Hawaii
Chemigation Guide

January 2013

A study guide
for persons seeking certification by the State of Hawaii Department of Agriculture
to buy, use, or supervise the use of fumigants classified as restricted use pesticides

This study guide was developed for the Pesticide Risk Reduction Education program, a program of the College of Tropical Agriculture and Human Resources, University of Hawaii at Manoa. Please direct any question or comment about this guide to:

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*Where trade names are used, no endorsement is intended, nor criticism implied of similar products not named.*
Table of Contents

Unit 1. Introduction .................................................................................................................. 5
  Learning Objectives .............................................................................................................. 5
  Terms to Know ...................................................................................................................... 6
  Overview of Chemigation ..................................................................................................... 7
  Scope of This Manual .......................................................................................................... 7
  Purpose of This Manual ....................................................................................................... 7
  History of Chemigation ....................................................................................................... 8
  Laws and Regulations .......................................................................................................... 8
  Integrated Pest Management (IPM) ..................................................................................... 11

Unit 2. Before You Chemigate............................................................................................... 13
  Learning Objectives ............................................................................................................ 13
  Terms to Know .................................................................................................................... 14
  Why Chemigate? .................................................................................................................. 15
  Considerations before Chemigating .................................................................................... 16
  Operation Plan ...................................................................................................................... 18
  Target Applications ............................................................................................................. 18

Unit 3. Safety Considerations ............................................................................................... 21
  Learning Objectives ............................................................................................................ 21
  Terms to Know .................................................................................................................... 22
  Protecting the Environment ................................................................................................. 23
  Protecting Workers: The Worker Protection Standard ....................................................... 27
  Protecting the Applicator ..................................................................................................... 28

Unit 4. Application Systems and Equipment .......................................................................... 31
  Learning Objectives ............................................................................................................ 31
  Terms to Know .................................................................................................................... 32
  Sprinkler Systems ................................................................................................................ 33
Unit 1. Introduction

Learning Objectives

After studying this unit, you will be able to:

• Define chemigation and how it is used in Hawaii.
• Explain the scope and purpose of this manual.
• Understand federal and state laws about chemigation.
• Define integrated pest management (IPM).

This unit explains what chemigation is. It defines the scope of the manual and discusses its purpose through an overview of all six units. This manual focuses on pesticide chemigation: applying herbicides, insecticides, fungicides, nematicides, and other chemicals through an irrigation system. You will learn about the laws requiring backflow prevention to reduce the threat of water pollution. You will also learn that chemigation is one aspect of a well-planned IPM program.
Terms to Know

Backflow—The movement of a liquid in reverse of the normal direction of flow in a piping system. In chemigation systems, backflow can also occur in the injection line, causing the pesticide supply tank to overflow.

Chemigation—The application of a pesticide or fertilizer through an irrigation system. This can occur on many sites, including greenhouses, crop fields, and golf courses.

Drip/trickle Irrigation (Microirrigation)—An irrigation method in which water is applied through drip emitters with very low flow rates using flexible hose or tape.

Fertigation—The application of fertilizer directly through an irrigation system.

PR Notice 87-1—Part of the Label Improvement Program (LIP). It requires pesticide registrants (manufacturers) to state on the product label whether (and how) a pesticide may be chemigated.

Rinsate—Pesticide-containing water (or other liquid) that results from rinsing a pesticide container, pesticide equipment, or other pesticide-containing articles.

Soil Amendments—Materials added to soil, such as peat moss, bark, perlite, or sand. Soil amendments may help improve nutrition, prevent compaction, or improve drainage.

Sprinkler Irrigation—An irrigation method in which water is sprayed or sprinkled through the air to the ground.

Surface/Gravity-Flow Irrigation Irrigation methods consisting of flood and furrow techniques.

Hawaii Department of Agriculture—The state agency that regulates pesticides and pesticide applicators under the authority of the Hawaii Pesticides Law and the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) on behalf of the Environmental Protection Agency (EPA).

Hawaii Department Health—The state agency responsible for implementing most environmental rules (other than pesticide application and registration) set by the EPA.
Overview of Chemigation

Chemigation is the application of agricultural chemicals through an irrigation system. These chemicals include fertilizers, soil amendments, herbicides, insecticides, fungicides, nematicides, algacides, and plant growth regulators. There are many benefits to chemigating as well as some drawbacks. Keep in mind that having an irrigation system does not always mean you can use it to apply pesticides. You may apply a pesticide through an irrigation system ONLY if the product label states that you may do so.

Think of your irrigation system as a distribution and application network with a hose, pipe, or other conduit that connects to a water source. This source can be groundwater (well water), surface water (from a reservoir, stream, or ditch), or municipal water provided by your local water supply agency or by private suppliers. The water distributes the pesticide through one of three types of systems:

- sprinkler,
- drip/trickle (also known as microirrigation), or
- surface/gravity flow (also known as surface run).

The right equipment is vital to successful—and legal—chemigation. This means you need the right kind of tanks, pumps, and calibration tubes. You also must have approved antipollution (safety) devices. Federal and state laws require safety devices on chemigation equipment to protect all source water. These devices will prevent backflow, spills, and any pollutant discharges into water bodies. Check valves, lowpressure drains, and vacuum relief valves, for example, keep the chemical-water mixture from draining or siphoning back into the water supply. Consult the pesticide label to find out:

- whether the product can be applied through an irrigation system,
- what type of system is allowed, and
- what safety (backflow prevention) devices are required for chemigation.

Scope of This Manual

This guide was written for people who are studying for a Hawaii Department of Agriculture examination to qualify for a restricted use pesticide certification in either one of the following categories:

- Commerical applicator category 11 (chemigation pest control). A requirement for certification in this category is concurrent certification in one of the following commercial applicator categories: 1A (agricultural plant pest control), 2 (forest pest control), 3 (ornamental and turf pest control), or 10 (demonstration, research and instructional pest control).
- Private applicator category 2 (agricultural chemigation pest control). A requirement for certification in this category is concurrent certification in the private applicator category 1 (general agricultural pest control).

Purpose of This Manual

The purpose of this manual is to help you practice pesticide chemigation safely and effectively in Hawaii. It starts by describing the federal and state laws that govern pesticide chemigation and safeguard the state’s public and private water sources. You will learn that the pesticide label is a legal document with the full force of federal law. The label tells you whether, where, and how you may chemigate.

Next, you will learn the benefits and drawbacks of pesticide chemigation as well as some important points to keep in mind before you begin. First, make sure that the location, soil type, and landforms of the site will allow successful chemigation. Of course, you must consider the specific pest(s) you wish to control. There are many types of pesticide chemigation; which to use depends on your target pest. These include the application of:

- fungicides,
- insecticides,
- herbicides,
As with any form of pesticide application, safety is a major concern. You must decrease environmental hazards such as drift and runoff. You must also protect workers through proper posting and restricted-entry intervals. Finally, the safety of the applicators themselves is vital. You will learn how to protect yourself and those around you while chemigating. You will also learn what to do in case of a pesticide accident or spill.

As a chemigator, your equipment is vital to success. This manual will describe the most common types of irrigation systems and the basic chemigation equipment for each. You will learn which type of injection pump is best for your purpose. You will also discover the importance of an accurate calibration tube and of safety devices. In addition, this manual will give maintenance and troubleshooting guidelines. These will help you better manage your chemigation tasks.

Because of the danger of water pollution while chemigating, this manual will devote an entire unit to backflow prevention. Water pollution is the greatest hazard of chemigation and carries severe health and legal consequences. You will learn about the most common—and effective—types of anti-pollution devices as well as some alternative ways to prevent backflow.

The final unit in this manual discusses calibration. Calibration helps you to apply pesticides uniformly and at the correct rate. This manual describes step by step how to calibrate the main types of irrigation equipment for chemigation. It also includes examples to help you do the calculations. Use manufacturers’ data only as a starting point. Always calibrate your own equipment before applying any pesticide for any purpose.

**History of Chemigation**

Applying chemicals with irrigation water is not new. Chemigation has existed since the 1950s and has expanded nationwide to several million acres. The earliest application of chemicals through sprinklers involved injecting fertilizer into an irrigation system. Herbigation followed and was most commonly done with center pivots and a long spray boom. Other chemicals then came into use: insecticides, fungicides, and nematicides. In time, all these terms became known as “pesticide chemigation.”

**Laws and Regulations**

Both federal and state laws control the practice of chemigation. Laws sometimes change, however, and new ones come into effect. For this reason, you should regularly check with the Hawaii Department of Agriculture, Pesticides Branch for the latest information.

**Federal Laws**

All pesticide applications, including those made through an irrigation system, are subject to the provisions of the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) as amended. FIFRA contains three mandates important to pesticide applicators:

1. Use pesticides only as directed by the label.
2. Purchase restricted use pesticides only if you are a certified applicator.
3. Apply restricted-use pesticides only if you are a certified pesticide applicator or are supervised by a certified applicator.

FIFRA also says that the site or crop to which you plan to apply the pesticide must appear on the label. It is a violation of FIFRA to use a pesticide if the site or crop is not listed on the label.

**Pesticide Labels**

One of the reasons a pesticide label is so important is that, under FIFRA, it is considered a legal document. This means that the label—the paper attached to the pesticide container along with any other material—has the same force as federal law. If you use a pesticide in a manner inconsistent with its labeling, you are breaking a law and may
be prosecuted. Before you buy or use any pesticide, read and fully understand everything on the product label.

Label Improvement Program (PR Notice 87-1)

A pesticide label must have the information you need to help you decide whether to buy the product for chemigation. As of 1988, the U.S. Environmental Protection Agency (EPA) began enforcing a Label Improvement Program (LIP). This program, which includes Pesticide Registration (PR) Notice 87-1, requires the registrants (manufacturers) of all pesticides under FIFRA to state on the label whether the product may be chemigated. The label cannot remain silent on chemigation. If the pesticide may not be applied through an irrigation system, the following statement must appear on the label:

Do not apply this product through any type of irrigation system.

If the label does not contain information about chemigation, the product cannot be chemigated.

If the product may be chemigated, the label must say which type(s) are allowed. For example, if a product may only be applied through drip irrigation, the label would read like this:

Apply this product only through drip irrigation systems. Do not apply this product through any other type of irrigation system.

The label requirements apply to pesticides labeled for use in:

- agriculture (e.g., food, fiber, and field crops; nursery stock; and sod),
- nurseries,
- turf farms,
- golf courses, and
- greenhouses.

They do not apply to products that are intended solely for:

- residential use,
- direct injection into plants, or
- postharvest application to produce.

They also do not apply to pesticides applied only as a solid or a gas.

Posting Requirements

On some sites, the EPA, under FIFRA, requires that you post chemigated areas when you use a Toxicity Category 1 product. This includes pesticides with the label signal word DANGER. The signs must clearly warn workers that pesticides are being applied in irrigation water. For products in other toxicity categories, always check the label to see whether posting is required. See Unit 3 (Safety Considerations) for more information about worker safety.

Antipollution Devices

Federal law also says that the label of any pesticide approved for chemigation must spell out what type of safety equipment is required to prevent pollution during chemigation. For example, pollution control features for sprinkler chemigation include an irrigation mainline check valve, a vacuum relief valve, and an automatic low-pressure drain. All of these devices are located on the irrigation pipeline. You may also need an injection-line check valve and a simultaneous interlock. See Unit 5 (Backflow Prevention) for details on safety equipment and backflow prevention.

Water Pollution Control Act (Clean Water Act)

The Water Pollution Control Act gives the federal government authority over surface waters such as streams, rivers, lakes, and oceans. If you, as a chemigator, pollute any of these water bodies, you may have violated this law. The HDOH also regulates water quality and pollution control in surface-water bodies within the state. Further, the HDOH has responsibility for protecting Hawaii’s groundwater from contamination.
Other Federal Laws

The Safe Drinking Water Act protects public drinking water. Its focus is on protection of drinking water quality. Your irrigation system may connect to a public drinking water source. If so, you will need to install special equipment to prevent backflow of chemicals into the drinking water supply.

The Resource Conservation and Recovery Act governs disposal of pesticides, pesticide containers, and rinsate. Be sure to follow label directions carefully before you discard these items.

Hawaii Laws

The State of Hawaii regulates pesticide use through the Hawaii Pesticides Law, the Hawaii Administrative Rules, and through the Hawaii Department of Health. These are discussed below.

Hawaii Pesticides Law

The Hawaii Pesticides and Law (HPL) lays out the basic authority and framework for the regulation of pesticides within the state. The requirements spelled out in this law are part of the Hawaii Revised Statutes. The HPL affects all pesticide applicators in Hawaii. Be sure to keep up with its current provisions.

HPL specifically states, “No person shall fill with water, through a hose, pipe or other similar transmission system, any tank, implement, apparatus, or equipment used to disperse pesticides, unless the tank, implement, apparatus, equipment, hose, pipe or other similar transmission system is equipped with an air gap or a reduced-pressure principle backflow device meeting the requirements under section 340E-2 and the rules adopted thereunder.”

Chapter 340E-2 authorizes the Department of Health to promulgate Hawaii Administrative Rules pertaining to: (1) the enforcement of standards are drinking water quality [Chapter 11-20 rules relating to potable water systems]; (2) the regulation of cross-connections and backflow prevention [Chapter 11-21 cross-connection and backflow control]; and (3) the administration of an underground injection control program [Chapter 11-23 underground injection control]. Chapter 11-21 specifically requires an approved reduced pressure principle backflow prevention device or air gap separation “before any piping network in which fertilizers, pesticides and other chemicals or toxic contaminants are injected or siphoned into the irrigation system.”

The HPL authorizes the Hawaii Department of Agriculture to promulgate regulations in order to carry out its duties under the law. These regulations are written down in the Hawaii Administrative Rules.

Hawaii Administrative Rules

The Hawaii Administrative Rules (HAR) requires all pesticide applicators who will use or supervise the use of restricted use pesticides through an irrigation system to be certified.

Chapter 11-21 of the HAR sets requirements for the location of backflow prevention devices on both public water systems and irrigation systems. For irrigation systems, specific types of backflow preventers are required at specific locations in the irrigation system. Section 11-21-7 requires a reduced pressure principle backflow preventer or air gap separation before any piping network in which fertilizers, pesticides and other chemicals or toxic contaminants are injected or siphoned into the irrigation system. In addition, chapter 11-21 sets forth requirements for maintenance, prohibits bypassing, and it provides for state inspection. Chapter 11-21 also provides, however, for county ordinances to preempt state and backflow requirements in the case where the Department of Health has approved in writing, the county ordinances. (The Department of Health has approved the cross-connection and backflow prevention ordinances for all four of Hawaii’s counties.) In general, these ordinances require the placement of approved backflow prevention devices in specific locations whenever activities treat, handle, manufacture, or use any liquids, chemicals, or waste products which may be
pollutional, dangerous to health, or have a non-
portable auxiliary water supply. Further they require
approval.

As a guideline, you should use the most strin-
gent backflow prevention devices whenever there
appears to be a conflict between requirements. The
air gap is the most effective backflow prevention
device. In cases where it is not possible to use an
air gap, and approved reduced pressure principle
backflow prevention device is generally acceptable.

There must be no chance of creating a backflow
into the original water source.

National Pollutant Discharge Elimination
System

The federal Clean Water Act (see above) ex-
tends the power of the EPA to the states. It allows
states to control pollutants released into state wa-
ters by issuing permits. These permits carry the
weight of both state and federal law. In Hawaii,
NPDES permits are issued by the Clean Water
Branch, Environmental Management Division of
the Department of Health. Their purpose is to as-
sure that the state’s ambient waters (ocean, streams,
rivers, lakes, and bays) meet Hawaii’s water qual-
ity standards. The Department of Health is respon-
sible for setting all of Hawaii’s water quality stan-
dards. As a chemigator, you must answer to HDOH
Clean Water Branch if you pollute state waters.

Examples of Unsafe Practices

The following practices are unsafe and should
never be used:

- Injecting a pesticide into an irrigation system on
  the suction side of the irrigation pump.

- Directly connecting an irrigation system to a pub-
  lic water system when applying a pesticide with-
  out using a backflow prevention device. (This
  is not only unsafe; it is also illegal.)

- Chemigating without effective safety devices in
  place.

Use the equipment and techniques described
in Unit 5 (Backflow Prevention) to avoid polluting
the water source.

Integrated Pest Management
(IPM)

Integrated pest management (IPM) is an eco-
logical approach to pest control. It involves the use
of all available tactics to manage pests below an
economic threshold level. Most important, it com-
bines all of the most effective pest control strate-
gies into a unified, site-specific plan. This plan may
include cultural, mechanical, and biological con-
trôle methods as well as chemical ones. Before you
use a pesticide, always consider viable nonchemical
control options first.

Chemigation and IPM

Whether you need to control grass mites in corn
or Johnsongrass in a pasture, you must first assess
what sort of problem the pests pose. This is where
scouting comes in. Scouting is the routine, system-
atic observation of a given area to record impor-
tant information about target pests. To do this,
record the presence of the pest on a site-by-site
basis. Inventory each area several times a year if
possible. Before you herbigate, for example, you
might record these facts:

- name of the pest,
- approximate height (of weeds),
- weed density/stage of growth,
- soil conditions (ex. slope and texture),
- any noxious weeds that will need intensive con-
trol, and
- sensitive areas (ex. streams, orchards, public
roadways, and schools).

Keep this information on a scouting form.
Make a map of the area on which you record data
from each scouting trip throughout the year.
If you are chemigating, you have already decided to use chemical control to address your pest problem. It is important to realize, though, that IPM plans may include both nonchemical and chemical methods. IPM focuses on managing causes rather than simply treating symptoms. In the long run, using a variety of methods is often the best way to reduce pest numbers to an acceptable level.

Unit 2 discusses basic factors to take into account before you begin to chemigate. You will learn the benefits and drawbacks of chemigation as well as the main requirements for a successful treatment.
Unit 2. Before You Chemigate

Learning Objectives

After studying this unit, you will be able to:

• Compare the benefits and drawbacks of chemigation.
• Decide whether a given location is suitable for chemigation.
• Understand what factors govern the suitability of chemigation.
• Know what to include in an operation plan.
• Distinguish between the different types of chemigation and their target pests.

This unit discusses some basic things to consider before chemigating. First, you should decide why you need to chemigate. Then, weigh the pros and cons of this method of pest control. You also need to make sure the land selected for treatment is suitable for chemigation. Hilly, rolling land, for example, often is not a good choice. The pesticide may be distributed unevenly on slopes or hills. Many other factors such as soil type may affect whether a certain area is suitable. This unit will help you understand the various types of chemigation specific to certain pests. Once you know what pest you want to target and what sort of area it has infested, you can form an operation plan and proceed with your treatment.
Terms to Know

**Backflow**—The movement of a liquid in reverse of the normal direction of flow in a piping system. In chemigation systems, backflow can also occur in the injection line, causing the pesticide supply tank to overflow.

**Infiltration Rate**—The rate at which irrigation water moves into the soil profile. It depends on soil structure, soil type, compaction, and other factors.

**Backsiphonage**—A vacuum caused by reduced pressure in a supply line of a piping system. This vacuum is one cause of backflow.

**Compaction**—A condition in which soil particles are packed too closely together. This can result from compression by heavy machinery, excessive soil tillage, dispersion of soil structure during wetting, and other factors. Compaction prevents water and pesticides from penetrating into the plant root zone.

**Drift**—The movement of a pesticide through the air as particles or vapors to nontarget areas.

**Fungicide**—A chemical that kills or otherwise inhibits fungi that cause disease in plants.

**Herbicide**—A chemical compound that kills or alters the growth and development of plants.

**Insecticide**—A pesticide used to control insect pests.

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

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

**Nematicide**—A chemical used to control nematodes.

**Overspray**—A spray application that overshoots the target area into a nontarget area.

**Postemergent Herbicide**—A pesticide applied after planting the crop but before the crop emerges. It kills weed seedlings that appear ahead of the crop.

**Preemergent Herbicide**—A pesticide applied before weed seeds germinate and begin to grow.

**Prescription Application**—An application made using the least amount of pesticide and water needed to incorporate the pesticide into the soil.

**Runoff**—Movement of water, possibly containing pesticides, away from the release site flowing across the soil surface or as subsurface drainage. Runoff liquid is neither intercepted by the crop canopy nor infiltrated into the soil.

**Traveling Gun**—A large, single-impact sprinkler that moves across the field on a wheeled cart connected by a hose to a reel. As the hose is reeled in, a swath is irrigated.

**Uniformity Coefficient (UC)**—A way to calculate the uniformity of an irrigation system, where 100 is “perfect uniformity.”
Why Chemigate?

When you chemigate, you have three main goals:

1. Apply the right amount of pesticide effectively and uniformly to the target area to control the target pest.
2. Protect the water supply from pollution.
3. Minimize human exposure to pesticides.

There are both benefits and drawbacks to chemigation. Weigh them carefully before you begin your treatment.

Advantages of Chemigation

There are many benefits in using an irrigation system to apply pesticide. These include:

- Effectiveness—Several years of field research and trials have proven the effectiveness of chemigation. These trials have tested many chemicals on a broad range of crops. The newer center pivots and other equipment allow you to apply exact amounts of foliar chemical with less water for best results.
- Application uniformity—You may achieve a more uniform application of pesticide than with other methods. This is especially true of center pivots with the new sprinkler devices.
- Prescription applications—You can use just the amount of water needed to move the pesticide to the desired soil depth. This helps to reduce the use of excess chemicals and water.
- Timing—Often, you can chemigate under a broad range of weather conditions. This gives you a wider window of opportunity in which to do the pesticide application.
- Activation of pesticide—Many pesticides (especially some herbicides) work only in moist soil. Even a light irrigation will activate these chemicals.
- Reduced soil compaction—Tractors and other heavy equipment used in conventional pesticide application can cause soil compaction. Chemigation greatly reduces compaction by reducing field traffic. A center pivot system, for example, causes compaction only in the tower wheel tracks.
- Reduced crop damage—Irrigation systems generally cause much less crop damage than tractors and regular sprayers. Most crop damage from chemigation systems comes from tower wheel tracks of a center pivot.
- Reduced hazard to applicator/operator—Unlike with other pesticide application methods, chemigators do not need to “ride the system.” Their main role is to calibrate the equipment and check at intervals to make sure everything is running smoothly. Also, chemigation often requires less mixing and loading than other methods.

   NOTE: Check the pesticide label for instructions on how often you must monitor the system during the treatment.
- Reduced environmental hazards—Chemigation, if done properly, may be less harmful to the environment than regular pesticide application. First, the chemicals are much more dilute in the irrigation water: 1/100 to 1/1,000 as much. Also, wind drift may be less of a problem. The pesticide travels in larger water droplets than in other methods, reducing the chance of drift.
- Reduced cost—When you compare the cost of chemigation to the cost of regular ground or aerial application of pesticides, you must weigh several factors. Although the initial cost of chemigation equipment may be high, in the end it may be cheaper than other methods. This is especially true if you apply the same chemical more than once.

Disadvantages of Chemigation

Unfortunately, there are some drawbacks to chemigation. These include:

- High cost of equipment—Besides an irrigation system, you will need special equipment to inject pesticides into the irrigation water. You will also need to install safety equipment to protect the water source from pollution. There may be...
other costs if you need to modify your equipment (ex. converting from a highpressure to a low-pressure system).

• Increased environmental hazards—By definition, a chemigation system connects to a water supply. Therefore, it may cause water pollution unless you install a backflow prevention device. There is also a risk of runoff because of the relatively large amounts of water needed to irrigate. In addition, overspray and wind drift may be a problem if you are using end guns on center pivot systems. Many people consider chemigation a greater risk to the environment for two reasons:
  - the volume of the product, and
  - the complexity of the injection equipment.

• Hazards to applicator/operator—Although pesticides used in chemigation are greatly diluted, the application rate remains the same. There is a risk of an inhalation hazard and dermal exposure for chemigators.

• Increased application time—It may take hours longer to chemigate a field than it would to treat it by conventional means, either on the ground or from the air. This could mean a greater chance of facing bad weather—such as high wind and freezing temperatures—while chemigating.

• Unnecessary water application—At times, you may want to apply a pesticide without adding more water to the field, crop, or turf. This is especially true early in the growing season and during rainy periods. You can reduce overwatering by using the lowest water application rate. You could also use a high-speed sprinkler system.

• Management concerns—Chemigation demands a high degree of training and skill in handling chemicals and in setting up and calibrating equipment. Calibration may be more complex than for other application methods. Also, as an applicator, you must understand the irrigation system and the required safety equipment. Finally, your equipment might malfunction while it is unattended. This could cause a misapplication of the chemical, resulting in an environmental hazard or human exposure.

• High cost of chemicals—The choice of pesticides may be limited for chemigation. A lower-cost pesticide, for example, may be labeled only for other application methods.

**Considerations before Chemigating**

There are many factors to take into account before you chemigate. These include:

• pesticide label requirements;
• water supply;
• location;
• soil type;
• topography;
• irrigation system features;
• irrigation system uniformity;
• drift, overspray, and runoff potential; and
• economic/management issues.

**Pesticide Label Requirements**

Your FIRST step before chemigating is to check the pesticide label. You can apply a pesticide through an irrigation system only if the label states that you may do so - and through what kind of system. In other words, the pesticide must be labeled for application in water through an irrigation system. The label will also tell you in what areas, such as greenhouses and turf farms, you may chemigate. See Unit 1 (Introduction) for a more detailed discussion of label requirements and related laws.

**Water Supply**

No chemigation system can draw water from any water supply unless that supply is protected from contamination. You must either:

• use a reduced pressure principle backflow prevention device or
• create a vertical air gap between the water supply and the irrigation system.

Safety devices are discussed in more detail in Unit 5 (Backflow Prevention).

Location of Treatment Area

How close is your irrigation system, pesticide storage and mixing areas to occupied buildings, neighboring crops, lakes and ponds, roadways, and public water supplies? The farther away you are from all nontarget areas, the better. Be especially careful with surface-water bodies. Rivers, streams, ponds, lakes, and drainage channels are at particular risk. Also consider wellheads and other groundwater sources. You must not endanger people, wild or domestic animals, or any sensitive areas when you chemigate. Federal court decisions and pesticide labels may require buffer zones between a target site and surrounding area. (A major pesticide contamination of groundwater occurred in Hawaii when a pesticide storage site was located uphill from a drinking water well. A spill allowed the pesticide to flow to the well and seep down the well into the groundwater.)

Soil Type

You may have several different soil types in your field. It is important to know your soil types because the rate at which water and chemicals enter the soil often differs with soil type. This is called the infiltration rate. Coarse-textured sandy soils can have high infiltration rates. This means that runoff is less of a problem in this type of soil than in fine-textured clayey soils. However, if you apply too much water to sandy soil, the pesticide may leach below the crop root zone. For clayey soils, the reverse is true. The risk of leaching (deep percolation) is lower, but the risk of runoff is higher. (This assumes that other factors such as slope, surface roughness, and compaction are equal.)

Topography

The topography, or the type of terrain, affects how well your irrigation system will disperse chemicals and water. Important variables are slope and landforms. On hilly, rolling terrain, the pesticide may be distributed unevenly. If the terrain varies along the length of the system, the pressure will vary. This may also cause uneven dispersal of the pesticide. To correct this problem, use pressure regulators or “dammerdikers” on each sprinkler device. Otherwise, your irrigation system may not work for chemigation.

Features of the Irrigation System

Irrigation systems differ in many ways. Choose a system based on the type of chemigation you need to do. For foliar application, you will need a sprinkler system. For soil applications, you can use any type of irrigation system. Also, make sure your system:

• has the right injection equipment,
• has effective safety devices,
• is properly designed, and
• is well maintained.

The entire system should be in good working order.

Distribution Uniformity of the Irrigation System

“Perfect uniformity” is the goal of every irrigator. It means that each point along the distribution lateral receives the same amount of water. Poor uniformity causes uneven application. Some areas may receive too much water while other areas receive too little.

The type of irrigation system you have often determines how evenly it will apply water and pesticide to the target area. Center pivot systems, for example, usually give uniform applications. Traveling gun systems, in contrast, often do not. You need to ensure some degree of uniformity before you can use your irrigation system for chemigation.

One of the most important factors affecting uniformity is pressure. Closely linked to this is system configuration or design. Well-designed low-pressure systems (35 to 50 psi or less at the
pivot point) can give excellent uniformity. They are also less prone to drift. There must be adequate overlap in the wetting pattern for the given sprinkler height and nozzle pressure. High-pressure systems (80 to 85 psi or greater at the pivot point) often give good uniformity, also. But applications made with high-pressure systems are more prone to drift.

Your irrigation equipment dealer can instruct you on how to measure the uniformity coefficient (UC) of your system. It applies mostly to sprinkler systems. In theory, the UC of a “perfectly” uniform application is 100. If the UC of your system is less than 85, you may want to adjust it to a higher level.

Potential for Drift, Overspray, and Runoff

Drift, overspray, and runoff are the main causes of loss from chemical applications. They can also lead to pollution, human exposure, and even lawsuits. Assess these conditions before chemigating:

- environmental and human safety concerns,
- weather (especially wind),
- type of sprinklers or emitters,
- system pressure,
- soil type,
- topography, and
- type and formulation of chemical(s).

If weather or other conditions worsen during your application, shut down your system until things improve.

Economics and Management

Compare the cost of chemigation to that of other application methods. As discussed above, you may find that over time, chemigation is less costly than conventional methods.

We have already seen that chemigation demands a high degree of skill, training, and management ability. If you decide to chemigate, make sure you or another responsible person is qualified to run a chemigation system safely and effectively. For more information on management, see Unit 4 (Application Systems and Equipment).

Operation Plan

After weighing all of the above factors, you have decided to chemigate. Now, you should prepare a written observation and operation plan. Include the following:

- A list or drawing of sensitive areas that may be subject to drift, overspray, or runoff. These may include—but are not limited to—wetlands, hospitals, schoolyards, parks, and public roads.
- A description of the methods you will use to prevent drift, overspray, and runoff. This includes monitoring wind speed and disabling end guns or sprinkler heads.
- A description of backflow prevention equipment or other devices to prevent backflow and backsiphonage.
- A description of how you will calibrate your system and recalibrate, if necessary.
- A description of how you plan to monitor your system to make sure that it is working properly.
- A statement that gives the flush time (fill time) for the chemigation system.
- A description of the required safety procedures for anyone who enters the treated area. This includes use of personal protective equipment (PPE), worker notification, and restricted-entry intervals (REIs).
- A description of emergency response procedures.

Follow this plan whenever you chemigate. Keep one copy of the plan with you at the site and another copy at your home or office.

Target Applications

Chemigation can be broken down into different types depending on your target pest(s). These include the application of

- fungicides,
- insecticides,
- herbicides, and
- nematicides.
Fungicides

Many farmers apply fungicides through an irrigation system to control fungal diseases. You can apply the chemical(s) either to the foliage (leaves) or to the soil. To treat foliage, use one of these sprinkler systems:

- center pivot,
- side-roll lateral, or
- hand-move lateral.

Traveling guns are less effective because they often give less uniform coverage.

A crucial factor to consider is the formulation of the fungicide. Be wary of copper-based fungicides. They can corrode aluminum pipes very quickly. For a foliar application, use a product that will not easily wash off. For a soil application, pick a formulation that will remain in the soil root zone. This type of chemigation works because you apply the fungicide when the leaf is wettest. This is also when the fungus is most active.

Insecticides

You may want to apply insecticides through an irrigation system to control insect pests. This seems to work best with center pivot systems. Here, too, it is important to choose the insecticide based on its formulation. For foliar application, the formulations best suited for chemigation are those that will adhere to plant tissues and are not highly water soluble. Choose products formulated to stick to the leaves of the plants sprayed. Certain adjuvants (ex. stickers or spreaders) will also help you achieve this result.

Herbicides

You can also apply herbicides through an irrigation system to control pest plants. This works especially well with center pivot systems. You can apply both preemergent and postemergent herbicides in this manner. You can also use preplant herbicides.

There are several important rules to follow when you apply herbicides through your irrigation system:

- Apply preemergent herbicides with enough water to distribute them in the top 2-1/2 inches of soil. The exact amount of water depends on:
  - soil type,
  - the amount of water in the soil when chemigation begins, and
  - the solubility of the product.
- Apply herbicides within five days after the last tillage. Otherwise, some weed seeds may have already started to germinate.
- Inject the herbicides continuously while irrigating or at the beginning of the irrigation set. Do not wait to apply the product at the end of the set.
  Some postemergent herbicides need only a small amount of water (1/2 inch or less). Too much water will cause the product to be washed off the leaf surface. The label will tell you how much water to use.

Nematicides

Applying nematicides through an irrigation system is an effective way to control nematodes. Some soil fumigants labeled for chemigation are particularly effective. They may be applied through sprinkler and drip/trickle irrigation systems. The product label will tell you how and where you may apply the pesticide.

If the label permits, you may apply these chemicals through the drench method using sprinklers or emitters.

Unit 3 explores the safety requirements for successful chemigation. You will learn how to protect the environment, workers, and yourself when you apply pesticides through an irrigation system.
Unit 3. Safety Considerations

Learning Objectives

After studying this unit, you will be able to:

• Lessen the environmental risks of chemigation.
• Understand how to avoid pollution by tailwater control and other methods.
• Protect farm workers from pesticide exposure in a chemigated area.
• Protect yourself and your coworkers from pesticide exposure while chemigating.

This unit discusses safety practices that are specific to pesticide chemigation. By reading it, you will learn how to lessen environmental threats such as drift, overspray, runoff, and deep percolation (leaching). This unit does not discuss backflow prevention and antipollution equipment. See Unit 5 (Backflow Prevention) for detailed information on those topics.

After studying this unit, you will understand the importance of field posting to keep farm workers out of recently chemigated areas. You will learn when to use protective clothing and equipment and how to report spills and other accidents. Finally, this unit describes the basics of personal safety while chemigating.

The core manual, Applying Pesticides Correctly: Guide for Private and Commercial Applicators, is a comprehensive guide to basic pesticide safety. It discusses safety issues for all applicators. See the Core Manual for more pesticide safety information.
Terms to Know

Deep Percolation—Movement of pesticide in water downward and radially through the soil profile below the target application depth. The pesticide mixture usually continues downward below the crop rooting zone to the groundwater. Also called “leaching.”

Degradation—The breakdown of a pesticide or other substance.

Diluent—Anything (usually water) used to dilute a pesticide.

Drift—The movement of a pesticide through the air as particles or vapors to nontarget areas.

End Gun—A large, high-pressure sprinkler located at the terminal of a pivot sprinkling system. It is used to extend the irrigated acreage into the corner of a field.

Furrow Damming (Dammer-Diking)—A technique to build up small earthen dams or dikes with a tillage tool. These dams, located in furrows, help reduce runoff in fields.

Overspray—A spray application that overshoots the target area into a nontarget area.

Pitting—A technique of punching holes in the soil from 6 to 10 inches in diameter and from 6 to 8 inches deep. These holes, spaced about 2 feet apart on center, help reduce runoff on steep slopes.

Restricted-Entry Interval (REI)—The length of time specified on the pesticide label between the time of the pesticide application and the time it is safe for a person to enter the treated area without label-required personal protective equipment (PPE) and/or appropriate training and certification.

Rinsate—Pesticide-containing water that results from rinsing a pesticide container, pesticide equipment, or other pesticide-containing articles.

Runoff—Movement of water, possibly containing pesticides, away from the release site flowing across the soil surface or as subsurface drainage. Runoff liquid is neither intercepted by the crop canopy nor infiltrated into the soil.

Tailwater—Water delivered to but not absorbed by a field. This excess water is often stored in a pond or redirected to another field. It is often associated with surface or flood/furrow irrigation systems.

Safety is the main concern when you apply any pesticide. Whether you use a boom sprayer, a fixed-wing aircraft, or an irrigation system, make sure that the pesticides you release attack only the target pest(s). The pesticides should not harm nontarget areas, farm workers, or your application team.
Protecting the Environment

“Environment” is another word for “nontarget areas.” When you chemigate, do your best to protect the surrounding areas from contamination caused by leaks, spills, drift, overspray, runoff, and deep percolation. Be especially sensitive to surface water nearby such as lakes and streams. If you use a center pivot system with an end gun, monitor it closely to make sure the gun does not overshoot the site. Its output should also not exceed the infiltration rate of the soil. Collect all tailwater within a storage tank or pit. Dispose of empty pesticide containers as directed on the product label. Finally, be sure you know what to do in case of a spill.

Drift

When water and pesticide are released from a sprinkler nozzle, part of the spray may evaporate. It is therefore not deposited in the target area. Spray droplets or vapors may drift in the wind out of the target area and end up on nontarget plants or soil. This nontarget application, or drift, can have the following results:

- Misapplication of a pesticide,
- illegal pesticide residues in or on a crop,
- water pollution and health hazards, and
- crop damage (ex. stunted growth) resulting in yield loss.

These actions are against the law. They can also damage your crops or a neighbor’s.

Furthermore, drift can pollute water, harm people, and injure plants.

Drift is sometimes a problem with center pivot sprinkler systems. The center pivot may dispense the spray mix at a greater height than regular ground equipment. This increases the chance of drift. Some of the newer center pivot systems have sprinkler devices placed on drop tubes. This lowers the height at which the spray mix is discharged. However, the lower sprinkler height also yields a smaller wetting pattern. Therefore, you may need more sprinkler devices to ensure good uniformity.

In general, spray nozzles or sprinkler devices with smaller droplet sizes are more likely to produce drift than those with larger droplets.

Take these steps to minimize wind drift:

- Cancel or postpone your pesticide application if winds are stronger than 10 to 15 mph. This is often a label requirement. At this point, the wind is likely to cause spray particles to drift off-target. As an applicator, you are responsible for monitoring the weather while chemigating, as directed by the label.
- Use drop nozzles on the spray boom to reduce the distance between the nozzle and the target.
- Increase the orifice (opening) size of your nozzles.
- Convert the irrigation system from high pressure to low pressure.
- Retrofit impact sprinklers with spray nozzles or devices.
- If practical, apply chemicals at night when the winds are often calmer.
- Regularly monitor your application.

Overspray

Overspray occurs when application equipment—especially end guns overshoots the target area. If you are chemigating an irregularly shaped area, turn off the end gun on your center pivot system. This will lessen the chance that you will overshoot into a nontarget area.

End Guns

End guns are a popular choice for many center pivot systems. They can add more than 5% to the irrigated area of the center pivot. However, end guns often have a high drift potential and poor distribution uniformity. They also contribute to surface runoff and overspray onto nontarget areas.

Some end guns operate continuously according to field size and layout. These cause the least problem. However, most end guns work on only part of the circle. Your application will be most uniform if you leave the end gun either on or off.
during the entire job—unless doing so will result in an offtarget application. Otherwise, unless you have a variable-rate injection pump, you must recalibrate the injection system. This will allow for changes in water flow.

End-gun shutoffs that fail are frequently the cause of off-target applications. If you use an end gun, carefully check the uniformity of your application throughout. In addition, make sure environmental conditions are favorable.

Corner Systems

Corner systems can include hand lines or set lines. Chemicals are injected through a separate pump (usually gas powered) at the corner of the field.

A corner system on a center pivot causes a difference in application rate. This happens because of variations in flow rate. The main system slows down as the corner arm extends and speeds up as the corner arm retracts. Intermittent use of a corner system also disturbs the pressure pattern in the rest of the system. This can reduce uniformity, requiring you to recalibrate your equipment. You can use variable-rate injection pumps to compensate for changes in water flow. As with end guns, if you use a corner system, carefully check your application for uniformity.

Surface Runoff

Runoff will occur whenever your irrigation system applies water faster than it can infiltrate into the soil. Many factors help determine when runoff will occur:

- application rate,
- soil infiltration (intake) rate,
- topography of the field (inclination, slope length, and aspect),
- roughness of the soil surface,
- crop canopy, and
- amount and orientation of plant residue.

Runoff water can carry chemicals out of the field and harm nearby plants and animals. The tainted water may also flow into rivers and lakes.

There is much you can do to prevent or lessen surface runoff of the water-pesticide mixture. First, assess the design of your irrigation system.

Center Pivot Design

The design of a center pivot system greatly affects the chance of runoff. Some center pivot systems are more likely than others to produce runoff. Sprinkler systems differ according to

- pump pressure,
- water flow, and
- crop need.

Nozzle type (impact sprinklers vs. spray nozzles) and configuration (spacing on the lateral) are very important. A center pivot covers more acres in the outer spans than it does in the inner spans. This means that the density and/or size of nozzles needs to increase as you move along the center pivot lateral. In general, uniform nozzle spacing between outlets (with variable discharge rates) is most often used.

In many cases, you can reduce the risk of runoff by using spray nozzles and by dropping your release height.

Tillage Practices

Tillage practices can greatly reduce the chance of runoff in your fields. For example, it helps to increase the water infiltration rates of the soil. Surface treatments, such as furrow damming (dammer-diking) and pitting in crop rows, help control runoff. They do this by preventing water from flowing out of the treated area. Furrow damming involves using a tillage tool that scrapes and carries loose soil down the furrow. This tool trips at preset intervals. The effect is to build up small earthen dams or dikes. Pitting involves punching holes into the soil. These holes are 6 to 10 inches in diameter, 6 to 8 inches deep, and about 2 feet apart on center. This technique greatly reduces runoff on steep slopes.
Another tip is to chemigate at a different time than you irrigate. This allows you to apply considerably less water and reduces the chance of runoff. Sometimes, using less water produces a more effective pesticide application. Using more water may actually reduce the effectiveness of the application. This is due to excessive soil percolation.

**Buffer Zones**

You can plant field borders to act as buffer strips. These borders contain vegetation that slows runoff and traps sediments. They also allow contaminants more time to be degraded by bacteria and sunlight.

**Tailwater Control**

Tailwater, often associated with flood/ furrow irrigation systems, is a type of surface runoff. It is water delivered to but not absorbed by a field. This excess water is often stored in a pond or redirected to another field. The size of the storage area depends on two factors:

- the rate and amount of runoff, and
- the rate and timing of reuse pumping.

You need only a small storage area if the reuse is almost immediate and is at a rate equal to runoff. A large storage area gives you more flexibility in managing tailwater. However, it also increases the risk of pollution. For larger tailwater storage areas, you will need a pump. The pump will help ensure the speedy return of runoff from the sump. You may have a delay in returning the runoff. In this case, the storage area can contain the polluted water until it is pumped out.

Runoff containing pesticides is dangerous. For automated pumping, you will need electrical service and permanently installed pipes. If you must channel tailwater back into a sprinkler system, follow these steps:

1. Make sure the pressure is greater than the normal irrigation line pressure. Or, create a low-pressure zone to allow tailwater into the pipe.
2. Use an interlock to prevent pumping tailwater into the system in case the irrigation system shuts down.

**NOTE:** If you have surface runoff problems with your irrigation system, do not chemigate with pesticides.

For help in designing a tailwater return system, contact the Natural Resources Conservation Service (part of the U.S. Department of Agriculture) or consult an irrigation specialist or a university expert.

**Deep Percolation**

Deep percolation can occur if too much water is applied to the soil. This is especially true with coarse-textured sandy soils. Deep percolation causes irrigation water, pesticides, and plant nutrient chemicals to leach below the crop root zone. They therefore have little effect on the crop or target pest. (In Hawaii some groundwater sources are contaminated with pesticides or nitrates which have leached from agricultural activities.) When the pesticide moves below the effective root zone, it may contaminate groundwater. You can control or prevent leaching in three ways:

- increase the travel speed of your system,
- use the least amount of water you need to distribute the pesticide, and
- ensure high distribution uniformity.

In addition, manage your irrigation system to allow for rainfall.

**Surface Water**

To protect groundwater as well as nontarget plants and animals, do not chemigate fields with exposed surface-water areas such as ponds or creeks.

You must also be careful that you do not overspray surface water near these fields. Avoid fields with connections to groundwater (ex. abandoned wells and subsurface drains). Check the pesticide label for any restrictions near surface water. In case of a spill, do not allow the chemical to flow into any surface water source. As discussed in Unit...
2 (Before You Chemigate), you should always assess the target area for its closeness to sensitive areas before you begin your treatment.

**Container Disposal**

Dispose of pesticide containers in accordance with label directions and with federal, state, tribal, and local laws and regulations. Usually, triple rinsing is adequate. A container must be triple rinsed to avoid being considered hazardous waste. Follow these steps:

1. Flush the container three times. Use a volume of diluent at least equal to 20% of the capacity of the container.
2. Use the rinsate as a diluent for the same pesticide.
3. Keep triple-rinsed containers in a locked and posted place until you send them to an approved landfill or recycling center. Crush or puncture triple-rinsed containers that you cannot return or recycle.
4. Dispose of all containers promptly to avoid unsightly buildup and health hazards.

**Spills**

If someone spills a pesticide during an application, you should do four things first, regardless of the size of the spill:

1. Avoid physical contact with the pesticide.
2. Keep people away from the spilled chemical and secure the area.
3. Control the spill and stop it at the source.
4. Confine the spill as much as possible.

Refer to the pesticide label for instructions about spill cleanup.

In addition, the core manual, Unit 12 (Transportation, Storage, Disposal, and Spill Cleanup), has detailed information on managing spills and how to report them.

**Minor Spills**

A minor spill usually involves smaller amounts of pesticide. However, even a minor spill demands special treatment if the chemical spilled may enter surface water or groundwater.

Make sure you do not get any pesticide on your skin, clothing, or shoes. Secure the area and warn people to keep out. Stop the spill and confine it as much as possible. If it starts to spread, dike it with an absorbent material such as soil, sawdust, or cat litter. If necessary, remove the contaminated soil to prevent pollution of groundwater. Take care not to disturb the gravel pack around irrigation wells when removing tainted soil.

Remember not to hose down the spill area because this will spread the chemical or cause it to leach. Do not leave the area until the spill is cleaned up or help arrives. Work carefully and do not rush.

**Major Spills**

The same basic steps apply for a major pesticide spill. Keep the pesticide off your skin and clothes and give first aid as necessary. Keep people out of the area, stop the spill at its source, and confine it as much as you can. For a major spill, however, you must notify certain state and local authorities. Notification is required by the Hawaii Emergency Planning and Community Right-to-Know Act (HEPCRA) for spills or leaks (“releases”) of certain quantities where the chemical could cause pollution or direct harm to people or wildlife.

**Pesticide Outcome**

What becomes of a pesticide after it is applied? Where will it go, how will it change, and in what form will it finally end up? Of course, the ideal outcome is absorption by the target pest(s). Plants, for example, take up herbicides with their leaves, stems, flowers, and roots.

However, plants and other organisms do not intercept all of the pesticide applied to the target site. Some of it degrades, or breaks down. The deg-
radation of pesticides is the beneficial process that removes pesticide residues from the environment. The two major types are:

- microbial degradation and
- photodegradation.

Microorganisms in the soil such as fungi and bacteria degrade pesticides. Over time, these organisms break down the chemicals. Microbial degradation works best when the soil is warm, moist, aerated, and fertile. In photodegradation, sunlight gradually breaks down the pesticide.

When a pesticide degrades, it changes chemically. It usually—but not always quickly—breaks down into nontoxic compounds. All pesticides degrade, although some may remain in the environment for many years.

Protecting Workers: The Worker Protection Standard

The main way in which you can protect farm workers and others nearby is to post the chemigated area. Posting warns others that pesticides have been applied through an irrigation system. As a certified chemigator in Hawaii, you are required to know the posting requirements of any pesticides you apply through an irrigation system. The label will tell you whether posting is required. Posting is designed to discourage unauthorized entry into treated areas by workers or the public.

Restricted-Entry intervals for the Treated Area

In general, no one should reenter pesticide-chemigated fields until no inhalation and/or dermal exposure risk exists. The Worker Protection Standard (WPS) requires growers who employ agricultural workers and pesticide handlers to take steps to protect them from exposure to pesticides. All workers must observe the restricted-entry intervals (REIs) given on the label. For more information about WPS, see the Core Manual, Unit 7 (Harmful Effects and Emergency Response).

For Toxicity Category 1 products (those with the signal word “Danger”) that may be applied by chemigation, the EPA requires this statement to appear on the label:

“Posting of areas to be chemigated is required when 1) any part of a treated area is within 300 feet of sensitive areas such as residential areas, labor camps, businesses, daycare centers, hospitals, inpatient clinics, nursing homes, or public facilities not including public roads, or 2) when the chemigated area is open to the public, such as golf courses or retail greenhouses.”

If you need to reenter the treated area before the end of the waiting period as given on the label, you must use the personal protective equipment (PPE) specified on the label. You should also be either a licensed applicator or a trained worker or handler.

Chemigation Posting

The pesticide label will spell out where to post treated areas, when to post, and for how long. It may require you to list the time and date of application and how to contact the applicator. In addition, it will give specific directions on the size and appearance of the sign. Post at least one sign at each site for which posting is required. A chemigation warning sign should include the words “Keep Out” at the top. At the bottom, the words “Pesticides Being Applied in Irrigation Water” should appear underneath a stop sign.

If you are chemigating with a fumigant, you must notify workers by posting signs that contain the following information:

- Danger/Peligro.
- Area under Fumigation: Do Not Enter/No Entre.
- Name of fumigant/Soil Fumigant in Use.
- Date and time of fumigation.
- Name, address, and telephone number of applicator.

This information appears in the Agricultural Use box on the product label.
Other Concerns

Posting required for chemigation does not replace other posting and REI requirements for farmworker safety. Be sure to observe legal application days before harvest (preharvest interval). Failure to properly post a chemigated field could result in prosecution. Check with the Hawaii Department of Agriculture, Pesticide Branch, to be sure that you are complying with state laws.

Protecting the Applicator

As discussed in Unit 2 (Before You Chemigate), chemigation may pose fewer risks to the applicator than other methods. Still, pesticides can endanger human health and environmental quality. The following is a brief discussion of applicator safety when using pesticides.

For more information, consult the Core Manual, which addresses personal safety throughout. In particular, Unit 7 (Harmful Effects and Emergency Response) and Unit 8 (Personal Protective Equipment) cover human health and safety issues. Refer to these units for detailed information on pesticide injury, response to a poisoning emergency, first aid, and protective clothing. Unit 8 also has guidelines on how to clean and maintain your PPE.

Health Effects

People can be exposed to pesticides in two major ways: acute exposure and chronic exposure.

Acute exposure is a single mishap with a pesticide, such as splashing the pesticide concentrate into your mouth or eyes during mixing. It can include spilling or spraying a pesticide onto your clothing, face, or body. Usually, symptoms begin quickly (within 24 hours).

Chronic exposure is repeated contact with low levels of pesticides over a long period (usually several years). Delayed health problems may follow. Exposure usually results from inadequate protective clothing or equipment. Causes include re-wearing tainted clothes, not bathing, or working in a contaminated area without the proper PPE.

LD50

The term “LD 50” expresses the level of toxicity of a chemical. “LD” means lethal dose. LD 50 is the dose, based on weight, that will kill 50% of a population of test animals. The higher the LD50 value, the less acutely toxic the chemical. This value is usually expressed as milligrams/kilogram of body weight. A chemical with an LD 50 of 5,000 mg/kg requires about 0.1 ounce of the chemical per pound of body weight to reach the LD 50 value. For a 150-pound person, this would be about 15 ounces.

The labels on pesticide products have “signal words” to convey the degree of toxicity of the product. Signal words also may tell you whether the product is caustic (burns) or is an environmental hazard. They are as follows:

- CAUTION: Slightly toxic.
- WARNING: Moderately toxic.
- DANGER: Highly toxic or hazardous in some manner. The labels of these pesticides carry the skull and crossbones symbol.

Acute oral exposure refers to a single dose taken by mouth (ingested). Acute dermal exposure means a single dose touching the skin or eyes (skin absorption). Acute inhalation exposure is an intake of a breath of contaminated air. This type of exposure may pose a significant risk to chemigators, especially when using soil fumigants.

Cautions and Common Sense

Some pesticides have such low toxicity that it takes a large (or long) exposure to cause illness, if at all. However, some people are more sensitive than others to certain chemicals. Even low-toxicity chemicals can irritate the nose, throat, eyes, and skin of some people. Know how to protect yourself and everyone around you from exposure to all pesticides.
Route of Entry

Pesticide product labels include “route of entry” statements. These explain how the chemical(s) may enter your body. The label will also explain how to avoid pesticide exposure and what parts of the body are most at risk. For example, a route of entry statement might read, “Poisonous if swallowed, inhaled, or absorbed through the skin. Rapidly absorbed through the skin and eyes.” This tells you that the pesticide can enter your body orally, dermally, and by inhalation. It also tells you that your skin and eyes are especially at risk.

Regardless of their toxicity, use pesticides carefully. Before you buy, handle, mix, or apply any pesticide, read the label carefully. If the label tells you to use protective clothing or equipment, then do so. As a pesticide applicator, the law requires you to obtain and use the safety equipment listed on the label.

Personal Protective Equipment

The pesticide label will specify what protective clothing you need. At the minimum, follow these guidelines:

- Wear a long-sleeved shirt and long-legged trousers. Or, you can wear coveralls that fully cover your arms and legs.

- Wear shoes and socks. Avoid sandals, thongs, and cloth or canvas shoes. When working with highly toxic pesticides, wear chemical-resistant boots. Leather footwear is a poor choice since leather readily absorbs liquids. If contaminated, leather shoes and boots should be discarded.

- Wear a hat with a wide brim that is easy to clean. This will keep pesticides away from your neck, eyes, mouth, and face. Avoid hats with cloth or leather sweatbands because these will absorb pesticides.

- Wear goggles or a face shield. Goggles will help protect your eyes, but a face shield is recommended.

- Wear gloves when handling pesticides. Choose unlined, chemical-resistant (ex. neoprene or nitrile) gloves that extend well up the forearm.

In most cases, wear the gloves under your shirtsleeves to keep pesticide from leaking into the glove. Avoid handling pesticides above your shoulders.

In the next unit, you will learn about the basic types of irrigation systems and equipment used for chemigation.
Unit 4. Application Systems and Equipment

Learning Objectives

After studying this unit, you will be able to:

• Compare and contrast the three main types of irrigation systems.
• Decide which type of irrigation system is best for your needs.
• Name and describe the different types of equipment needed for chemigation.
• Know what antipollution devices are required for chemigation.
• Understand the basic management principles necessary for successful chemigation.

The heart of any chemigation operation is its equipment. For a successful chemigation, you must first choose which irrigation system is best for your needs: sprinkler, drip/trickle, or surface/gravity flow. You must then have the system properly designed and installed. This unit will discuss the three main types of irrigation systems. It will also describe the different types of sprinkler systems.

You will learn important details about the equipment that makes up a chemigation system. This includes tanks, pumps, calibration tubes, and antipollution devices. Just as important, this unit will teach you some vital do's and don'ts for successful chemigation. These management tips will help you prevent problems and avoid common pitfalls.
Terms to Know

Agitation—The process of stirring or mixing. Some pesticide formulations (such as wettable powders) require constant agitation to be effective and to ensure even distribution.

Dilution Ratio—A specified proportion of pesticide to water (ex. 1:100).

Drip/Trickle Irrigation (Microirrigation)
- An irrigation method in which water is applied through drip emitters with very low flow rates using flexible hose or tape.

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

Flood Irrigation—A surface irrigation method in which water is applied to the soil without flow controls such as furrows or borders.

Furrow Irrigation—A surface irrigation method in which water flows through small ditches or furrows that guide the water across the field.

Precipitate—An insoluble solid substance, or deposit, that forms on water-emitting devices.

Proportional Rate Injection System Device that delivers pesticide into the waterline in a way that maintains a constant proportion of pesticide to the water flow rate.

Sprinkler Irrigation—An irrigation method in which water is sprayed or sprinkled through the air to the ground.

Surface/Gravity-Flow Irrigation Irrigation methods consisting of flood and furrow techniques.

Traveling Gun—A large, single-impact sprinkler that moves across the field on a wheeled cart connected by a hose to a reel. As the hose is reeled in, a swath is irrigated.

Venturi—An injector device that operates on a pressure differential between the inlet and outlet of the injector. It creates a vacuum, which results in suction or a “venturi” effect.
The three basic types of irrigation systems are:

- sprinkler,
- drip/trickle (microirrigation), and
- surface/gravity flow.

Sprinkler systems are often used for irrigation, and some are well suited for chemigation. Many drip systems are also effective in applying fertilizers and pesticides. Surface/gravity-flow irrigation methods are not commonly used in Virginia and are less appropriate for chemigation.

**Sprinkler Systems**

There are many types of sprinkler systems used for chemigation. These include:

- center pivot,
- self-propelled linear or lateral move,
- solid set,
- hand-move lateral,
- side-roll lateral, and
- towline lateral.

The traveling (big) gun is not suitable for chemigation and is mainly used for pasture irrigation.

Of these sprinkler systems, the center pivot and self-propelled linear move systems are best suited for chemigation. This is because they tend to give a more uniform application. Linear systems provide the most consistent application.

**Center Pivot**

Center pivot sprinkler systems are very popular for chemigation. Well-designed and operated center pivots give good uniformity in water and chemical application. The key to good uniformity is to select the right sprinkler package for your field and configure the equipment with care to limit drift and runoff.

One way to control runoff is to apply the minimum amount of irrigation water when your system is running at its maximum speed. A practical minimum application rate for a typical center pivot system is about 0.1 inch. This works out to about 2,700 gallons per acre. See Unit 3 (Safety Considerations) for more information about controlling surface runoff with center pivot sprinklers.

As discussed in Unit 3 (Safety Considerations), end guns and corner systems are often used with center pivot irrigation systems. Using either system, however, can lead to problems with uniform application. This lack of uniformity is due to variations in system pressure and distribution pattern. In general, the use of end guns and corner systems during chemigation is NOT recommended.

**Self-Propelled Linear or Lateral Move**

Self-propelled linear systems, like the center pivot, can apply both water and pesticide very uniformly. For a given pumping rate, these systems will apply less water as their speed increases. They move laterally across a field instead of in a circle.

Self-propelled systems have two advantages:

- they can irrigate an entire rectangular field, and
- they can be configured as either high- or low-pressure systems.

However, they are also very expensive.

**Stationary Systems**

Stationary sprinkler systems (ex. solid set) do not move during the application. They are set on different areas of the field and remain in place during the treatment. This often means that fields must be treated over several sets.

In this way, they are unlike the center pivot and self-propelled linear systems. Their biggest problem is wind distortion of the sprinkler pattern.

Another problem with these systems is the risk of chemical exposure when moving them from one application site to the next. Stationary systems, however, may give more uniform application because the treatment is made in blocks.
Traveling Gun

The traveling gun—also called traveling big gun or hose drag traveler—can give extra mobility. These systems can easily be moved from one field to another. However, traveling guns apply water and pesticide much less uniformly. Like the stationary systems, they are prone to wind distortion.

The hose and volume gun equipment also may increase workers’ risk of chemical exposure.

A traveling gun system works best when there is little wind. However, it is likely to give poor uniformity even under the best conditions. In addition, higher application rates may sharply increase the risk of runoff. All these drawbacks make traveling guns a poor choice for chemigation. Their main use is to irrigate pastureland.

Drip/Trickle (Microirrigation) Systems

Drip or trickle irrigation is the frequent, low-volume application of water to soils. The water (and pesticide) passes through emitters, orifices, or porous tubing. Most drip systems apply water to the soil surface or within the root zone. Some may be installed below the surface. This reduces soil evaporation and encourages root growth in a limited area. Drip systems are not suitable for broadcast or foliar applications. They work best with fertilizers, soil amendments, and herbicides that must be applied to the soil surface (laterals) or incorporated to a certain depth below the surface (subsurface drip systems).

Emitters

Emitters are openings through which the water/pesticide mixture emerges. Most emitters lie on the ground. However, you can also suspend them above ground or bury them. The latter is common with drip tape.

Types of Emitters

There are many different types of emitters. They include:

• point source emitters,
• line emitters,
• microsprays or sprinklers, and
• porous hose/double wall emitters.

Point source emitters, or “drippers,” usually deliver about 1 to 2 gallons per hour at each point. Line emitters, which are perforated tubes, deliver 0.15 to 2 gallons per hour per foot of length. Microsprays, or “jets,” have higher discharge rates. They spread the water over a much larger area, which reduces the application per square foot of soil surface. Finally, porous hose/double wall emitters are in-row, full-length watering devices. These devices, however, give poor uniformity and are not recommended for chemigation.

Surface/Gravity-Flow Systems

In general, surface or gravity-flow (furrow and flood) irrigation systems are of limited use in chemigation. This is true for the following reasons:

• Water distribution is typically non-uniform along the row.
• These systems cannot be used for foliar applications.
• Many pesticide labels do not allow furrow or flood applications.
• Surface systems may not wet the soil enough on ridge tops of hill- or bed-planted crops.
• The wetting pattern may concentrate the product on ridge tops or hills.
• The chemical(s) may not be distributed evenly along the length of the furrow if the water flows too slowly.
Furrow Irrigation

In furrow irrigation, small ditches or furrows guide the water across the field. Forming the furrow, or bed, is crucial because it influences:

• the rate of flow,
• the amount of water applied, and
• the uniformity of the application.

Furrow-slicking devices and bed-forming machines produce a smooth, firm, clod-free surface that helps the water flow more freely during the first irrigation.

Flood Irrigation

In flood irrigation, you apply water to the soil without flow controls such as furrows or borders. For the first irrigation, you will need a water application of at least 2 to 2-1/2 inches. You will also need a reuse pit to collect tailwater. Collect and apply tailwater on the same field or on other crops for which the chemical is labeled. See Unit 3 (Safety Considerations) for more information about tailwater control.

Surge-Flow Irrigation

Surge valves, or surge-flow irrigation, may help you get a more uniform water application with surface irrigation systems. They also reduce deep seepage and runoff by pulsating flows across a field. With experience, you can program surge valves to apply water and pesticides uniformly when field conditions are good. The pesticide label will tell you whether the product may be applied through a surge-flow system.

Chemigation Equipment

Before you can apply chemicals through an irrigation system, you will need some basic equipment. Some of this equipment the antipollution devices - is required by law. Make certain that your equipment is compatible with the products that you will apply through the system. Every chemigation system needs:

• a pesticide supply tank with agitator,
• an injection pump or device,
• a calibration tube, and
• safety devices to protect the water source.

If you are chemigating in a greenhouse, you may also need a proportional rate injection pump.

Pesticide Supply Tanks

Choose a pesticide supply tank made of noncorrodible materials. The best choices are stainless steel, fiberglass, or polyethylene plastic. Avoid tanks made of iron, copper, aluminum, or brass. They are more likely to rust, corrode, or produce toxic fumes. Certain formulations need constant agitation, either hydraulic or mechanical. Check the label for instructions. It will state whether you must place the product in a certain type of tank. The product label, in addition, will include a warning of any problems with chemical incompatibility.

Some pesticides are flammable. Again, check the label to see if your product is flammable and, if so, what precautions you must take. These may include:

• using explosion-proof electric motors and wiring,
• keeping a separation distance (so that a spark of electricity cannot cause an explosion), and
• diluting the chemical.

Make sure all wiring meets the requirements listed in the National Electrical Code for hazardous area applications.
Other Factors

Your pesticide supply tank should keep all windborne foreign materials out. These include dirt, leaves, crop residue, and rainwater. It also should be completely drainable with a sump at the drain port for ease in rinsing. Put accurate, easily readable gallon marks on the outside of the tank.

If you also fertigate, you may need more than one type of tank. For example, you may need a larger-capacity tank for fertilizers and a smaller one for pesticides.

If you store pesticides in a tank, federal law requires you to:

- display the maximum quantity of the tank,
- attach a complete pesticide label,
- make sure the tank is structurally sound, and
- secure the tank by tightly closing the lid.

Virginia law requires you to label concentrate service containers (tanks) of all types and sizes. The labeling must indicate whether the product to be stored or transported will be diluted or applied as an end-use concentrate.

Be sure your pesticide supply tank has a manually operated valve. This valve allows you to close the chemical supply line in case of equipment failure or shutdown.

Injection Pumps and Devices

The chemical injection pump is the heart of your chemigation system. Ideally, the pump should have a delivery accuracy of ± 1% within its operating range. In practice, however, changes in temperature and other factors may cause your pumping rates to vary.

The pump should be easy to adjust for different injection rates and be mechanically sound. Make sure all of its components are made of noncorrodible materials. In addition, be sure to clean your pump after each use. Any remaining pesticide within a pump can shorten the pump’s life and cause seals or hoses to fail.

Capacity and Output Rates

Make sure the capacity rate of your pump matches the application rates of the chemical(s) you plan to use. No one pump can do all jobs. Chemical application rates vary widely. You may need a pump injection rate as low as 2 gallons per hour or one as high as 400 gallons per hour. Most pumps are graduated in units or percentages. These may indicate the amount of liquid pumped at a certain setting. These settings, however, are not exact. You will need to verify all settings and values by calibration. See Unit 6 (Calibration) for more information on calibration procedures.

Do not operate a pump at either its maximum or its minimum output. You could damage the pump or produce incorrect pumping rates. Piston pumps are especially easy to damage in this way. They tend to lose their suction power as you reduce the stroke length of the piston. It is best to run the pump in the middle of its output range.

Positive Displacement Type

Some pesticides labeled for chemigation may require the use of a positive displacement pump. This type of pump has three main features:

1. Its output cannot be easily throttled.
2. Each pump stroke injects a given volume.
3. It gives a high volume output.

Diaphragm and piston pumps are examples of positive displacement pumps.

Diaphragm

Diaphragm pumps have a membrane, or diaphragm, separating the drive mechanism from the pesticide. Both single- and dualport pumps are available. It is important to choose the right diaphragm. This will eliminate leakage problems that are more common with piston pumps.

Many researchers and experts agree that diaphragm pumps are the best all-around pumps for injecting pesticides into irrigation. Chemigators have used them since the mid-1980s. Although they
are usually more expensive than either piston or venturitypes, diaphragm pumps have several benefits:

- They have only a few moving parts and are dependable.
- A very small part of the pump is exposed to the pesticide. This cuts down on corrosion, wear, and leakage. It also reduces maintenance costs as well as the chance of pesticide exposure.
- It is easy to adjust the injection rate while the pump is operating. For most diaphragm pumps, just turn a micrometer type adjustment knob.

However, the discharge flow rate of many diaphragm pumps may suffer if there are changes in irrigation mainline pressure. These changes may cause the discharge pressure of the pumps to vary a great deal.

NOTE: Select the diaphragm material in accordance with the chemicals being pumped.

**Piston**

Piston pumps were the first pumps available for chemigation. They come as both single- and dual-piston units with a wide range of capacities. Their main advantage is their relatively high capacity. They are mostly used to apply fertilizers at high injection rates.

Piston pumps have two big drawbacks:

- Their seals wear rapidly with abrasive materials, which can cause leaks. This increases maintenance costs and the chance of pesticide exposure.
- Calibration is often time-consuming. To change the injection rate, you have to stop the pump and adjust the stroke length mechanically. Then, you must restart the pump and check the new injection rate. Some newer pumps, however, allow adjustment during operation.

Like the diaphragm pump, discharge flow rate of piston pumps will change as the irrigation pipeline pressure varies.

**Proportional Rate (Differential Pressure) Type**

Some injection devices use a different system: proportional rate (differential pressure).

A proportional rate injection system meters chemicals into an irrigation waterline. It is used mostly to apply fertilizers. However, you can also use this system to apply pesticides. Proportional control is activated by a feedback system that monitors the flow rate of the irrigation pipeline. It then varies the injection rate accordingly.

Proportional rate injection devices do not work in the same way as the injection pumps described above. Those pumps (diaphragm and piston) deliver a calibrated amount of pesticide per unit time (ex. 2 gallons per hour). Proportional rate devices, however, deliver pesticide into the waterline in a way that maintains a constant proportion of pesticide to the water flow rate. This proportion is called the “dilution ratio.” For example, suppose you set your proportional device at a dilution ratio of 1:100. This means it will deliver 1 part (ex. quart) of pesticide into every 99 parts (ex. quarts) of water. This also means that the rate of injection (ex. gallons per hour) will vary with the water flow rate.

There are several different types of proportional rate injection systems. They include:

- venturi type,
- displacement diluters,
- positive displacement pump, and
- EC-controlled injection units.

Each has its benefits and drawbacks.

**Venturi Type**

Venturi units generate a differential pressure, or zone of low pressure, across a venturi device. This means they use a difference between the inlet and outlet pressure of the injector to add chemical(s) into the irrigation water. This creates a reduced-pressure zone, which draws the pesticide out of the pesticide supply tank and into the bypass line. The differential pressure is controlled by either:
• a pressure-reducing valve installed in the main line of the irrigation system, or
• a small auxiliary (centrifugal) pump that works with the venturi device.

Venturi meters are mainly used in drip irrigation systems. They are most common in vegetable production, greenhouses, university research plots, and tree fruit production. Their benefits include relatively low cost and simplicity. They are also easy to calibrate if they are used with an in-line flow meter. Venturi units are sometimes called positive pressure pesticide application systems.

Venturi-type proportional rate devices use pressure differences to draw pesticide into the water stream. If the pipeline pressure is constant, injection rates will be accurate. Their dilution ratio is usually low, around 1:15. Thus, they are most useful for small jobs. You can adjust the amount of pesticide that enters the water stream by changing the orifice size or the water pressure.

NOTE. Venturi systems must maintain a minimum difference in pressure (pressure differential) to produce the suction needed.

**Displacement Diluters**

Displacement diluters are similar to venturi-type devices. They have no moving parts, and the pesticide concentrate goes into a container. Some water from the waterline enters the container and displaces an equal volume of pesticide, which enters the waterline through a separate opening. The incoming water does not mix with the pesticide because of the density differences between the liquids. The rate of dilution for displacement diluters is greater than that for venturi units. However, the dilution ratio still depends on the flow rate and pressure of the water supply.

**Positive Displacement Pump**

A positive displacement pump injects a fixed amount of pesticide into the waterline. These pumps are either hydraulic (water powered) or electric. With hydraulic pump proportional rate devices, a flow of water powers a piston pump that injects a fixed amount of pesticide into the waterline with each stroke. With electrically driven devices, a rotary piston-type water meter monitors the flow of water. Again, a fixed amount of pesticide flows into the water stream with each stroke.

**EC-Controlled Injection Units**

EC injection units monitor the electrical conductivity, or in-line flow, of the pesticide in the waterline. This varies the operating speed of the pump. A proportional rate injection device or pump injects pesticide into the line whenever the conductivity falls below a certain level.

**Calibration Tubes**

A calibration tube should go in the line between the pesticide supply tank and the injection pump. Use it to measure the output of the injection unit when you calibrate and during the actual chemigation. The capacity of your injection system will affect the size of calibration tube you need. Make sure your calibration tube is:

- clear (transparent),
- breakage resistant,
- ultraviolet (UV) resistant, and
- graduated in units of volume (pints, ounces, or milliliters).

To properly calibrate an injection system, you should monitor the pesticide injection for at least 5 minutes. This means the calibration tube must be large enough to hold the pesticide that will accumulate during that time.

You do not have to permanently attach the calibration tube to the injection system. However, you need to be able to attach it to the suction line quickly and easily while the pump is running. This allows you to check the injection rate from time to time. For more information on calibration procedures, see Unit 6 (Calibration).

**Antipollution Devices**

Antipollution (safety) devices reduce hazards to the environment in case of equipment failure during chemigation. Your irrigation system must
ensure that any interruption of water or pesticide flow automatically prevents backflow into the water supply.

Safety devices are required by law. See Unit 1 (Introduction) for more information on laws governing chemigation and backflow prevention. These laws aim to prevent water pollution as it might occur in many ways. Without properly functioning safety equipment in place, failure of the irrigation equipment could have these results:

- The pesticide mixture could flow from the pesticide supply tank back to the water supply if pressure in the irrigation main line is lost. If the water supply is the drinking water supply, this will result in exposure of water consumers to Chemigation chemicals possibly resulting in serious injury or death. If the water source is an irrigation source, this may result in either groundwater or surface water contamination requiring expensive cleanup.

- The injection pump could shut off while the irrigation pump continues to run. This could cause the water to flow back through the injection system and flood the supply tank. This could result in a spill of chemicals at the tank site causing environmental contamination and damage and human exposure to full strength chemicals requiring potentially expensive cleanup and potentially serious illness to people living and working nearby and to cleanup workers.

- If both the injection pump and the irrigation pump shut down, the pesticide mixture in the irrigation pipeline could be siphoned back into the water supply. This would result in the environmental and public health damage described in the water supply contamination above.

- If the irrigation pump shuts down and the injection pump continues to run, undiluted pesticide could be injected into the irrigation line. This could pollute the water supply or load the irrigation line with pesticides. The undiluted pesticides, in turn, might later flow onto the field at a high rate. In the first case, this would result in the same environmental and public health damage described as a result of water supply contamination above. In the second case (undiluted pesticides), this would cause damage to crops, or render the crops unusable and possibly hazardous waste due to heavy chemical exposure.

**Procedures and Equipment**

To protect the water supply, start by choosing the right chemigation equipment. Your equipment should resist chemical corrosion and stand up to the weather. It should also be the right size for the job. Then, inspect and maintain all equipment to make sure that it is working properly. Finally, manage your chemigation system for safe and effective chemical application.

Required safety devices may include the following:

- Reduced pressure principle backflow preventer (also called reduced-pressure backflow assembly [RPBA] or reduced-pressure zone valve [RPZ]) if connected to a public water source or approved air gap if irrigation system is receiving water from public water source.

- Reduced pressure principle backflow preventer, RPBA or RPZ located before the injection point if chemigation is taking place on an irrigation system to protect the rest of the irrigation system as well as the irrigation system source.

- Irrigation mainline check valve.

- Vacuum relief valve.

- Low-pressure drain.

- Pump interlock.

- Flow interrupter (normally closed solenoid valve) or quick-acting, spring-loaded check valve on the chemigation injection line.

- Injection-line check valve.

- Inspection port.

These and other safety devices are discussed in more detail in Unit 5 (Backflow Prevention).
Management Principles

Good management is vital to the success and safety of chemigation. Any time you apply a chemical through an irrigation system, you must take certain steps before and after the application. Most chemigation-related accidents result from:

- careless practices,
- poor choice of equipment,
- lack of knowledge on how to handle chemicals safely,
- lack of monitoring, or
- poor system maintenance.

Taking safety precautions is an investment in the health and safety of the environment, other people, and you. It also helps you get good results. See Unit 3 (Safety Considerations) for more information on environmental protection and personal safety.

Read the Label

Before you start to chemigate, ALWAYS read the product label and comply with all directions and restrictions. The label will state whether you may apply the product through an irrigation system and, if so, which type of system. It will give you specific directions on application rates, the crops you can treat, and any protective equipment you may need. In addition, it will give details on restricted-entry intervals, worker notification and posting requirements, and antipollution devices. The label may also tell you how to dispose of empty pesticide containers. Be sure to read all the sections of the pesticide label before you buy the product and again before you chemigate. See Unit 1 (Introduction) for more information on labels and label requirements.

Inspection, Maintenance, and Repair

Keep your chemigation equipment in good working order. Regularly inspect all hoses, clamps, and fittings and replace them as needed. Also, inspect pumps, tanks, and electrical devices. Before you chemigate, conduct a site assessment and check the following to be sure they are working properly:

- Irrigation mainline check valve, vacuum relief valve, and low-pressure drain.
- Pesticide injection-line check valve.
- Irrigation system and pumping plant main control panel.

Pay special attention to all equipment parts that will contact chemicals. These parts—from the supply tank to the point of injection on the irrigation pipeline—should be made of chemically resistant materials. In addition, heat, sunlight, and pressure may degrade the injection tubing. Some manufacturers recommend replacing injection-line hoses each year.

Monitoring

During chemigation, check the irrigation system and pesticide injection equipment to make sure they are operating correctly. To do this, you must keep the area around the main control panel, water pump, supply tank, and injection pump free from chemical contamination. One way to do this with a center pivot system is to plug the nozzle outlets near the equipment.

Plugging First Nozzles on Center Pivots

Plug the nozzle outlets near your equipment. This procedure is called plugging first nozzles on center pivots. It will greatly reduce the chance of chemical pollution and will allow you to monitor more effectively.
Flushing

You should flush your injection and irrigation systems by running water through them each time you chemigate. Flush the tank and the injection equipment as well as the distribution and application systems.

Injection System

Flush the injection system with clean water after each use. This will keep precipitates (deposits) from forming. It will also help prevent product incompatibility by removing all traces of the pesticide. You should flush your injection system while the irrigation system is still running. This allows you to apply rinse water to the treated site. Pump water through the system for at least the flush or fill time of the system.

Irrigation System

After injection is complete, run the irrigation pump for at least 15 minutes—or the fill time - whichever is longer. Drip systems may take longer to completely flush. If the irrigation system shut itself down automatically, flush the system as soon as you discover the shutdown. Extend the flushing period to at least 30 minutes as a precaution against backflow.

Avoiding Clogging

Clogging is a common problem in drip irrigation. Follow these guidelines to avoid clogging:

- Use pesticides that are soluble in water. Or, choose a pesticide that can be mixed or suspended uniformly in and carried by water.

- Before you combine chemicals in a tank mix or stock solution, check the label to make sure they are compatible. Then, conduct a compatibility test. For example, you could mix a small amount of the chemicals in a jar and observe the results. Water sources and contents vary widely. Check: – pesticide-to-water compatibility, and – pesticide-to-pesticide compatibility.

- Use pesticides that will not harm your system components.

- Place the chemical injection point upstream of the filter. This will allow the filtration system to remove any precipitates that might otherwise clog the drip system.

- Inject sanitizing agents such as sodium hypochlorite or sulfuric acid to control precipitates.

Troubleshooting

Good management often means preventing a problem before it starts. If you regularly inspect and monitor your equipment, you can protect both your investment and the environment. Here is a list of do’s and don’ts to help you practice good management when using pesticides. It applies to all pesticide application, not just chemigation.
Table 4-1. Management practices for optimal use of pesticides

<table>
<thead>
<tr>
<th><strong>DO</strong></th>
<th><strong>DON'T</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Do learn about the pests and controls.</td>
<td>Don’t compulsively use a chemical without looking for the best control method.</td>
</tr>
<tr>
<td>Do reduce excessive treatment.</td>
<td>Don’t think that more chemical will provide better control - it won’t. It may be less effective or may even cause environmental problems such as leaching or harm to wildlife.</td>
</tr>
<tr>
<td>Do read labeling.</td>
<td>Don’t assume a set application rate is universal. Variations among crops and soils make a difference when using pesticides. Also, labels, formulations, and requirements often change.</td>
</tr>
<tr>
<td>Do optimize application timing.</td>
<td>Don’t just spray. The time of day or year can influence pesticide effectiveness. Remember to check the label for tips on individual chemicals.</td>
</tr>
<tr>
<td>Do rotate crops and farming practices.</td>
<td>Don’t plant the same crop in the same location year after year, if possible. Rotation reduces disease, insects, and weeds while enhancing pesticide effectiveness.</td>
</tr>
<tr>
<td>Do identify high-risk areas.</td>
<td>Don’t assume that you should apply the same rate of chemical to all areas. Some areas should be safeguarded from any pesticide use if groundwater contamination or other environmental hazards exist.</td>
</tr>
<tr>
<td>Do use pesticides only when needed.</td>
<td>Don’t just spray. Save yourself some time and money by using a pest management system where applications are made only after scouting. If the damage seen when scouting verifies that pesticides are needed, consider using chemical control.</td>
</tr>
<tr>
<td>Do use appropriate safety measures with your equipment spraying.</td>
<td>Don’t assume that all sprayers are alike. Correct calibration and safety devices must be tested before spraying.</td>
</tr>
<tr>
<td>Do use alternative pesticides.</td>
<td>Don’t use products in the same chemical family year after year. This encourages pest resistance and buildup of residue levels. Choose an alternative, if available.</td>
</tr>
<tr>
<td>Do use integrated pest management.</td>
<td>Don’t just spray. An integrated management program will allow pesticide used wisely to be more effective and may curtail pest resistance to chemicals.</td>
</tr>
<tr>
<td>Do optimize pesticide placement.</td>
<td>Don’t spray where the chemical won’t be effective.</td>
</tr>
</tbody>
</table>
Table 4-1. Management practices for optimal use of pesticides (continued)

<table>
<thead>
<tr>
<th><strong>DO</strong></th>
<th><strong>DON’T</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Do use biological controls.</td>
<td>Don’t just spray. If effective, biological controls can save you the money you normally use on pesticides. This program may be better.</td>
</tr>
<tr>
<td>Do consider cultivation.</td>
<td>Don’t just spray. Cultivation for part or all the weed control in the field may be more economical.</td>
</tr>
<tr>
<td>Do use lowest effective pesticide rates.</td>
<td>Don’t just apply the maximum rate. Some areas may be able to use less pesticide for effective control of pests.</td>
</tr>
<tr>
<td>Do use resistant crop varieties.</td>
<td>Don’t rely on pesticides alone. Save yourself some time and expense by preplanning your pest management strategy.</td>
</tr>
<tr>
<td>Do consider terrain, water sources, and other sites that require specific application techniques.</td>
<td>Don’t assume all areas can be aerially sprayed, power sprayed, or hand sprayed. Specific geological areas where pesticide contamination can occur or where neighbors may receive drift may require special attention.</td>
</tr>
<tr>
<td>Do optimize crop planting time.</td>
<td>Don’t rely on pesticides alone. Planting a crop at the right time may allow the crop to outcompete less seasonable weeds.</td>
</tr>
<tr>
<td>Do optimize pesticide formulation.</td>
<td>Don’t just spray. Using spreaders, stickers, or other adjuvants may optimize the pesticide’s usefulness, allowing you to use less chemical for an effective job of control.</td>
</tr>
</tbody>
</table>
Learning Objectives

After studying this unit, you will be able to:

• Define backflow, backsiphonage, and backpressure.
• Understand why backflow prevention is important and required by law.
• Name and describe the various types of antipollution (safety) devices.
• Identify which safety devices are required on chemigation systems.

Injecting a pesticide into an irrigation system can pollute the water source if safeguards are not in place. To prevent water pollution, federal and state laws require all chemigators to install backflow prevention equipment on their irrigation systems. In this unit, you will learn about backflow and how it can threaten public and private water supplies. The unit will list the basic types of safety equipment required by the federal Label Improvement Program (LIP), also known as Pesticide Registration (PR) Notice 87-1. You will also learn about alternatives to the standard backflow prevention devices such as a two-pump system with an air gap. This unit will discuss the various backflow prevention devices, how they work, and where they are located. These devices play a crucial role in safe and effective chemigation.
Terms to Know

Atmospheric Port—Located on a reduced pressure-principle backflow preventer, it prevents leaked pesticide and water from backflowing by ejecting the fluid into the atmosphere.

Automatic Low-Pressure Drain—This device intercepts leakage past the mainline check valve and discharges the leakage from the main line. It is always located upstream of the point of pesticide injection.

Backflow—The movement of a liquid in reverse of the normal direction of flow in a piping system. In chemigation systems, backflow can also occur in the injection line, causing the pesticide supply tank to overflow.

Backpressure—The higher pressure from a pump or elevated tank, compared to the pressure in the water supply piping system to which the pump or tank is connected. Backpressure could cause backflow.

Backsiphonage—The type of backflow caused by the reduction of pressure (vacuum or partial vacuum) in the piping system.

Check Valve—A device that provides quickacting, positive (absolute) closure. It prevents the backflow of water when the irrigation or injection system fails, resulting in the loss of system pressure.

Cross Connection—A connection, either direct or indirect, between a potable water supply and a system or device that could contain nonpotable water.

Interlock—The electronic or hydraulic interconnection of irrigation pumps and pesticide injection units. If the system pressure or flow rate drops below a certain level, the injection system (or the injection and irrigation systems) will shut down.

Opening (Cracking) Pressure—The pressure required from the pesticide supply pump (or tank, if gravity pressure) to open a spring-operated injection-line check valve.

Potable Water—Water that is suitable for human use and consumption.

Reduced-Pressure Principle Backflow Preventer—A device made of two spring-loaded check valves and a high-flow atmospheric port between them. (The port is controlled by a pressure differential valve.) It is required for all municipal (public) water supply hookups.

Vacuum Relief Valve—A device that automatically breaks the vacuum in an irrigation pipeline or injection line. This valve helps prevent backsiphonage.

Venturi—An injector device that operates on a pressure differential between the inlet and outlet of the injector. It creates a vacuum, which results in suction or a “venturi” effect.
**Backflow**

“Backflow” is the flow of a liquid through a hose or pipe in reverse from its normal direction. Backflow can occur in the pesticide injection line, causing the pesticide supply tank to fill and overflow with water from the water supply line to which the tank is improperly connected. Backflow may result from either “backsiphonage” or “backpressure.”

**Backsiphonage**

“Backsiphonage” is the type of backflow caused by the reduction of pressure (vacuum or partial vacuum) in the piping system.

Some common causes are:

- high liquid velocity in pipelines,
- a line break or repair that is lower than a service point,
- lowered main pressure due to a high rate of water withdrawal (ex. fire fighting), and
- reduced supply pressure on the suction side of the booster pump.

The main characteristic of backsiphonage is a vacuum within a supply line. This vacuum creates a siphoning effect. Backsiphonage can also occur if a lot of water is withdrawn at once. If the water is flowing through the pipeline at high speed, the pressure on the line drops. This difference in pressure can cause backsiphonage into the pipeline.

**Backpressure**

“Backpressure” is a cause of backflow. Backpressure can cause backflow when a supply line is connected to a high-pressure system and the system’s pressure exceeds the pressure of the supply line.

Example: When a pesticide injection pump fails, pressure drops in the pesticide injection line and, as a result, water from the irrigation mainline abnormally flows “upstream” through the pesticide injection line and possibly, even further into the pesticide supply tank.

Some common causes of backpressure are:

- booster pumps,
- connections to boilers,
- cross connections with another system running at a higher pressure, and
- elevated piping.

Backpressure is most likely when the irrigation water distribution system is subjected to a pressure higher than its regular operating pressure. A booster pump, for example, might generate enough pressure to force water back to source of the irrigation water.

**Cross Connection**

A “cross connection” is any physical connection between a public water system and a source of nonpotable liquid, solid, or gas. A connection that has the potential to cause backflow is also a cross connection.

Cross connections include:

- hose-end sprayers (hydraulic aspirator connections)
- submerged hoses
- removable sections
- changeover or swivel devices

Refer to the Manual of CrossConnection Control, 9th edition (Foundation for Cross-Connection Control and Hydraulic Research, University of Southern California, December 1993, p. 10) for more information on the above terms.

**Source Water and the Law**

Since 1964, pesticide use in the United States has tripled. Between 1.1 and 2.5 billion pounds per year are applied to plants and animals. Using pesticides greatly improves the yield and quality of food and fiber. This, in turn, improves public health.
The widespread use of pesticides and other chemicals, however, makes many people worry about the quality of their land, water, food, and air. Chemigation, closely linked with water sources, is an obvious target of concern for water purity. Both groundwater and surface water can be at risk.

**Groundwater and Surface Water**

Groundwater moves below the earth’s surface between rocks, gravel, sand, and silt. Half of the U.S. population relies on groundwater for its source of drinking water. Many rural residents use groundwater as a source for drinking water and to irrigate crops. In Hawaii, about 90% of the drinking water comes from groundwater sources. This heavy dependence on groundwater makes protecting Hawaii's groundwater especially critical. Improper use of pesticides can pollute not only groundwater but also lakes, streams, and ponds. If pesticides leach through the soil, pass the effective rooting zone of the crop, or run off the target site, they can taint the groundwater supply.

As discussed in Unit 3 (Safety Considerations) and Unit 4 (Application Systems and Equipment), wise management can limit environmental dangers from chemigation. Always:

- follow label directions,
- mix and calibrate accurately,
- prevent spills and backflow,
- dispose of waste properly, and
- follow integrated pest management (IPM) techniques.

Under federal law, pesticide labels must state which safety equipment is required for chemigation of the product. Chemigation systems that draw from a domestic or municipal water supply must have a reduced pressure-principle backflow preventer or an air gap system between the domestic or municipal water supply and the chemical injection point. Chemigation systems that use surface water must include a check valve. We will discuss this equipment in more detail below.

**Label Improvement Program (PR Notice 87-1)**

As you learned in Unit I (Introduction), the federal Label Improvement Program (LIP) requires that all pesticides registered under the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) include label instructions about chemigation. The label must either forbid chemigation or allow it. In addition, if chemigation is approved, the label must list the safety devices required for the irrigation system. On the irrigation pipeline, these include:

- a check valve,
- a vacuum relief valve, and
- an automatic low-pressure drain.

On the injection line, there must be:

- an automatic, quick-closing check valve and
- a normally closed solenoid valve.

*NOTE. An injection-line check valve (with 10 psi opening or cracking pressure) is often substituted for these two devices.*

The system must also contain:

- interlocking, automatic shutoff controls;
- a pressure switch; and
- a metering-type injection pump or device. This type of pump allows the operator to meter, or measure, the pesticide flow to the irrigation line.

The LIP requires this equipment in order to prevent backflow into the water source. However, these requirements help chemigators in other ways. For example, they may encourage users to inject chemicals consistently and precisely. This, in turn, reduces the amount—and cost—of chemicals applied. See Unit 1 (Introduction) for more information about state and federal laws to protect source water.
Schematic of a pesticide injection system with the eight required items*

(A) Mainline Single Check Valve          (E) Interlocking System Controls
(B) Low Pressure Drain                   (F) Solenoid Operated Valve
(C) Air/Vacuum Relief Valve             (G) Pesticide Injection Pump
(D) Pressure Switch                     (H) Injection Line Check Valve

* Figure 5, in "Core Training Manual For Backflow Prevention In Chemigation of Pesticides" (revised 3/17/03). David F. Zoldoske, Director, Tim Jacobson, Education Specialist, and Edward M. Norum, Agricultural Engineer (The Center for Irrigation Technology, California Agricultural Technology Institute, California State University, Fresno), for California Environmental Protection Agency, Department of Pesticide Regulation, Environmental Monitoring Branch. <http://www.cdpr.ca.gov/docs/gwp/chem/grower_manual.pdf>
Backflow Prevention Systems

If your chemigation system is connected to a domestic or municipal water supply, you must use either a:

- two-pump system with an air gap or
- an approved reduced pressure-principle backflow preventer.

Install effective safety devices between the irrigation pump discharge and the point of pesticide injection (unless you are using a two-pump system with an air gap). You should also put safety devices between the pesticide supply tank or container and the point of pesticide injection (except for venturi meters). Venturi systems use positive pressure to apply pesticide. They also have different backflow prevention requirements. These devices are discussed in detail below.

Who Is Affected?

Anyone who chemigates—ex. farmers, greenhouse growers, nursery operators, and golf course caretakers—must comply with state and federal chemigation safety laws. This includes operators of all types of irrigation systems.

There are two exceptions:

- When an air gap exists.
- When the fill tube or spout does not contact or fall below the water level of the application equipment.

Backflow Safety Equipment

The following devices are either required or recommended for chemigation systems.

Refer to the pesticide label to find out which safety equipment is required for chemigation of the product.

Reduced Pressure-Principle Backflow Preventer

The reduced pressure-principle backflow preventer is located upstream of the point of injection. It is also called a reduced-pressure backflow assembly (RPBA) or a reduced pressure zone valve (RPZ). This device consists of two spring-loaded check valves. They have an atmospheric port between them. Whenever pressure drops at one of the valves, the port opens and water drains out. In this way, the check valves prevent backflow, and the atmospheric port prevents backsiphonage. The reduced pressure principle backflow preventer is required if your irrigation system is connected to a domestic or municipal water supply.

Irrigation Mainline Check Valve

The irrigation mainline check valve is located between the irrigation pump discharge and the point of injection into the irrigation pipeline. It is required on all chemigation systems, with two exceptions:

- if you use the reduced pressure-principle backflow preventer, or
- if you use a two-pump system with an air gap.

The mainline check valve works closely with the vacuum relief valve and the automatic low-pressure drain.

The irrigation mainline check valve has a crucial role to play. Along with the vacuum relief valve and the low-pressure drain, it is the heart of the antipollution system. It keeps the pesticide mixture from draining or siphoning back into the water supply. These valves must be spring loaded and have a watertight seal. They should also be easy to inspect, maintain, and repair. Make sure your check valves have fittings so you can remove them easily. Inspect the mainline check valve before each chemigation.

Vacuum Relief Valve

The vacuum relief valve allows air into the irrigation pipeline when its pressure drops below atmospheric pressure. This prevents formation of a vacuum that could cause backsiphonage. It also
helps prevent collapse of the irrigation line. Like the irrigation mainline check valve, it, too, is required on all chemigation systems, with two exceptions:

- if you use the reduced pressure-principle backflow preventer, or
- if you use a two-pump system with an air gap.

The vacuum relief valve is located on top of the horizontal irrigation pipeline. It is usually on the chemigation valve on the upstream side of the “flapper.” It should lie between the waterline check valve and the water supply. Check the valve from time to time to make sure it is working properly and that no debris has entered the valve.

The opening to the vacuum relief valve should be at least 3/16 the diameter of the irrigation pipe minimum. The American Society of Agricultural Engineers (ASAE) recommends that the vacuum relief valve be at least 3/4 inch in diameter. You could mount the valve on the inspection port as long as it does not prevent inspection of other safety devices.

**Automatic Low-Pressure Drain**

The automatic low-pressure drain is a self-activating device that helps prevent backflow of pesticide/water mixture into the water source. It must be placed on the bottom side and lowest point of the irrigation pipeline between the irrigation pump and the mainline check valve and upstream of the point of pesticide injection.

The drain opens automatically when pressure drops in the irrigation main line. This means that the pesticide–water mixture in the irrigation line cannot drain into the water supply. Instead, the pesticide and water flows away from the irrigation line between the flapper or check valve and the irrigation pump or water source. Use a hose or pipe to discharge the drainage at least 20 feet away from the water source. Do not allow water from the hose or pipe to flow toward the source.

The low-pressure drain should have an opening at least 3/4 inch in diameter. It should be level and not extend beyond the inside surface of the bottom of the irrigation pipe. The outside opening of the drain must be at least 2 inches above the grade. Often, the mainline check valve, the vacuum relief valve, and the low-pressure drain are sold as a package. Together, they comprise the chemigation valve. Inspection and injection ports may also be included as part of the chemigation valve.

**Injection-Line Check Valve**

The check valve on the pesticide injection line has two main purposes. First, it prevents the pesticide supply tank from overflowing due to backpressure. It is necessary on all chemigation systems. The check valve keeps the irrigation water from flowing back through the injection line into the pesticide supply tank. If this valve were not in place and the injection pump shuts down, the pesticide supply tank could overflow.

Second, the valve will prevent gravity flow from the pesticide supply tank into the irrigation pipeline if the pump shuts down. The injection-line check valve should be spring loaded with a minimum opening (cracking) pressure of 10 psi. The check valve should be as close as possible to the point of pesticide injection. It should also be made of chemical-resistant materials. Inspect this valve for damage or other problems before each chemigation.

**Simultaneous Interlock**

The simultaneous interlock is also called the functional systems interlock. It ensures that the chemical injection pump will stop whenever the irrigation pump does. Such pump failure is generally the result of loss of pressure in the irrigation main line. This interlock is required on all chemigation systems. It prevents pesticide from flowing into the irrigation pipeline if the irrigation water stops flowing.

**Engine-Driven Pump**

If you have a system with an enginedriven irrigation pump, belt the injection pump to the drive shaft or to an accessory pulley of the engine. You could also run the injection equipment from the engine’s electrical system. Once you do this, you
have interlocked the irrigation and injection systems. When the engine stops, the injection pump also stops.

**Electric Motor-Driven Pump**

The interlock works differently for irrigation pumps driven by electric motors. Generally, you need a separate, small electric motor to drive the injection pump. The electrical controls for both motors must interlock so that if the irrigation pump stops, the injection pump also stops. Make sure all wiring conforms to the National Electric Code. Some pesticides are flammable. Consult the label for details on any special precautions or safety guidelines.

**Other Interlock Systems**

The “dual interlock” system will shut off the irrigation system if the injection pump stops or malfunctions. This type of interlock can show you where the chemical application ended if the system shuts down. When the flow stops in the injection line, the irrigation system shuts down.

Another type of injection pump uses flowing water to power the pump. When the water flow stops, so does the injection pump. These water pumps are used when there is no other source of power at the injection point.

**Pressure Switch**

The irrigation pipeline or water pump must include a pressure switch. For automated control, the pressure switch should be electrically interlocked with the control panel on the irrigation system. This switch will stop the irrigation system and the injection pump if pressure drops in the injection discharge line.

**Normally Closed Solenoid Valve**

The normally closed solenoid valve is required for pesticide injection. (See Appendix D for EPA-approved alternatives to this valve.) It is also called the flow interrupter. It can be electrically interlocked with the engine or motor driving the injection pump. Or, it can be hydraulically controlled from the irrigation main line. It is located on the inlet side of the pump. This valve shuts off all pesticide from the injection line.

Make sure the solenoid valve is compatible with the product you plan to use. It will contact the pesticide concentrate and must be resistant to these chemicals. Inspect the valve often to make sure it is working properly.

**Flow Sensor**

The injection-line flow sensor shuts down the injection pump if there is no flow in the injection line. The sensor will also shut down the pump if the flow falls below a preset level. Place the sensor just upstream from the injection-line check valve. The flow sensor should interlock with the injection pump so that the system will shut down if:

- a hose plugs up or breaks,
- the pump stops, or
- the pesticide supply tank is empty.

**Freshwater Faucet**

A freshwater faucet is not a safety device. However, it is a convenient source of water for cleanup and for rinsing empty pesticide containers. Install the faucet well upstream from the chemical injection point. If possible, the faucet should also be upstream of the irrigation mainline check valve. In this way, you can prevent backflow into the faucet. Never use the faucet as a port for injecting any pesticide. Label it as nonpotable water so that it is clearly not a source of drinking water.

**Injection-Line Strainer**

You may need a strainer to prevent clogging of the injection pump, check valve, or other equipment. Place it between the pesticide supply tank and the injection pump. The mesh size will depend on which pesticide you use. A manual valve on the pesticide supply tank outlet to shut off flow is useful. Strainers are required on all chemigation systems used to inject fertilizers.
Water Supply Filter

You also need a filter in the waterline, upstream from the injection point, to collect sediment and other debris that may come from the water source. This is especially true if you use water from a pond or open storage tank.

Injection Hoses, Clamps, and Fittings

Inspect all hoses, clamps, and fittings before each chemigation. Replace any that are defective or damaged. Make sure that any components that contact pesticides concentrated or dilute—are made of noncorrosive materials.

Inspection Port

The inspection port should lie between the irrigation pump and the mainline check valve. It should be at least 4 inches in diameter. The port allows you to inspect the check valve for leaks and soundness before each chemigation. You may also be able to inspect the low-pressure drain. Often, you can use the vacuum relief valve connection as the inspection port. If you remove the vacuum relief valve, you can put your hand into the opening to manipulate the valve. This allows you to check whether the closure on the irrigation mainline check valve is working properly.

Injection Port

The injection port is where the pesticide enters the irrigation pipeline. It must be downstream from the water outtake and the mainline check valve. The injection port is where the injection-line check valve attaches to the irrigation waterline or chemigation valve.

Alternative Safety Designs

The equipment described above is either required or recommended for most chemigation systems. The pesticide label will tell you which safety devices are required for chemigation of the product. However, other methods to prevent water pollution are acceptable to the Environmental Protection Agency (EPA). These include the following:

- Two-pump system with an air gap.
- Separate pipelines for chemicals and water.
- Injection point higher than the pesticide supply tank.

See Appendix D for a list of alternative chemigation safety equipment.

Two-Pump System with an Air Gap

One way to prevent water pollution is to use a two-pump system with an air gap between the discharge of one pump and the intake of the other. One pump discharges water into a reservoir, and the other pump draws water from it. Make sure that the air gap between the end of the fill pipe and the top rim of the reservoir tank is at least twice the inside diameter of the fill pipe. The air gap should not be less than 1 inch. Since you inject the chemicals after the second pump, the chemicals and the water source are not directly connected. The physical water break eliminates backflow if it is installed correctly.

The air gap system has its drawbacks. It is not always practical and may require extensive modification. You may need to resize pumps, power units, and reservoirs for it to work. It may also expose water to dust, debris, and other contaminants. The air gap may not be as effective if it is near an obstruction. Obstructions can hamper the flow of air into the outlet pipe. This, in turn, increases the chance of backsiphonage.

Separate Pipelines for Chemicals and Water

Another way to prevent a crossover between chemicals and the water source is to use a separate pipeline on a center pivot for the chemical. To do this, you will need to add two items to your center pivot system:

- a second (smaller diameter) pipeline, and
- a spray nozzle system.
Having two pipelines means you cannot mix the chemical with the water supply. However, as with the air gap system, it requires many changes to your existing system. In addition, the separate-pipeline system tends to give poor results in application uniformity.

**Injection Point Higher Than the Pesticide Supply Tank**

One of the ways that chemicals can end up in the irrigation system—and the water source—is through gravity flow. You can solve this problem by locating the injection point (port) higher than the pesticide supply tank. The chemicals will then flow down, away from the water source, even if the system shuts down. If the pesticide supply tank is below the injection point, you must add 1 psi per 1-foot rise in elevation to the 10 pound (psi) cracking pressure of the injection-line check valve.
Unit 6 Calibration

Learning Objectives

After studying this unit, you will be able to:

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

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

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

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

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

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

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

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

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

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

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

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

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

Tools and Equipment

To calibrate properly, you will need a few basic tools. These include:

- a stopwatch,
- a steel tape measure (at least 100 feet long),
- a pocket calculator, and
- marking flags visible from a distance.

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

System Uniformity

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

Uniformity of the Spray Pattern

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

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

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

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

Water Volume

There are several important factors to consider when you select how much water to use during chemigation. These are:

- the capacity and speed of your system,
• the type of chemical you will apply,
• label directions for volume needed per unit area,
• the degree of incorporation into the soil (specified on the label), and
• the rate of infiltration into the soil.

Measurements

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

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

Six Basic Steps

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

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

We will start with the center pivot system.

Calibrating a Center Pivot System

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

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

Measurements

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

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

**Full Circle**

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

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

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

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

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

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

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

**Example 1**

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

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

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

$$\text{Acreage of the circle} = \frac{4,521,600 \text{ sq ft}}{43,560 \text{ sq ft per acre}} = 103.8 \text{ acres}$$

**Partial Circle**

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

**Example 2**

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

$$\text{Area of the half-circle} = \frac{\text{Square footage of the half circular field}}{2} = \frac{4,521,600 \text{ sq ft}}{2} = 2,260,800 \text{ sq ft}$$

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

$$\text{Acreage of the half-circle} = \frac{2,260,800 \text{ sq ft}}{43,560 \text{ sq ft per acre}} = 51.9 \text{ acres}$$
Treating Comers

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

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

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

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

**Example 3**

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

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

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

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

\[
= \frac{50,000 \text{ sq ft}}{43,560 \text{ sq ft per acre}} = 1.15 \text{ acres}
\]

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

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

**Example 4**

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

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

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

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

**Example 5**

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

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

\[
\frac{155.7 \text{ pints}}{8 \text{ pints per gallon}} = 19.5 \text{ gallons}
\]

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

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

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

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

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

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

where \( \pi = 3.14 \), and

\( r = \) the distance from the pivot point to the outermost pivot tower.

**Example 6**

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

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

\[
= (2 \times 3.14) \times 1,200 \text{ ft}
\]

\[
= 6,28 \times 1,200 \text{ ft}
\]

\[
= 7,536 \text{ ft}
\]

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

**Example 7**

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

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

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

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

**Example 8**

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

\[
\text{Revolution time} = \frac{7,536 \text{ ft}}{5.5 \text{ fpm}}
\]

\[
= 1,370 \text{ min per revolution}
\]
To convert the revolution time from minutes to hours, divide by 60:

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

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

**More about Travel Speed**

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

**Troubleshooting**

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

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

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

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

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

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

**Example 9**

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

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

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

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

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

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

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

**Example 10**

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

**Troubleshooting**

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

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

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

where 63.08 is a constant.

**NOTE:** 63.08 is determined like this:

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

**Example 11**

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

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

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

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

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

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

where 2.13 is constant.

**NOTE:** 2.13 is determined like this:

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

**Example 12**

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

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

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

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

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

**Calibrating a Stationary Sprinkler System**

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

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

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

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

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

2. Convert into acres.

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

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

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

**Example 13**

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

\[
\begin{align*}
\text{Area (square feet)} & = 10 \times 40 \text{ ft} \times 800 \text{ ft} \\
& = 320,000 \text{ sq ft}
\end{align*}
\]

Convert the area from square feet to acres:

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

\[
\begin{align*}
& = \frac{320,000 \text{ sq ft}}{43,560 \text{ sq ft per acre}} \\
& = 7.3 \text{ acres}
\end{align*}
\]

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

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

**Example 14**

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

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

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

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

**Example 15**

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

\[
\begin{align*}
\text{Total pesticide needed} & = 7.3 \text{ acres} \times 4 \text{ lb per acre} \\
& = 29.2 \text{ lb}
\end{align*}
\]

**Step 4: Determine the Injection Time**

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

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

**Irrigation Time**

To determine the irrigation time, you need to know:

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

Following are explanations and examples:

**Water Application Rate**

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

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

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

where \(\text{gpm} = \) Average sprinkler flow rate (gpm),
\(L = \) Spacing of sprinklers on lateral (ft),
\(M = \) Spacing of laterals on main line (ft), and
\(96.3 = \) a constant used as a conversion factor

**Example 16**

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

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

**How Much Water per Acre**

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

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

**Troubleshooting**

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

**Example 17**

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

• the total irrigation time, and
• when (and for how long) to inject the herbicide.

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

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

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

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

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

Therefore:

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

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

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

Step 5: Determine the Injection Rate in Gallons per Hour

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

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

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

Example 18

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

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

Step 6: Determine the Injection Pump Setting

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

\[
\text{Pump setting} = \frac{\text{Injection rate}}{\text{Pump capacity}}
\]

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

Example 19

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

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

Calibrating a Drip/Trickle System

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

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

Step 1: Determine the Size of the Treated Area

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

If your field is rectangular, you can calculate the area if you know:

- the length of the field, and
- the width of the field.

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

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

**Example 20**

A rectangular field is 250 feet wide and 800 feet long. What is the area of the field? Follow the steps below.

1. Make sure you express both dimensions in feet. If either or both distances are not in feet, convert them to feet. In this case, both dimensions are expressed in feet:
   - Length = 800 feet
   - Width = 250 feet

2. Calculate the area of the rectangular field. Multiply the length of the field by its width.
   \[
   \text{Area of a rectangular field} = \text{length} \times \text{width} = 800 \text{ ft} \times 250 \text{ ft} = 200,000 \text{ sq ft}
   \]

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

   \[
   \text{Acreage of rectangular field} = \frac{\text{Square footage of the field}}{43,560 \text{ sq ft per acre}} = \frac{200,000 \text{ sq ft}}{43,560 \text{ sq ft per acre}}
   \]
Therefore, you know that the size of the treated field is 4.59 acres.

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

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

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

You must know:

• broadcast rate per acre,
• row spacing, and
• bandwidth.

Example 21

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

\[
\frac{\text{Amount of pesticide needed}}{\text{per acre of field}} = \frac{12 \text{ in}}{36 \text{ in}} \times \frac{2 \text{ qt per acre}}{2 \text{ qt per acre}}
\]

\[
= \frac{0.67 \text{ qt per acre of field}}{\text{per acre}}
\]

Step 3: Determine the Total Amount of Pesticide You Need

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

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

Example 22

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

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

\[
= \frac{4.59 \text{ acres}}{4.59 \text{ acres}} \times 0.67 \text{ qt per acre}
\]

\[
= 3.08 \text{ qt}
\]

Step 4: Determine the Injection Time

As with a stationary sprinkler system, you will inject the pesticide during only part of the irrigation. Therefore, you need to decide when to inject the pesticide into your drip/trickle system and for how long. First, you must determine three factors:

• the flow rate of the emitters (in gph),
• the total amount of water needed, and
• the total irrigation time.

Flow Rate of the Emitters

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

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

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

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

### Example 23

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

\[
\text{Flow rate (gph)} = \text{Fluid oz per min} \times 0.47 = 2.13 \text{ fl oz per min} \times 0.47 = 1.0 \text{ gph}
\]

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

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

\[
\text{Flow rate (gph per acre of field)} = \frac{\text{gph per emitter}}{\text{Number of emitters per acre of field}} = 1.0 \times 1,000 = 1,000 \text{ gph}
\]

### Total Amount of Water Needed

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

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

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

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

### Example 24

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

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

\[
\text{Total water needed (in) per acre} = \frac{12 \text{ in}}{36 \text{ in}} \times \frac{1}{2} \text{ acre-inch} = 0.167 \text{ in}
\]

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

\[
\text{Total water needed (gal) per acre} = 0.167 \text{ in} \times 27,152 = 4,534 \text{ gal}
\]

### Total Irrigation Time

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

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

### Example 25

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

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

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

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

### Injection Time

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

#### Example 26

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

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

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

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

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

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

#### Example 27

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

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

Finally,

\[ \text{Injection rate (gph)} = \frac{9 \text{ gallons}}{1 \text{ hr}} = 9 \text{ gph} \]

### Step 6: Determine the Injection Pump Setting

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

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

As noted earlier in step 6 in “Calibrating a Center Pivot System” on page 8, this is only a rough estimate. You will probably have to adjust your setting for most accurate results.
Example 28

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

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

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

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

\[
= 18\%
\]

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

A. First, figure the area of the circle in square feet.

Area of the circle = \pi \times \text{length of the radius squared}

\begin{align*}
&= 3.14 \times (1,000 \text{ ft})^2 \\
&= 3,140,000 \text{ sq ft}
\end{align*}

Then, convert the area from square feet to acres.

\text{Acreage of the circle} = \frac{\text{square footage of circular field}}{43,560 \text{ sq ft per acre}}

\begin{align*}
&= \frac{3,140,000 \text{ sq ft}}{43,560 \text{ sq ft per acre}} \\
&= 72.1 \text{ acres}
\end{align*}

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

A. First, figure the area of the triangle in square feet.

Area of the triangular field = \frac{\text{base} \times \text{height}}{2}

\begin{align*}
&= \frac{400 \text{ ft} \times 225 \text{ ft}}{2} \\
&= 45,000 \text{ sq ft}
\end{align*}

Then, convert the area from square feet to acres.

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

\begin{align*}
&= \frac{45,000 \text{ sq ft}}{43,560 \text{ sq ft per acre}} \\
&= 1.03 \text{ acres}
\end{align*}

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

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

A. 

Total pesticide needed = Area treated (in acres) \times Application rate

= 72.1 acres \times 1.5 pints per acre

= 108.2 pints

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

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

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

A. 

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

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

A. 

\[
\text{Revolution time} = \frac{\text{Circumference (ft)}}{\text{Travel speed (fpm)}} = \frac{7,536 \text{ ft}}{5.0 \text{ fpm}} = 1,507 \text{ min per revolution}
\]

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

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

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

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

A. If you change your speed settings.

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

A. 

\[
\text{Injection rate (gph)} = \frac{\text{Total amount of product needed (gal)}}{\text{Injection time (hr)}} = \frac{13.5 \text{ gal}}{25.1 \text{ hr}} = 0.54 \text{ gph}
\]

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

A. 

\[
\text{Pump setting (% of capacity)} = \frac{\text{Injection rate}}{\text{Pump capacity}} = \frac{0.54 \text{ gph}}{4 \text{ gph}} = 14%
\]

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

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

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

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

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

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

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

Then, convert the area from square feet to acres.

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

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

\[
= 6.4 \text{ acres}
\]

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

A. Use this formula:

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

where gpm = Average sprinkler flow rate (gpm),

L = Spacing of sprinklers on lateral (ft),

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

96.3 = a constant used as a conversion factor

So,

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

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

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

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

A. 

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

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

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

A. During the first 2.1 hours of irrigation:

First half of irrigation time = \( \frac{4.2 \text{ hr}}{2} \)  
= 2.1 hr

**Q 23.** The injection rate for your stationary sprinkler system is 24 gph. If your injection pump has a capacity of 50 gph, what is the initial setting for the pump?

A. Pump setting (% of capacity) = Injection rate \( \frac{24 \text{ gph}}{50 \text{ gph}} \)  
= 48%

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

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

A. First, figure the area of the rectangle in square feet.

\[
\text{Area of a rectangular field} = \text{Length} \times \text{Width} \\
= 800 \text{ ft} \times 350 \text{ ft} \\
= 280,000 \text{ sq ft}
\]

Then, convert the area from square feet to acres.

\[
\text{Acreage of rectangular field} = \frac{\text{Square footage of the field}}{43,560 \text{ sq ft per acre}} \\
= \frac{280,000 \text{ sq ft}}{43,560 \text{ sq ft per acre}} \\
= 6.4 \text{ acres}
\]

**Q 25.** You are treating part of a field using a drip/trickle system. Your row spacing is 36 inches, and the target area is a 12-inch band along the row. The label of your soil fungicide gives a broadcast rate of 2 quarts of product per acre. How much fungicide will you apply per acre of field?

A. Amount of pesticide needed per acre of field = \( \frac{\text{Bandwidth}}{\text{Row spacing}} \times \frac{\text{Broadcast rate per acre}}{2 \text{ qt per acre}} \)  
= \( \frac{12 \text{ in}}{36 \text{ in}} \times \frac{2 \text{ qt per acre}}{\text{acre}} \)  
= 0.67 qt per acre of field

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

A. Flow rate (gph) per emitter = Fluid oz per min \( \times \) 0.47  
= \( 2.13 \text{ fl oz per min} \times 0.47 \)  
= 1.0 gph

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

A. First, determine the total water needed in inches per acre.

\[
\text{Total water needed (in)} = \frac{\text{Bandwidth}}{\text{Row spacing}} \times \text{Label amount} \\
= \frac{\text{in}}{\text{acre}} \times \text{in per acre}
\]
\[ \frac{12 \text{ in}}{36 \text{ in}} \times \frac{1}{2} \text{ acre-inch} = 0.167 \text{ in} \]

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

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

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

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

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

A.

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

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

\[ = 4.534 \text{ hr} \]

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

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

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

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

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

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

\[ = 16\% \]

You would use 16\% of capacity as your first calibration attempt.
Appendix A. Conversions
Factors
Appendix A. Conversion Factors

As discussed in Unit 6 (Calibration), it is often necessary to compute equivalent measures for pesticides that are used in a chemigation application. The following chart will help you in performing quick conversions.

Today, many growers are using chemical proportioners or injectors. Various amounts of dry and liquid pesticides may be used, and many requests are now being received for equivalent measures, volumes, and dilutions. The following table may assist the grower in making such determinations.

**KEEP POSTED FOR READY REFERENCE WHEN NEEDED**

<table>
<thead>
<tr>
<th>Conversion Factor</th>
<th>Equivalent Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 teaspoon</td>
<td>5 cc or ml*</td>
</tr>
<tr>
<td>1 tablespoon</td>
<td>3 teaspoons = 1/2 fluid oz = 1/16 cup = 15 cc or ml*</td>
</tr>
<tr>
<td>1 fluid ounce per gallon</td>
<td>7,490 parts per million</td>
</tr>
<tr>
<td>1 ounce</td>
<td>28.35 grams</td>
</tr>
<tr>
<td>1 pound</td>
<td>453.6 grams = 0.12 gallons (water)</td>
</tr>
<tr>
<td>1 fluid ounce</td>
<td>2 tablespoons = 29.6 cc or ml</td>
</tr>
<tr>
<td>1 cup</td>
<td>8 fluid oz = 1/2 pint = 16 tablespoons = 48 teaspoons = 236.5 cc or ml</td>
</tr>
<tr>
<td>1 pint</td>
<td>16 fluid oz = 32 tablespoons = 1 lb water = 473 ml</td>
</tr>
<tr>
<td>1 quart</td>
<td>2 pints = 4 cups = 32 fluid oz = 64 tablespoons = 946 ml = 0.946 liters</td>
</tr>
<tr>
<td>1 gallon</td>
<td>4 quarts = 3.785 liters = 8.34 lbs (water) = 0.133 cu ft = 8 pints = 16 cups = 128 fluid oz</td>
</tr>
<tr>
<td>1 cubic foot</td>
<td>0.80357 bushels = 7.48 gallons = 62.4 lbs (water)</td>
</tr>
<tr>
<td>1 bushel</td>
<td>1.25 cubic feet = 2,150.4 cubic inches = 35.24 liters</td>
</tr>
<tr>
<td>1 cubic yard</td>
<td>22 bushels = 27 cubic feet</td>
</tr>
</tbody>
</table>

50 square feet of bench or bed area x 6 inches deep = 25 cubic feet or 20 bushels = little less than 1 cubic yard

* Usually these will be about 6 and 18 cubic centimeters, respectively, because the surface tension of liquids will not permit a level measurement.

The following equations are useful for chemigation calibration:

27,000 gallons = 1 acre-inch
450 gallons/minute = 1 acre-inch/hour

**Test Plot Conversion Tables**

<table>
<thead>
<tr>
<th>Concentration (ppm)</th>
<th>Equivalent Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 part per million</td>
<td>1 milligram/liter</td>
</tr>
<tr>
<td></td>
<td>= 1 milligram/kilogram</td>
</tr>
<tr>
<td></td>
<td>= .001 percent</td>
</tr>
<tr>
<td></td>
<td>= .013 ounces in 100 gal of water</td>
</tr>
<tr>
<td>0.1 percent</td>
<td>1,000 ppm = 1,000 milligrams/liter</td>
</tr>
<tr>
<td>0.01 percent</td>
<td>100 ppm = 100 milligrams/liter</td>
</tr>
<tr>
<td>0.001 percent</td>
<td>10 ppm = 10 milligrams/liter</td>
</tr>
<tr>
<td>0.0001 percent</td>
<td>1 ppm = 1 milligram/liter</td>
</tr>
</tbody>
</table>

PAGE 80 EDITED 5-19-2010.
Appendix B. List of Alternative Chemigation Safety Equipment
Appendix B. List of Alternative Chemigation Safety Equipment

As discussed in Unit 5 (Backflow Prevention), the labels of pesticides that may be chemigated must include all required backflow prevention devices. In certain cases, however, approved alternative devices may be used. A list and discussion of this alternative safety equipment follow.

BACKGROUND: In March 1987, the U.S. Environmental Protection Agency issued PR Notice 87-1, a set of rules for improving directions on labels of agricultural pesticides intended for application through irrigation systems. The Notice said that labels of such pesticides must require the use of certain types of safety devices to protect groundwater from pesticide contamination. The Agency later approved alternatives to some of the required devices specified in PR Notice 87-1. The alternative devices, in some situations, may be less expensive, more reliable, or more available than those devices originally required. However, if there is no approved alternative for a required device, then the required device must be used.

Listed below are the original devices specified in PR Notice 87-1 and their corresponding alternatives.

Original Device

Functional normally-closed, solenoid-operated valve located on the intake side of the injection pump.

Alternative Device 1

Functional spring-loaded check valve with a minimum of 10 psi cracking pressure—The valve must prevent irrigation water under operating pressure from entering the pesticide injection line and must prevent leakage from the pesticide supply tank on system shutdown. This valve must be constructed of pesticide-resistant materials. (Note: this single device can substitute for both the solenoid-operated valve and the functional automatic quick-closing check valve in the pesticide injection line.)

Alternative Device 2

Functional normally-closed hydraulically-operated check valve—The control line must be connected to the main waterline such that the valve opens only when the main waterline is adequately pressurized. This valve must prevent leakage from the pesticide supply tank on system shutdown. The valve must be constructed of pesticide-resistant materials.

Alternative Device 3

Functional vacuum-relief valve located in the pesticide injection line between the positive-displacement pesticide injection pump and the check valve—This alternative is allowed only for those chemigation systems using a positive-displacement pesticide injection pump; it is not for use with venturi injection systems. This valve must be elevated at least 12 inches above the highest fluid level in the pesticide supply tank and must be the highest point in the injection line. The valve must open at 6 inches water vacuum or less and must be spring-loaded or otherwise constructed such that it does not leak on closing. It must prevent leakage from the pesticide supply tank on system shutdown. The valve must be constructed of pesticide-resistant materials.

Original Device

Functional main waterline check valve and main waterline low-pressure drain.

Alternative Device 1

Gooseneck pipe loop located in the main waterline immediately downstream of the irrigation water pump—The bottom side of the pipe at the loop apex must be at least 24 inches above the highest sprinkler or other type of water-emitting device. The loop must contain either a vacuum-relief or combination air–and–vacuum-relief valve at the apex of the pipe loop. The pesticide injection port must be located downstream of the apex of the pipe loop and at least 6 inches below the bottom side of the pipe at the loop apex.
Original Device

Positive-displacement pesticide injection pump.

Alternative Device 1

Venturi systems (including those inserted directly into the main waterline, those installed in a bypass system, and those bypass systems boosted with an auxiliary water pump)—Booster or auxiliary water pumps must be connected with the system interlock such that they are automatically shut off when the mainline irrigation pump stops or, in cases where there is no mainline irrigation pump, when the water pressure decreases to the point where pesticide distribution is adversely affected.

Venturi devices must be constructed of pesticide-resistant materials. The line from the pesticide supply tank to the venturi must contain a functional automatic quick-closing check valve to prevent the flow of liquid back toward the pesticide supply tank. This valve must be located immediately adjacent to the venturi pesticide inlet. This same supply line must also contain either a functional normally-closed solenoid-operated valve connected to the system interlock or a functional normally-closed hydraulically-operated valve that opens only when the main waterline is adequately pressurized.

In bypass systems, as an option to placing both valves in the line from the pesticide supply tank, the check valve may be installed immediately downstream of the venturi water outlet.

Original Device

Vacuum-relief valve.

Alternative Device 1

Combination air–and–vacuum-relief valve.
**Pesticide Risk Reduction Education** is a program of the College of Tropical Agriculture and Human Resources of the University of Hawaii at Manoa. It receives funding from the U.S. Environmental Protection Agency via the U.S. Department of Agriculture’s Pesticide Safety Education Program. Its staff provides study guides, short courses, and a newsletter for Hawaii’s applicators of restricted use pesticides. These education and training activities support the State of Hawaii Department of Agriculture’s program for certification of applicators of restricted use pesticide.

**Pesticide Risk Reduction Education**  
http://pestworld.stjohn.hawaii.edu/epp/pat.html

**Certification of Restricted Use Pesticide Applicators**  
http://hawaii.gov/hdoa/pi/pest/pesticide-applicator-certification-recertification