   \]

17. Q. How much must the pressure increase to double the outflow?

   A. Pressure must be increased four times to double the flow rate.

18. Q. What are closed mixing and loading systems?

   A. Closed mixing and loading systems are systems designed to prevent pesticide from coming in contact with handlers or other persons during mixing and loading.

19. Q. What are enclosed application systems?

   A. In enclosed application systems, a cab, cockpit, or other enclosure that surrounds the occupants and prevents them from coming in contact with pesticides outside of the enclosure.

20. Q. When should you consider installing a pesticide containment system?

   A. If you often mix and load pesticides in one place, or if you often clean equipment at one location.

21. Q. What are the advantages of pesticide containment systems?

   A. They can save time and money. They make spill cleanup easier, and they reduce pesticide waste by allowing reuse of rinse water and spill cleanup water. They also help prevent the harm that spills and runoff can cause to the environment or to people.

22. Q. What two precautions should you take to avoid getting pesticides into your water source at a mix-load site?

   A. 1. Keep the water pipe or hose well above the level of the pesticide mixture, and use a device to prevent back-siphoning, if necessary.
      2. Avoid mixing or loading pesticides in areas where a spill, leak, or overflow could allow pesticides to get into water systems.

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