

State of California  
Department of Pesticide Regulation

# Pest Control Aircraft Pilot Study Guide

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**For the Following Commercial  
Pesticide Applicator Examinations:**

Apprentice Pest Control Aircraft Pilot Certificate  
Journeyman Pest Control Aircraft Pilot Certificate



This publication resulted from a contract  
between the Pest Management and Licensing Branch of the  
Department of Pesticide Regulation  
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# Introduction

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This manual is written for pilots who intend to become certified to operate an aircraft in California to conduct pest control with pesticides or by releasing predatory or beneficial insects. If you make aerial pest control applications for hire to property you do not own or control, or if you work for a commercial pest control business that makes pest control applications for hire, you fall within the **commercial applicator** category and you must successfully pass the **Apprentice Pest Control Aircraft Pilot Certificate** (AP) or **Journeyman Pest Control Aircraft Pilot Certificate** (JP) examinations. If you plan to make aerial pest control applications as a pilot, and only to land that you own or manage, you still fall within the **commercial applicator** category. For both of these situations, you must take the Apprentice examinations and be supervised by a journeyman pilot until you qualify for, and pass, the Journeyman examination.

## THE EXAMINATIONS

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California regulations require a pilot who performs aerial pest control to satisfactorily pass the **Law and Regulations and Basic Principles** examination as well as the **Apprentice Pest Control Aircraft Pilot Certificate** examination before taking the **Journeyman Aircraft Pest Control Aircraft Pilot Certificate** examination. To begin this process, you must complete the examination application and submit this, along with the examination fees, to the Department of Pesticide Regulation (DPR). You can download application materials from the DPR website at <http://www.cdpr.ca.gov/docs/license/lcforms.htm>, or you may obtain these materials from a county agricultural commissioner's office.

**The Laws, Regulations, and Basic Principles Examination.** The Laws, Regulations, and Basic Principles Examination tests your knowledge and skills in working with, handling, and applying pesticides in general. The following two study manuals are recommended for preparing for this examination:

- **The Laws and Regulations Study Guide.** This manual may be downloaded from the DPR website at <http://www.cdpr.ca.gov/docs/license/lcpubs.htm>. You

may also purchase a copy from the Department of Pesticide Regulation, Pest Management and Licensing Branch, 1001 I Street, P.O. Box 4015, Sacramento, CA 95812-4015. Phone (916) 445-4038 (see further information on ordering this study guide in Chapter 1).

- ***The Safe and Effective Use of Pesticides, Second Edition.*** (UC ANR Publication #3324). This manual may be purchased from the University of California, ANR Publications, 6701 San Pablo Avenue, Oakland, CA 94608. Phone (800) 994-8849. On line orders may be placed at <http://anrcatalog.ucdavis.edu/InOrder/Shop/Shop.asp>.

## SCOPE OF THIS MANUAL

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This manual focuses on the skills and knowledge needed to safely and properly apply pesticides with an aircraft. It covers all the information found on the private and commercial Aircraft Pilot Pest Control Certificate examinations. It consists of the following nine chapters:

- Chapter 1. ***Laws and Regulations for the Aerial Applicator***—an overview of the federal and California state laws and regulations pertaining to pilots involved in the aerial pest control.
- Chapter 2. ***Pest Management***—concepts of managing pests and how aerial pest control fits into pest management programs.
- Chapter 3. ***Pesticide Safety***—a review of the hazards associated with pesticide handling and application, the ways these hazards can be mitigated, and the emergency procedures to follow in case of spills or accidents.
- Chapter 4. ***Safe Pesticide Handling Techniques***—ways pesticides must be applied, handled, stored, and transported to protect people and the environment.
- Chapter 5. ***Aerial Pesticide Dispersal Systems***—descriptions and functions of the systems used to apply liquids and granules by aircraft.
- Chapter 6. ***Aerial Application Guidance Systems***—descriptions and uses of systems used by pilots to make precise aerial pest control applications.
- Chapter 7. ***Preparing for an Aerial Application***—steps pilots must take to plan for and carry out efficient and effective aerial pest control applications.
- Chapter 8. ***Calibrating Aerial Application Equipment***—procedures to use to accurately calibrate liquid and granule application equipment used on aircraft.
- Chapter 9. ***Aerial Application Technology***—methods of making aerial application of pesticides, including managing offsite pesticide drift.

## HOW TO USE THIS MANUAL

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Since this manual is a study guide, each chapter is followed by a series of review questions to help you test your comprehension of the concepts presented. These review questions are similar to the types of questions you will find on the DPR examinations, so they will also help you become familiar with the examination process.

It is suggested that you read a chapter and then test your comprehension of the material by answering the review questions. Check your answers with the answer sheet on page 178, then go back and review the sections of the chapter pertaining to the questions you were unable to answer correctly. Repeat this process with each of the chapters.

Some of the information presented in this manual may be outside of the scope of knowledge or skills expected of pilots, but the information may prove to be interesting or useful. This type of information has been put into sidebars for supplemental reading.

## WHAT KNOWLEDGE AND SKILLS ARE EXPECTED OF PILOTS

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The examinations for Pest Control Aircraft Pilot certification are based on a set of ***performance objectives*** that have been established by a panel of experienced aerial pest control pilots and pesticide regulatory agency personnel. These performance objectives reflect the basic knowledge and skills and the legal requirements needed by an entry-level pilot who plans to make pest control applications by air. Table 1 is a listing of these performance objectives. The performance objectives listed in ***italics*** on this list are covered in the Laws, Regulations, and Basic Principles examination, so they will either not be discussed in this study guide or will be reviewed briefly.

Table 1

## Aerial Applicator Performance Objectives

Performance Objectives in *Italics* are covered in the *Laws and Regulations and Basic Principles* examination)

### Laws and Regulations Pertaining to Aerial Application

#### A. California and Federal Regulations

1. Know the sections of California laws and regulations, and federal regulations that deal with aerial application
  - a. Understand requirements for DPR's aerial applicator license/certificate
  - b. Understand regulations covering aerial application including restrictions relating to hazardous materials
  - c. Understand label and state restrictions relating to flying height of applications
  - d. ***Be aware of congested areas and restrictions and understand differences between FAR part 91 and 137***

#### B. Pesticide Label Restrictions

1. Recognize that pesticide product labels may or may not provide information on aerial application and may have restrictions regarding aerial applications, such as sensitive areas, buffer zones, and California restricted materials
  - a. Identify where to get information on local restrictions relating to aerial applications
  - b. Interpret label instructions that provide information on aerial uses of pesticides
  - c. Identify how to interpret labels that have no reference to aerial uses
  - d. Understand what "spray quality" means

### Pest Management

#### A. Vegetation Control

1. Know the types of pest management information about which aerial applicators should be knowledgeable and where to obtain the information
  - a. ***Know what a weed is and identify it***
  - b. ***Understand weed classification and weed life cycles***
  - c. ***Understand the importance of applying herbicides at the correct plant growth stage***
2. ***Know how herbicides are classified***
  - a. ***Understand the differences between selective and nonselective herbicides***
  - b. ***Understand the differences between contact and systemic herbicides***
  - c. ***Understand the differences between preplant, preplant incorporated, preemergence, post plant/preemergence, and post emergence herbicides***
  - d. ***Understand the differences between non-residual and residual herbicides***
3. ***Recognize the factors that affect herbicide effectiveness***

(continued on next page)



(Table 1, continued)

- a. *Understand how leaf shape and surface affect herbicide effectiveness*
- b. *Understand how weather conditions affect herbicide effectiveness*
- c. *Understand how weed growth stage and age affect herbicide effectiveness*
- d. *Understand how soil type affects herbicide action*
- e. *Understand how soil moisture affects herbicide action*
- f. *Understand how cultural activities affect herbicide action*
- g. *Understand the concepts of herbicide tolerance and herbicide resistance*

B. Insect and Mite Control

1. *Recognize characteristics of pest insects and mites*
  - a. *Know basic features used to identify insects and mites*
  - b. *Understand general insect and mite growth cycles*
  - c. *Understand growth stages of mites and insects in order to achieve optimum control*
  - d. *Understand that different classes of insecticides work on different insect life stages*
  - e. *Recognize that different classes of insecticides work on different types of insects (piercing, sucking vs. chewing, etc.)*
2. *Know how different classes of insecticides and miticides work*
3. *Recognize factors that affect insecticide and miticide effectiveness*

C. Plant Disease Control

1. *Recognize what can cause plant disease symptoms*
  - a. *Understand why you need to correctly identify the cause of plant disease symptoms*
  - b. *Know environmental conditions that can stress plants and cause abnormal growth or disease-like symptoms*
  - c. *Understand why it is necessary to recognize and relieve environmental stress on plants*
2. *Recognize pest organisms that can cause plant diseases*
  - a. *Understand that plant disease identification is based on symptoms and laboratory tests*
  - b. *Understand the general characteristics of fungi that cause plant diseases*
  - c. *Understand how most fungi reproduce and how they cause plant diseases*
  - d. *Understand the general characteristics of bacteria that cause plant diseases*
  - e. *Understand what a virus is and the types of plant diseases they cause*
  - f. *Understand what nematodes are and how they cause plant diseases*
3. *Know conditions necessary for a plant disease to develop*

(continued on next page)

(Table 1, continued)

4. *Understand how plant diseases can be controlled*

- a. *Understand how protectant fungicides work*
- b. *Understand how eradicant fungicides work*
- c. *Understand how systemic fungicides work*
- d. *Understand factors that affect fungicide effectiveness*

D. Aerial Application of Pesticides as a Component of Pest Management Programs

1. Recognize the general requirements for effective pest management through aerial application of pesticides
  - a. Understand the advantages and limitations of applying herbicides by air for vegetation and weed management
  - b. Understand the advantages and limitations of applying insecticides and miticides by air for controlling insect and mite pests
  - c. Understand the advantages and limitations of applying fungicides by air for controlling or suppressing plant-infecting organisms
2. Understand the long-term objectives of integrated pest management (IPM) programs

**Pesticide Application Safety**

A. Mixing and Loading

1. Know how to work safely around aircraft when mixing and loading pesticides
  - a. Describe the main considerations for mixing and loading operations
  - b. Describe the basic requirements for mixing and loading equipment
  - c. Understand what is meant by a closed mixing system
  - d. Understand the safety features required for mixing and loading equipment
  - e. Identify when pesticides should be mixed and the order of mixing pesticides in a tank mix
  - f. Identify the general features of dry loading equipment
  - g. Identify who should be responsible for ensuring mixers are trained, ensuring that the pesticide is registered for aerial use, and that mixing instructions are available

B. Pilot's Equipment

1. Understand the personal protective equipment (PPE) requirements for pilots when entering and exiting aircraft, cleaning windshields, making nozzle adjustments and performing other tasks outside of the cockpit that requires contacting contaminated equipment

C. General

1. Know safe pre-application procedures for aerial application
  - a. Recognize the importance of safe operating procedures for everyone involved in an aerial application operation

(continued on next page)

(Table 1, continued)

- b. Describe the safety requirements for the person performing mixing and loading tasks, including where to walk around the aircraft
  - c. Describe the requirements for pilot and crew personal habits – including physical and mental alertness and the use of alcohol and drugs
  - d. Understand the requirements for regular aircraft and application equipment maintenance
2. Know the most serious hazards associated with aerial application and how to reduce these risks

#### D. Protecting the Environment, Sensitive Areas, and the Public

- 1. Recognize ways to prevent harmful environmental effects to agricultural land and sensitive areas while making aerial applications
- 2. Know how to protect people from exposure during an aerial application

#### E. Emergency Procedures

- 1. Recognize the reasons for most accidents in aerial application and understand how accidents can be reduced
- 2. Know why load jettison may be required and understand its effects on the aircraft
- 3. Know pilot procedures if an aircraft crashes
- 4. Know ground crew procedures if an aircraft crashes

### Application Technology

#### A. Know safe application techniques that must be practiced by the pilot

- 1. Understand how to avoid exposure to spray during an application
- 2. ***Understand the flight dynamics of application techniques***
- 3. Understand the importance of allowing sufficient time for making turns during an application
- 4. Know how to recognize obstacles in and around the field being sprayed
- 5. Understand the importance of looking back and looking forward during applications
- 6. Understand the importance of flying contours when making applications on uneven terrain
- 7. Understand the safety precautions when flying under wires

#### B. Dispersal and Guidance Systems

- 1. Know what an aerial application dispersal system is and its general specifications
  - a. Be familiar with the major components of dispersal systems
  - b. Understand the necessary requirements for hoppers and tanks
- 2. Recognize the various types of spray pumps and how they are powered
  - a. Understand the features and advantages of fan driven pumps
  - b. Understand the importance of proper placement of fan driven pumps

(continued on next page)

(Table 1, continued)

- c. Understand the features and advantages of hydraulic pumps
- 3. Know where filters should be located in the system, their function, and when to clean them
- 4. Know where pressure gauges should be positioned and how they should be checked for accuracy
- 5. Understand the purpose of dry break couplings and how they function
- 6. Understand the purpose of check valves or positive shut off valves on nozzles
- 7. Understand the purpose of a suck back spray valve and how it functions
- 8. Understand the requirements for pipes, hoses, and fittings in an aerial dispersal system
- 9. Understand the requirements for spray booms and boom couplings
- 10. Know what spray nozzles do and identify the main types of nozzles
  - a. Know how to select the correct type and number of nozzles based on the required spray output and the manufacturer's specified flow rates
  - b. Know which factors must be considered when selecting nozzles
  - c. Understand how droplet size varies for a given nozzle setup
  - d. Know what factors affect nozzle wear
  - e. Understand proper nozzle orientation and placement
- 11. Understand how electronic flow meters work
- 12. Understand how typical dry material spreaders work and be familiar with their components
- 13. Know the various types of navigation and swath guidance systems
  - a. Be familiar with smoke generators
  - b. Be familiar with global positioning systems

#### C. Application Procedures

- 1. Understand back and forth and racetrack application patterns and when they are typically used
- 2. Know the importance of field exit and entry angles when making applications
- 3. Understand why speed during an application should be constant
- 4. Understand what trimming runs or headland passes are and when they should be used
- 5. Know the importance of the first and last flights of the day
- 6. Know the standard precautions for ferrying to and from a treatment site
- 7. Know what to check after arriving at a treatment site and before beginning applications
- 8. Understand the guidelines to observe during an application
- 9. Know the methods to use to ensure that the correct number of swaths is treated

(continued on next page)

(Table 1, continued)

#### D. Swath Characteristics

1. Understand what a uniform distribution pattern is
2. Understand what a triangular distribution pattern is
3. Understand what a trapezoidal distribution pattern is
4. Know the differences between “total swath width” and “effective swath width”
5. Recognize the factors that affect swath characteristics
6. Understand how liquid swath characteristics can be determined
7. Understand how granular swath characteristics can be determined
8. Understand how changing the droplet size affects drift
9. Understand how droplet size is affected by increasing nozzle orifice size
10. Understand how pressure affects output and droplet size
11. Understand how granular swath width varies with airspeed and output rate
12. Recognize how airspeed affects the distribution of deposited material across the swath
13. Understand how height of application affects swath width
14. Understand how fixed wing aircraft wingtip vortices affect spray patterns
15. Know the procedure for determining the locations of the outboard nozzles on a spray boom
16. Know how propeller or rotor wake affects droplet distribution and how to compensate for this

#### E. Calibration

1. Understand the term “flow rate”
2. Understand why flow rate is calibrated and when calibration should be done
3. Know the formulae for calculating flow rates and output
4. Recognize what to check if flow rates are too high or too low

#### F. Meteorology

1. Know why weather should be monitored and of what in particular the pilot should be aware
2. **Understand the term “density altitude”**
3. **Understand how air density can affect aircraft engine power, takeoff and landing, rolls, and climb capability**
4. **Understand how air density varies with temperature, pressure, and humidity**
5. Understand the problems associated with wind shift

#### G. Drift and Offsite Pesticide Movement Control

1. Know the hazards from offsite pesticide drift

(continued on next page)

(Table 1, continued)

2. Recognize ways that offsite drift problems can be minimized
3. Understand the classification of droplet sizes and the importance of droplet size with respect to drift and coverage
4. Recognize which types of pesticides can be applied with larger droplet sizes and which require smaller droplet sizes
5. Know the definition of VMD (volume median diameter) and what this measurement is used for
6. Understand how orifice size, nozzle orientation, pump pressure, and nozzle placement on the boom affect droplet size and offsite pesticide drift
7. Understand how evaporation can affect droplet size and recognize what conditions promote evaporation
8. Know how to minimize offsite movement caused by evaporation
9. Understand how wind and thermals can affect drift and offsite movement
10. Know what an inversion is, how it can be identified, and how it can result in offsite movement

# 1

# Laws and Regulations for the Aerial Applicator

---

**A**erial applications of pesticides are regulated by state and federal laws (Figure 1.1). Because all pesticides can be hazardous under certain circumstances and have the potential to injure people or contaminate the environment, state and federal laws require certification of competent and highly qualified, skilled pilots. These pilots must work with well-trained and efficient ground crews to reduce the potential for injury to people and the environment.

Aerial pest control pilots working in California must be certified as an entry-level apprentice pilot before earning a journeyman-level certification. This certification is provided by the Department of Pesticide Regulation. Local county agricultural commissioners are authorized to impose additional aerial application restrictions or prohibit the use of specific pesticides if unmitigated hazards are present or regional conditions are such that they could increase potential risks.

Pesticide label information is dictated in part by federal and state regulatory requirements. Labels are legal documents with use directions and requirements that you must follow when making any pesticide application. They may impose restrictions on, or prohibitions of, aerial application methods.

## FEDERAL REGULATIONS

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Title 14 of the Code of Federal Regulations (14 CFR) contains the federal rules pertaining to aeronautics and space. The parts of 14 CFR most relevant to aerial applicators include:

- Part 61—Certification, Pilots and Flight Instructors
- Part 91—General Operating and Flight Rules
- Part 133—Rotocraft External-load Operations
- Part 137—Agricultural Aircraft Operations

The first three parts listed above (14 CFR 61, 14 CFR 91, and 14 CFR 133) pertain to all pilots; the fourth, 14 CFR 137, is specific to aerial pesticide applicators. It is useful to obtain copies of Parts 61, 91, and 133 to better understand the provisions of 14 CFR 137. All four parts are available from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402. There is a fee for each of these publications. Sidebar 1 gives the website addresses for downloading these publications free.

### Agricultural Aircraft Operations

The Federal Aviation Administration (FAA) Regulation Part 137 of the Code of Federal Regulations Title 14 (14 CFR 137) prescribes rules governing agricultural aircraft operations within the United States and the requirements for commercial and private Agricultural Aircraft Operator Certificates for those operations. This regulation consists of four subsections—general provisions, certification rule, operating rule, and records and reports.

FIGURE 1.1

State and Federal laws regulate the aerial application of pesticides. These laws also address the certification of commercial and private agricultural aircraft operators.



Regulations are constantly changing, so be sure to obtain the latest version of this regulation from the Internet or Superintendent of Documents. FAA inspectors administer the knowledge and skills test to agricultural aircraft operators applying for this certificate. The certificate holder then examines any pilots working for him or her under this certificate to ensure that they meet the standards of Part 137. This requirement does not meet the California Department of Pesticide Regulation requirements for California Pest Control Aircraft Pilot certification described on pages 20-23.

## General Provisions

Agricultural aircraft operation involves any operation of an aircraft for the purpose of:

- dispensing an *economic poison*
- dispensing other substances intended for plant nourishment, soil treatment, propagation of plants, or pest control
- engaging in dispensing activities directly affecting agriculture, horticulture, or forest preservation





## Sidebar 1

## Web Addresses for Downloading Free Publications

The Department of Pesticide Regulation *Laws and Regulations Study Guide*, California laws and regulations for pest control operations, and FAA regulations covering pilot and aerial applicator operations can easily be downloaded at no cost from the Internet.

- DPR Laws and Regulations Study Guide:  
<http://www.cdpr.ca.gov/docs/license/lcpubs.htm>
- California Code of Regulations, Title 3, Food and Agriculture Code-Pesticides and Pest Control Operations  
<http://www.cdpr.ca.gov/docs/inhouse/calcode/3ccrcovr.htm>
- 14 CFR 61 Certification: Pilots, Flight Instructors, and Ground Instructors:  
[http://www.access.gpo.gov/nara/cfr/waisidx\\_02/14cfr61\\_02.html](http://www.access.gpo.gov/nara/cfr/waisidx_02/14cfr61_02.html)
- 14 CFR 91 General Operating and Flight Rules:  
[http://www.access.gpo.gov/nara/cfr/waisidx\\_01/14cfr91\\_01.html](http://www.access.gpo.gov/nara/cfr/waisidx_01/14cfr91_01.html)
- 14 CFR 133 Rotorcraft External-load Operations:  
[http://www.access.gpo.gov/nara/cfr/waisidx\\_02/14cfr133\\_02.html](http://www.access.gpo.gov/nara/cfr/waisidx_02/14cfr133_02.html)
- 4 CFR 137 Agricultural Aircraft Operations:  
[http://www.access.gpo.gov/nara/cfr/waisidx\\_99/14cfr137\\_99.html](http://www.access.gpo.gov/nara/cfr/waisidx_99/14cfr137_99.html)

Using an aircraft to dispense live insects for pest control is not an **agricultural aircraft operation** under this federal regulation, but it is considered a pest control activity in California. Therefore, DPR requires you to possess a valid Pest Control Aircraft Pilot Certificate to dispense live insects for pest control.

An **economic poison** is any substance or mixture of substances used to prevent, destroy, repel, or mitigate pests such as insects and mites, rodents, weeds, nematodes, and fungi and other microorganisms. It is also any substance or mixture of substances intended for plant growth regulation, plant defoliation, or plant desiccation. Under this definition, pesticides are economic poisons.

In a public emergency, you may deviate from the operating rules of this FAA regulation to the extent necessary for relief and welfare activities approved by an agency of the United States or of a state or local government. You must send a report describing the incident where you deviated from the operating rules of this regulation to the nearest FAA District Office within 10 days after your operation took place. The report must describe the aircraft operation and the reasons for it.

## Operator Certification Rule

Pilots conducting agricultural aircraft operations must possess a valid Agricultural Aircraft Operator Certificate issued under the provisions of the 14 CFR 137 regulations. The only two exceptions to this rule are:

- federal, state, or local governments conducting agricultural aircraft operations using public aircraft
- pilots possessing a rotocraft external-load operator certificate under the provisions of 14 CFR 133 and only dispensing water on forest fires by rotocraft external-load means

You must apply for an Agricultural Aircraft Operator Certificate on a form and in a manner prescribed by the Federal Aviation Administration. You file this form with the FAA district office that has jurisdiction over the area in which your home base of operations is located.

You may not operate under a different business name than the one shown on your commercial Agricultural Aircraft Operator Certificate.

You must keep your Agricultural Aircraft Operator Certificate at your home base of operations and present it for inspection on the request of any federal, state, or local law enforcement officer. You are also required to allow FAA personnel to make inspections, including on-the-job inspections, at any time and place. The purpose of these inspections is to determine if you are in compliance with applicable regulations and with provisions of your Agricultural Aircraft Operator Certificate.

### Federal Certification Requirements

There are two types of federal Agricultural Aircraft Operator Certificates—one for private operator pilots and one for commercial operator pilots. Applicants for these certificates must meet the requirements listed below and successfully pass tests of knowledge and skills. An Agricultural Aircraft Operator Certificate is effective until it is surrendered, suspended, or revoked. The holder of an Agricultural Aircraft Operator Certificate that is suspended or revoked must return it to the FAA Administrator through the FAA district office that has jurisdiction over the area in which the certificate holder's home base of operations is located (Figure 1.2).

One basis for suspending or revoking a certificate would be if the holder of the certificate permits any aircraft owned or leased by him or her to be in violation of the general operating and flight rules (14 CFR 91), including carrying narcotic drugs, marijuana, and depressant or stimulant drugs or substances.

**Private Agricultural Aircraft Operator.** The applicant for a private Agricultural Aircraft Operator Certificate must:

- hold a current U.S. private, commercial, or airline transport pilot certificate and be properly rated for the aircraft to be used
- have at least one certified and airworthy aircraft, equipped for agricultural operations
- show, or have the person who is designated as the chief supervisor of agricultural aircraft operations for him or her show, that he or she has satisfactory knowledge and skill regarding agricultural aircraft operations



FIGURE 1.2

The Federal Aviation Administration (FAA) issues Agricultural Aircraft Operator Certificates to pilots who meet specific qualifications and intend to make aerial applications of pesticides.

**Commercial Agricultural Aircraft Operator.** The applicant for a commercial Agricultural Aircraft Operator Certificate must have available the services of at least one person who holds a current U.S. commercial or airline transport pilot certificate and is properly rated for the aircraft to be used. The applicant may be that person. In addition, the applicant must:

- have at least one certified and airworthy aircraft equipped for agricultural operations
- show, or have the person who is designated as the chief supervisor of agricultural aircraft operations for him or her show, that he or she has satisfactory knowledge and skill regarding agricultural aircraft operations

### Knowledge Test

Whether you are working towards a private or commercial Agricultural Aircraft Operator Certificate, you must show knowledge about the following:

- steps to be taken before starting operations, including surveying the area to be worked
- performance capabilities and operating limitations of the aircraft you will use
- safe flight and application procedures
- safe handling of economic poisons and the proper disposal of used containers for those pesticides (you are not required to demonstrate this knowledge if your operator certificate contains a prohibition against the dispensing of economic poisons)
- the general effects of pesticides on plants, animals, and people, with emphasis on those normally used in the areas of intended operations (you are not required to demonstrate this knowledge if your operator certificate contains a prohibition against the dispensing of economic poisons)
- the precautions to be observed in using pesticides (you are not required to demonstrate this knowledge if your operator certificate contains a prohibition against the dispensing of economic poisons)
- primary symptoms of poisoning of people from pesticides, the appropriate emergency measures to be taken, and how to contact poison control centers (you are not required to demonstrate this knowledge if your operator certificate contains a prohibition against the dispensing of economic poisons)

### Skills Test

You must successfully pass the skills test in your certified and airworthy aircraft that has been equipped for agricultural operations. You must perform the following maneuvers at that aircraft's maximum certificated takeoff weight, or the maximum weight established for a special purpose load, whichever is greater:

- short-field and soft-field takeoffs
- approaches to the working area
- flare-outs
- swath runs

- pull-ups and turnarounds
- rapid deceleration (quick stops) in rotary wing aircraft only

### Amending a Certificate

Your Agricultural Aircraft Operator Certificate may be amended:

- by the FAA Administrator
- upon application by you, the holder of that certificate

To amend your certificate, file an application with the FAA district office having jurisdiction over the area in which your home base of operation is located. Submit the application at least 15 days before the date that you propose for the amendment to become effective, unless that office approves a shorter filing period. The district office grants requests to amend certificates if it determines that safety in air commerce and the public interest allows this.

## Operating Rule

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No one may operate an aircraft for agricultural operations unless the aircraft is certified, airworthy, and equipped for agricultural operations. The aircraft must also be equipped with a suitable and properly installed shoulder harness for use by each pilot.

You must carry in the aircraft a copy of your Agricultural Aircraft Operator Certificate under which your operation is conducted. You must present this for inspection upon request by any federal, state, or local law enforcement officer. The registration and airworthiness certificates issued for the aircraft need not be carried in the aircraft. However, they must be available for inspection at the base from which your dispensing operation is conducted.

**Private Agricultural Aircraft Operator Limitations.** A person conducting an agricultural aircraft operation under the authority of a private Agricultural Aircraft Operator Certificate may not operate that aircraft

- for compensation or hire
- over a congested area
- over any property unless he or she is the owner or lessee of the property or has ownership or other property interest in the crop located on that property

### Manner of Dispensing Pesticides

It is illegal to dispense pesticides or other materials from an aircraft in a manner that creates a hazard to people or property. Pesticides that are dispensed from an aircraft must be used

- only for the use for which they are stated on the registered pesticide label
- according to any safety instructions or use limitations on their labels
- in accordance with any federal or state laws

The only exception to the above requirements is if the pesticide is being dispensed for experimental purposes under the supervision of a federal or state agency authorized by law to conduct research in the field of economic poisons, or under a permit issued by the U.S. Environmental Protection Agency (U.S. EPA).

## Personnel

The holder of an Agricultural Aircraft Operator Certificate must ensure that everyone working in the agricultural aircraft operation is informed of his or her duties and responsibilities for the operation. An individual who has met the knowledge and skill requirements listed on pages 14-16 must supervise the operation.

**Pilot in Command.** The pilot in command of an aircraft must hold a pilot certificate and meet the qualifications for a private operator pilot or commercial operator pilot. In addition, he or she must demonstrate to the holder of the Agricultural Aircraft Operator Certificate conducting the operation that he or she has met the knowledge and skill requirements listed on pages 14-16. If the holder of that certificate has designated a qualified person to supervise his or her agricultural aircraft operations, the demonstration must be made to that designated person. However, a demonstration of the knowledge and skill requirement is not necessary for any pilot in command who meets both of the following qualifications:

- at the time of the filing of an application by an agricultural aircraft operator, is working as a pilot in command for that operator; and
- has a record of operation under that applicant that does not disclose any question regarding the safety of his or her flight operations or his or her competence in dispensing agricultural materials or chemicals

## Class 'D' and Class 'E' Airspaces

Except for flights to and from a dispensing area, you may not operate an aircraft within Class 'D' Airspace, or within an associated, active, surface-based Class 'E' Airspace, unless you receive authorization for that operation from the control tower (Figure 1.3).

You may not operate an aircraft in weather conditions below visual flight rule (VFR) minimums within a surface-based Class 'E' Airspace unless you obtain authorization for that operation from the appropriate air traffic control facility. An aircraft receiving authorization from a control tower or air traffic control facility may be operated in an active Class 'E' Airspace under special VFR weather minimums without meeting the requirements of 14 CFR 91—General Operating and Flight Rules—during that operation.

## Airport Traffic Patterns

You may deviate from an airport traffic pattern when authorized to do so by the control tower for that airport. At an airport without a functioning control tower, you may deviate from the traffic pattern only if you

- coordinate your operation in advance with the airport management
- limit any deviations to the actual agricultural aircraft operation
- avoid landings and takeoffs on ramps, taxiways, or other areas of the airport not intended for such use (except for emergencies)
- keep the aircraft clear of, and give way to, aircraft conforming to the traffic pattern for the airport

An aircraft receiving authorization to deviate from an airport traffic pattern during an application operation is exempt from the airport traffic pattern requirements of 14 CFR 91—General Operating and Flight Rules—during that operation only.



FIGURE 1.3

You must receive authorization from the control tower if you operate an aircraft within a Class 'D' Airspace or associated, active, surface-based Class 'E' Airspace.

### Operation without Position Lights

You may operate an agricultural aircraft without position lights if prominent unlighted objects are visible for at least one-mile and takeoffs and landings at an airport with a functioning control tower are made only as authorized by the control tower operator. You may operate an aircraft without position lights at an airport not having a functioning control tower if prominent unlighted objects are visible for at least one mile and takeoffs and landings are made with the permission of the airport management and no other aircraft operations requiring position lights are in progress at that airport.

An agricultural aircraft receiving authorization to operate without position lights is exempt during these instances from meeting the position light requirements of 14 CFR 91—General Operating and Flight Rules.

### Operations over Non-Congested Areas

During the actual dispensing operation, including approaches, departures, and turn-arounds reasonably necessary for the operation, you may operate an aircraft over non-congested areas at altitudes below 500 feet above the surface. You can operate the aircraft closer than 500 feet from people, vessels, vehicles, and structures as long as you conduct the operations without creating a hazard to people or property on the surface. An agricultural aircraft being operated below 500 feet above the surface in non-congested areas is exempt from meeting the operating height requirements of 14 CFR 91—General Operating and Flight Rules, during dispensing operations.

### Operation over Congested Areas

You may operate an agricultural aircraft over a congested area at altitudes required for the proper accomplishment of the agricultural aircraft operation if you conduct the operation with the maximum safety to people and property on the ground. Before conducting an operation over a congested area, you must

- obtain written approval from the appropriate official or governing body of the political subdivision over which the operation is conducted
- submit a specific operation plan to the appropriate personnel of the Federal Aviation Administration District Office having jurisdiction over the congested area where you plan to conduct the operation. The plan must include consideration of obstructions to flight, the emergency landing capabilities of the aircraft, and details of any necessary coordination with air traffic control. The FAA District Office must approve this plan *before* beginning the operation.
- give notice of the intended operation to the public by some effective means, such as daily newspapers, radio, television, or door-to-door notification

Agricultural operations in congested areas are exempted from the congested area altitude restrictions of 14 CFR 91—General Operating and Flight Rules, during actual dispensing as long as you have obtained the necessary approvals and given notice to the public.

**Single Engine Aircraft.** Except when flying rotary wing aircraft, you may not take off a loaded aircraft or make a turnaround over a congested area.

You may not operate your aircraft over congested areas below the altitudes prescribed in 14 CFR 91—General Operating and Flight Rules, except during the actual dispensing

operation and approaches and departures necessary for that operation. You must operate the aircraft in a pattern and at such an altitude that you can land it in an emergency, without endangering people or property on the ground.

**Multi-Engine Aircraft.** When taking off a multi-engine airplane over a congested area, you must be able to bring the airplane to a safe stop within the effective length of the runway from any point during takeoff up to the time of attaining. In applying this requirement, you base takeoff data on still-air conditions. You do not correct for any uphill gradient of one percent or less when the percentage is measured as the difference in elevation between the ends of the runway divided by the runway's total length. For uphill gradients greater than one percent, the effective takeoff length of the runway is reduced 20 percent for each one-percent grade.

Using the accelerate/stop distance data, you must be able to stop the aircraft safely over the longest distance imposed by one of the following three conditions:

- with all engines operating at normal takeoff power
- 105 percent of the minimum control speed with the critical engine inoperative in the takeoff configuration
- 115 percent of the power-off stall speed in the takeoff configuration

The weight of a loaded multi-engine airplane must allow for a safe rate of climb with one engine inoperative. The rate of climb must be at least 50 feet per minute at an altitude of at least 1,000 feet above the elevation of the highest ground or obstruction within the area to be worked, or at an altitude of 5,000 feet, whichever is higher.

Under these conditions, it is assumed that

- the propeller of the inoperative engine is in the minimum drag position
- the wing flaps and landing gear are in the most favorable positions
- the remaining engine or engines are operating at the maximum continuous power available

It is illegal to operate any multi-engine aircraft over a congested area below the altitudes prescribed in 14 CFR 91—General Operating and Flight Rules, except during the actual dispensing operation and the approaches, departures, and turnarounds necessary for that operation.

**Pilots.** In order to operate an aircraft over a congested area, you must have at least

- 25 hours of pilot-in-command flight time in the make and basic model of the aircraft—at least 10 hours of which must have been acquired within the preceding 12 calendar months
- 100 hours of flight experience as pilot-in-command in dispensing agricultural materials or chemicals

**Aircraft.** The aircraft you operate over congested areas must

- have had, within the preceding 100 hours of time in service, a 100-hour or annual inspection by an authorized person, or have been inspected under a progressive inspection system
- be equipped with a device capable of jettisoning at least one-half of the aircraft's maximum authorized load of agricultural material within 45 seconds (helicopters are exempted from this requirement)



- have a means to prevent inadvertent release by the pilot or other crewmember if the aircraft is equipped with a device for releasing the tank or hopper as a unit

If the aircraft is a large or turbine-powered multi-engine civil airplane of U.S. registry, it must meet the above qualifications and have been inspected in accordance with the applicable inspection program requirements of 14 CFR 91—General Operating and Flight Rules.

## Records and Reports

For each operation conducted, the holder of a commercial Agricultural Aircraft Operator Certificate must maintain and keep, at the home base of operations designated in his or her application, the following records:

- name and address of the person for whom the agricultural aircraft services were provided
- date of the service
- name and quantity of the materials dispensed for the operation conducted
- name, address, and certificate number of each pilot used in that agricultural aircraft operation and the date each pilot met the knowledge and skill requirements

You must keep these records at least 12 months and make them available for inspection by federal authorities upon request.

**Change of Address.** As a holder of an Agricultural Aircraft Operator Certificate, you must notify the FAA in writing in advance of any change in the address of your home base of operations.

**Termination of Operations.** If you are the holder of an Agricultural Aircraft Operator Certificate and you cease operations, you must surrender your certificate to the FAA District Office last having jurisdiction over your operation.

## CALIFORNIA PEST CONTROL AIRCRAFT PILOT CERTIFICATION REQUIREMENTS

If you operate any aircraft in California for the purpose of pest control, you must possess a valid Pest Control Aircraft Pilot Certificate issued by the Department of Pesticide Regulation (Figure 1.4). This includes the following:

- pilots employed by a licensed Pest Control Business
- pilots employed by vector control agencies or districts
- pilots who perform pest control on their own property or property that they lease or manage (private applicators)

DPR issues two types of certificates for pilots: the Apprentice Pest Control Aircraft Pilot Certificate (AP) and the Journeyman Pest Control Aircraft Pilot Certificate (JP). Both of these certificates require passing a core commercial applicator examination, the DPR *Laws, Regulations, and General Principles* examination, and either the AP or the JP exami-



FIGURE 1.4

To make pesticide applications by air in California, a pilot must possess a valid Pest Control Aircraft Pilot Certificate issued by the Department of Pesticide Regulation.



nation. This manual is the study guide for the AP and JP examinations. All the requirements for the AP and JP certificates are described in the following section. The rest of this manual covers information that is included in the AP and JP examinations. The ***Laws and Regulations Study Guide*** may be downloaded free from the Internet at <http://www.cdpr.ca.gov/docs/license/lcpubs.htm>, or may be purchased from DPR by sending the Publication/Video Order Form (DPR-003) with payment to: Department of Pesticide Regulation, Attention: Publications, P.O. Box 4015, Sacramento, CA 95812-4015. Contact DPR or a local county agricultural commissioner office for the order form or download the order form from the Internet at <http://www.cdpr.ca.gov/docs/dprdocs/dpr003.pdf>.

To obtain applications for the certification exam and other information on requirements for aerial applicator pilot certification, visit the DPR website at <http://www.cdpr.ca.gov>. You can also obtain forms and information about exams and exam schedules from your local county agricultural commissioner office.

Table 1-1 summarizes the FAA and DPR requirements for the commercial or private agricultural operator, pilot in command, journeyman pest control aircraft pilot, and apprentice pest control aircraft pilot.

## Apprentice Pest Control Aircraft Pilot Certificate (AP)

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To qualify for taking the examinations for the Apprentice Pest Control Aircraft Pilot Certificate, you must

- have a valid FAA Commercial Pilot Certificate, or, if treating your own property, a valid FAA Private Pilot Certificate
- have a valid FAA Medical Certificate
- submit an application and initial application fee to the Department of Pesticide Regulation
- pay an examination fee for each of the two exams you must take

You must pass the ***Laws, Regulations, and Basic Principles*** and ***Apprentice Pest Control Aircraft Pilot*** examinations to earn the certificate.

**Additional Requirements.** You must work under the supervision of a Journeyman Pest Control Aircraft Pilot. Once you possess a valid Apprentice Pest Control Aircraft Pilot Certificate, you must accumulate at least 20 hours of approved continuing education every two years before renewing your certificate. You must meet the requirements for continuing education hours during the valid period of your certificate. Included in the 20 hours of continuing education are at least four hours pertaining to pesticide laws and regulations and at least four hours pertaining to aerial application techniques and/or aerial pest control equipment. DPR will inform you of the required number of continuing education hours if your initial certificate is issued for less than two years.

Before making an application, you must also register with the county agricultural commissioner each year in every county where you intend to perform aerial pest control applications.

Table 1.1

### Qualifications and Requirements that Are Needed for Each Level of the Agricultural Aerial Application Operation.

	Ag Aircraft Operator or Business Owner	Journeyman Pest Control Aircraft Pilot	Apprentice Pest Control Aircraft Pilot	Public Agency Hiring Pilot
FAA Commercial or Private Ag Operator Certificate	YES	NO	NO	NO
FAA Commercial or Private Pilot Certificate	NO	YES	YES	YES
FAA Skills and Knowledge Test	YES	Must Have Statement of Competency Issued by Operator	Must Have Statement of Competency Issued by Operator	NO
FAA Medical Certificate	NO	YES	YES	NO
DPR Laws and Regulations Exam	Must Hold QAL or Have QAL on Staff	YES	YES	NO
DPR Apprentice Pilot Exam	NO	YES	YES	NO
DPR Journeyman Pilot Exam	NO	YES	NO	NO
DPR Category Exams	Must Hold QAL or Have QAL on Staff	NO	NO	NO
Must Work Under Supervision of Journeyman Pilot	NO	NO	YES	NO

## Journeyman Pest Control Aircraft Pilot Certificate (JP)

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To qualify for taking the examination for the Journeyman Pest Control Aircraft Pilot Certificate, you must

- have a valid FAA Commercial Pilot Certificate, or, if treating your own property, a valid FAA Private Pilot Certificate
- have a valid FAA Medical Certificate
- have possessed, within the last two years, a valid California JP Certificate or AP Certificate for one year and have at least 150 hours in a fixed wing aircraft or at least 50 hours in a helicopter
- pay a fee for the Journeyman Pest Control Aircraft Pilot Examination

You must pass the Journeyman Pest Control Aircraft Pilot Examination to earn the certificate

**Additional Requirements.** Once you possess a valid Journeyman Pest Control Aircraft Pilot Certificate, you must accumulate at least 20 hours of approved continuing education every two years before renewing your certificate. You must meet the requirements for continuing education hours during the valid period of your certificate. Included in the 20 hours of continuing education are at least four hours pertaining to pesticide laws and regulations and at least four hours pertaining to aerial application techniques and/or aerial pest control equipment. DPR will inform you of the number of continuing education hours if your initial Journeyman Pest Control Aircraft Pilot Certificate is issued for fewer than two years.

You must also register with the county agricultural commissioner in each county where you intend to perform aerial applications. You must register each year before making any aerial pest control applications.

## CALIFORNIA LAWS AND REGULATIONS

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Laws are statutes passed by the California Legislature and signed by the Governor. Pesticide and pest control laws are found in the California Food and Agricultural Code (<http://www.leginfo.ca.gov/calaw.html>). The Director of DPR adopts regulations after they are approved by the Office of Administrative Law and filed with the Secretary of State.

Title 3 of the California Code of Regulations (3 CCR) deals with pesticides and pest control operations (<http://www.cdpr.ca.gov/docs/legbills/regshome.htm>). Regulations are designed to interpret and carry out the requirements of the laws. Sidebar 2 details the purposes of pesticide and pest control laws and regulations.

The county agricultural commissioner may adopt additional regulations applicable to his or her county. These supplement the regulations adopted by the Director of DPR and may govern the conduct of pest control operations as well as the records and reports of those operations. The Director of DPR must approve each regulation adopted by a county agricultural commissioner before it becomes operative.

Laws or regulations change when new situations arise that are not covered by existing laws and regulations. For example, pesticides and pesticide application equipment are constantly being improved or modified. Some improvements often require people to use pes-



FIGURE 1.6

The U.S. Environmental Protection Agency works with the California Department of Pesticide Regulation in assuring that pesticides are safely and legally used.

ticides differently. Pest problems and pest management techniques usually differ from year to year and affect how people use pesticides. In addition, as regulators identify new health and environmental problems, they create or modify laws or regulations to deal with them. For instance, the federal **Worker Protection Standard** was a change in the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) that strengthened requirements to protect people who handle pesticides or work in pesticide-treated areas.

**Enforcement Agencies.** The Director of the Department of Pesticide Regulation and the county agricultural commissioners are responsible for regulating all aspects of pesticide sales and use and protecting public health and the environment from any adverse effects that may occur from the legal use of pesticides. The county agricultural commissioners act under the direction and supervision of the Director of DPR. In any county that does not have a county agricultural commissioner, the Director of DPR may act as the agricultural commissioner.

Applicators who fail to comply with federal and state pesticide laws and regulations are subject to fines and/or imprisonment (Figure 1.5). They also face the possible loss or suspension of their applicator licenses or certificates. The offices of the State Attorney General or local district attorneys prosecute violators. In addition, county agricultural commissioners may issue citations and levy fines on violators of certain pesticide-use regulations. Sidebar 3 summarizes the responsibilities of DPR, county agricultural commissioners, and other state and federal government agencies.

**Cooperating Agencies.** Other state and federal agencies are involved in cooperative enforcement with DPR and the county agricultural commissioners. Federal agencies include:

- **U.S. Environmental Protection Agency (U.S. EPA).** The U.S. EPA is responsible for registering pesticides for specified uses, taking into consideration both safety and benefits (Figure 1.6). The U.S. EPA must register all pesticides before they are



## Sidebar 2

### Reasons for Pesticide Laws and Regulations

Pesticide laws and regulations are necessary in order to

- provide for the proper, safe, and efficient use of pesticides essential for the production of food and fiber and for protection of public health and safety
- protect the environment from environmentally harmful pesticides by prohibiting, regulating, or controlling uses of these pesticides
- assure agricultural and pest control workers of safe working conditions where pesticides are present
- permit agricultural pest control by competent and responsible licensees and permittees under strict control of the Director of the California Department of Pesticide Regulation and local county agricultural commissioners
- assure users that economic poisons are properly labeled and are appropriate for the use designated by the label
- encourage the development and implementation of pest management systems, stressing application of biological and cultural pest control techniques with selective pesticides when necessary to achieve acceptable levels of control with the least possible harm to nontarget organisms and the environment



FIGURE 1.5

Aerial applicators must comply with federal and state pesticide laws.

sold, held for sale, or distributed in commerce. The U.S. EPA also oversees and reviews state and county regulatory programs for compliance with federal requirements, including the federal Worker Protection Standard.

- **U.S. Food and Drug Administration (U.S. FDA).** The U.S. FDA is responsible for enforcing pesticide residue tolerances on food shipped in interstate commerce (Figure 1.7). As part of these activities, U.S. FDA regulates pesticide residue levels in domestically produced and imported foods. They also investigate incidents in which pesticide residue levels exceed the allowed tolerance levels on food.

In addition to DPR's role as the state lead agency in regulating all aspects of pesticide use, several other state agencies in California monitor and regulate pesticide use. These include the Department of Health Services, Air Resources Board, Department of Fish and Game, Department of Forestry, Occupational Safety and Health Administration, California Integrated Waste Management Board, Department of Water Resources, State Water Resources Control Board and Regional Water Control Boards, and the Department of Consumer Affairs' Structural Pest Control Board.

## PESTICIDE LABEL RESTRICTIONS

Manufacturers must register pesticides first with the U.S. EPA and then DPR before anyone can buy or use them in California. These agencies register individual pesticide **products**, not generic pesticide active ingredients. The registration procedure is established to protect people and the environment from ineffective or harmful chemicals. Sidebar 4 lists the information that a manufacturer provides to register a pesticide.

The registration procedure includes an evaluation of each chemical and establishes how U.S. EPA classifies the material at the federal level. Pesticides either are classified as



FIGURE 1.7

The U.S. Food and Drug Administration enforces pesticide residue tolerances on food shipped in interstate commerce.



## Sidebar 3

## Responsibilities of Government Agencies in California's Pesticide Regulatory Program

REGULATORY PROGRAM	WHO DOES IT	WHAT IT CAN DO
Registering pesticides	EPA, DPR	Refuse or accept registration. Suspend, cancel, or reregister pesticides.
Classifying pesticides	EPA, DPR	EPA classifies pesticides as restricted or nonrestricted use in the United States. DPR may impose more stringent restrictions for California, based on special conditions existing in the state.
Permitting	CAC	Issue, revoke, or refuse restricted use pesticide permits (with use conditions) to growers, other private applicators, or certified applicators.
Certifying private and commercial applicators, pest control advisers, pest control businesses, and dealers	DPR*	Administer tests and issue certificates to commercial applicator certificate applicants. Revoke, suspend, or refuse certificates upon violation of pesticide laws.
Registering applicators and advisers, certifying private applicators	CAC	Register licensed agricultural pest control businesses, maintenance gardener pest control businesses, pest control aircraft pilot and licensed pest control advisers. Through written examination, certify private applicators.
Monitoring pesticide residues on food and feed	EPA, USDA, DPR, CAC**	Test food and feed for pesticide residues. Quarantine or destroy illegally contaminated commodities. Bring case of violation to county district attorney or State Attorney General for prosecution.
Regulating pesticide use and worker safety	EPA, DPR, CAC, DHS	Have general authority to regulate pest control operations, including restrictions on the time, place, and manner of application; inspect training programs and records. Various warning and enforcement powers. Provide applicators and advisers with information on local pesticide use conditions. Inspect pesticide use records and pest control recommendations to verify proper pesticide use.
Pesticide illness investigation	DPR, CAC, DHS	Participate in pesticide illness investigations and in development of worker safety regulations. Confirm compliance with worker training requirements.

(Continued on Next Page)

(Sidebar 3, Continued)

REGULATORY PROGRAM	WHO DOES IT	WHAT IT CAN DO
Pesticide disposal and storage	DPR, DHS, WRCB, WQCB, ARB, CAC	Regulate the storage and disposal of hazardous wastes, including unused pesticides and empty containers.
Protecting wildlife	EPA, FWS, DFG, CAC, DPR	Investigate fish and wildlife losses. Identify and monitor endangered species. Restrict pesticide use to protect endangered species and other wildlife.
Citing or prosecuting violators	EPA, DPR, CAC, SPCB, State Attorney General, Local District Attorneys	Agricultural commissioner may levy civil penalties with fines. DPR may request Attorney General to take civil action. Attorney General may file accusation. DPR may suspend or revoke applicator's certificate. CAC may suspend, revoke, or refuse permits and county registration.

\*In California, Structural Pest Control Operators are licensed by the Structural Pest Control Board, California Department of Consumer Affairs. Vector Control Certificates are issued by the Department of Health Services.

\*\*13 other state and 5 federal agencies monitor various parts of the environment for pesticides and other substances.

#### KEY TO ABBREVIATIONS

<b>ARB</b>	California Air Resources Board	<b>FWS</b>	U.S. Fish and Wildlife Service
<b>CAC</b>	County Agricultural Commissioner	<b>SPCB</b>	Structural Pest Control Board, California Department of Consumer Affairs
<b>DPR</b>	California Department of Pesticide Regulation	<b>USDA</b>	U.S. Department of Agriculture
<b>DFG</b>	California Department of Fish and Game	<b>WRCB</b>	California Water Resources Control Board
<b>DHS</b>	California Department of Health Services	<b>WQCB</b>	California Water Quality Control Board
<b>EPA</b>	U.S. Environmental Protection Agency		



**general use** or **restricted use**. A general use pesticide is one that can be sold without a permit or applicator certificate and can be used by the public. However, only certified pesticide applicators can buy, use, or supervise the use of a federal restricted use pesticide. The State of California designates many federally classified general use pesticides as restricted use due to local hazards or specific health concerns. With few exceptions, you must obtain a restricted material permit from the county agricultural commissioner to buy any California restricted use pesticide.

To complete registration, manufacturers supply container labels meeting all federal and state requirements. These labels become legal documents and contain necessary information for users (Figure 1.8). Some labels refer to other documents, such as special local need labeling or endangered species range maps. Agricultural-use pesticide labels also refer to the Worker Protection Standard provisions of the Code of Federal Regulation (40 CFR part 170). These and other documents referred to on pesticide labels become part of the pesticide **labeling**; therefore, users must follow any directions or requirements in the referenced labeling.

Regulations set the format for pesticide labels and prescribe what information they contain. Some packages are too small, however, to have all this information printed on them. In these cases, U.S. EPA requires manufacturers to attach **supplemental labels**. On metal and plastic containers, manufacturers put supplemental labels in plastic pouches glued to the side of the containers. Paper packages usually have supplemental labels inserted under the bottom flaps.

The information and instructions contained on pesticide labels is legally binding. Any use of a pesticide that deviates from the container label, any referenced labeling, or supplemental label is illegal and subjects the user to possible fines, imprisonment, and/or loss of their applicator certificate. For certain legal exceptions to label-required personal protective equipment, see Sidebar 18 on page 66.

FIGURE 1.8

Pesticide labels provide all the legal requirements for use and other information that users must know to handle and apply the product safely.

**Bayer CropScience**

## Dropp® SC COTTON DEFOLIANT

For Agricultural Use Only

ACTIVE INGREDIENT: Thiocarbonyl (M-phospho)-1,2,3-triazolo-5-pyridinyl 42.4%

INERT INGREDIENTS 57.6%

\*Net Wt. 4.0 lbs. of Defoliant per gallon TOTAL 100%

EPA Reg. No. 254-750 EPA Est. No. 34660-WG-1

**KEEP OUT OF REACH OF CHILDREN**  
**CAUTION — CAUCION**

For MEDICAL AND TRANSPORTATION Emergencies ONLY Call 24 Hours A Day 1-800-934-7577  
For PRODUCT USE Information Call 1-800-888-8888 (1-800-888-8888)

**FIRST AID**

<b>IF SWALLOWED:</b>	<ul style="list-style-type: none"> <li>• Immediately call a poison control center or doctor for treatment advice.</li> <li>• Do not induce vomiting unless told to do so by a poison control center or doctor.</li> <li>• Have person sip a glass of water if able to swallow.</li> <li>• Do not give anything by mouth to an unconscious person.</li> </ul>
<b>IF INHALED:</b>	<ul style="list-style-type: none"> <li>• Move person to fresh air.</li> <li>• If person is not breathing, call 911 or an ambulance, then give artificial respiration, preferably mouth-to-mouth if possible.</li> </ul>
<b>IF IN EYES:</b>	<ul style="list-style-type: none"> <li>• Call a poison control center or doctor for further treatment advice.</li> <li>• Hold eyes open and rinse slowly and gently with water for 15-20 minutes.</li> <li>• Remove contact lenses, if present, after the first 5 minutes, then continue rinsing.</li> <li>• Call a poison control center or doctor for treatment advice.</li> </ul>
<b>IF ON SKIN OR ON CLOTHING:</b>	<ul style="list-style-type: none"> <li>• Take off contaminated clothing.</li> <li>• Rinse skin immediately with plenty of water for 15-20 minutes.</li> <li>• Call a poison control center or doctor for treatment advice.</li> </ul>

For MEDICAL Emergencies Call or Write A Day 1-800-834-7577  
Have the product container or label with you when calling a poison control center or doctor or going for treatment.

**PRECAUTIONARY STATEMENTS**

**HAZARDS TO HUMANS AND DOMESTIC ANIMALS**  
**CAUTION**

Hazardous if swallowed, inhaled, or absorbed through the skin. Avoid breathing spray mist. Avoid contact with skin, eyes, and clothing. Do not contaminate water, food, or feed.

**PERSONAL PROTECTIVE EQUIPMENT**

Applicators and other handlers must wear:

- Long-sleeved shirt and long pants
- Goggles
- Gloves





#### Sidebar 4

### Scientific Data and Other Information Manufacturers Must Provide to DPR to Register a Pesticide in California

1. Exposure Information: data on risks of exposure and how people can be protected
  - safety related to exposure
  - mixer, loader, applicator exposure
  - management of poisoning
  - toxicology of adjuvants and other components of the formulation
  - indoor exposure information
  - if material is a rodenticide, metabolic pathway and mode of action
  - foliar residue and field restricted entry data
2. Residue test method
3. Residue data
4. Efficacy
5. Hazard to bees
6. Closed-system compatibility
7. Effects on pest management
8. Inert ingredient hazard
9. Volatile organic compounds: their relationship to air quality
10. Other data as requested by the Director of the Department of Pesticide Regulation, such as:
  - information on drift potential
  - phytotoxicity
  - contaminants or impurities in the product
  - analytical and environmental chemistry
  - effects of tank mixes on the product (compatibility)

## Chapter 1

## Review Questions

SEE PAGE 178 FOR ANSWERS

1. Certification of apprentice and journeyman pilots for making pesticide applications by air in California is performed by the
  - a. Federal Aviation Administration (FAA)
  - b. U.S. Environmental Protection Agency (U.S. EPA)
  - c. California Department of Pesticide Regulation (DPR)
  - d. country agricultural commissioners
2. The Code of Federal Regulations Title 14, Part 137 pertains to
  - a. certification of pilots and flight instructors
  - b. general operating and flight rules
  - c. rotorcraft external-load operations
  - d. agricultural aircraft operations
3. Dispensing live insects by air is an agricultural aircraft operation and is considered a pest control activity
  - a. throughout the United States
  - b. only when used to control public health pests
  - c. in California
  - d. only when used to control forest pests
4. An exception to the requirement for pilots to possess a valid Agricultural Aircraft Operator Certificate is
  - a. aerial spraying in forests by a California-certified Journeyman pilot
  - b. aerial spraying operations conducted on land owned or operated by the pilot
  - c. spraying operations on nonagricultural land conducted by the holder of a commercial Pest Control Operator certificate
  - d. spraying operations conducted by federal, state, or local governments using public aircraft
5. One of the areas included on the knowledge test for the commercial Agricultural Aircraft Operator Certificate is
  - a. safe flight and application procedures
  - b. short-field and soft-field takeoffs
  - c. pull-ups and turnarounds
  - d. approaches to the working area

6. Unless you have authorization from an appropriate air traffic control facility, you may not
  - a. make flights to and from a dispensing area
  - b. operate an aircraft in weather conditions below VFR minimums within an active, surface-based Class 'E' Airspace
  - c. operate the aircraft below 500 feet above the surface for any purpose
  - d. operate the aircraft for compensation or hire
7. How many hours of approved continuing education must apprentice and journeyman pilots accumulate to renew their Pest Control Aircraft Pilot Certificates?
  - a. 4 hours of laws and regulations and 4 hours of aerial application techniques every two years
  - b. 20 hours every year, including 4 hours of laws and regulations and 4 hours of aerial application techniques
  - c. 20 hours every two years, including 4 hours of laws and regulations and 4 hours of aerial application techniques
  - d. 40 hours every two years, including 4 hours of laws and regulations and 4 hours of aerial application techniques
8. Why are some pesticide products that are classified by EPA as **general use** pesticides classified by DPR as **restricted use**?
  - a. to comply with recommendations of local consumer awareness programs
  - b. to prevent their use by farm operations
  - c. to address specific health concerns
  - d. to require they be packaged in smaller sized containers
9. The purpose of the federal **Worker Protection Standard** is to
  - a. protect the public from pesticide exposure
  - b. provide health benefits to agricultural workers
  - c. provide safety standards for pesticide application equipment
  - d. protect people who handle pesticides or work in pesticide-treated areas
10. A benefit of aerial application of pesticides is that it
  - a. can often enable more accurate timing of control sprays
  - b. is less disruptive to beneficial organisms
  - c. avoids outbreaks of secondary pests
  - d. uses less pesticide product



# 2 Pest Management

Pest management programs should safely prevent, suppress, or eliminate pests that cause damage, interfere with the cultivation of desirable plants, interfere with the intended use of facilities, roads, rights-of-way, and other areas, or threaten human health. Several philosophies and management methods may be part of an *integrated pest management* (IPM) program. IPM programs emphasize preventing pest damage by anticipating pest problems and suppressing or quickly taking control action whenever possible. Goals of IPM include protecting the environment, conserving natural enemies, and avoiding secondary pests. If pesticides are part of the IPM program, pest managers must use them sensibly and apply them at favorable times when pests are most susceptible and beneficial organisms are least susceptible.

Aerial pesticide applications fit into the goals of many pest management programs. Aerial applications can provide more accurately timed control treatments without waiting for suitable ground conditions. This may allow treatments with minimal adverse impacts to other cultural practices. This ability to respond quickly can allow pest managers to reduce the amount of pesticides required to manage certain pests (Figure 2.1).

FIGURE 2.1

Aerial application of pesticides is compatible with many pest management programs because it allows timely treatment of pests.



Aerial pesticide applications provide viable options for weed control and vegetation management, for managing many pests that attack agricultural crops and forests, and for controlling some of the pests that threaten human health.

## AERIAL APPLICATION

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Fixed winged and rotary winged aircraft provide effective alternatives to using ground application equipment and methods. Their flight capabilities exempt them from the constraints imposed by adverse ground conditions that could impede ground equipment. These conditions include soil too wet for supporting ground equipment or fields with obstacles such as levees, props for supporting tree limbs, or low-hanging tree limbs. Aircraft can treat more area in the same period when compared to ground equipment because of their high airspeed plus large swath capabilities. Therefore, aircraft can quickly complete a pesticide application when there is a short period for optimal pest control. For example, rainy weather very often produces conditions for a swift and virulent pathogen outbreak while making it impossible to use ground equipment. Brown rot can quickly develop after it rains during bloom of fruit or nut trees. Disease control applications may be impossible to perform if wet soil does not support ground equipment. Ground applications may also be delayed by changing weather if it takes too long to cover the treatment site because of the relative slow speed of ground equipment.

Pest control pilots that are DPR-certified to make pest control applications in California work in two general use settings, agricultural and nonagricultural. Typical agricultural use settings include

- field and row crops
- vine and tree crops
- grain crops
- ornamental plants, turf, and sod production
- forests used for recreation and commercial production, including forest nurseries
- rangeland and pastures
- nurseries for ornamental plants and food crops

Applications may also take place on large nonagricultural, industrial, or commercial land use settings, such as airports or equipment storage yards. These applications generally are for weed control or vegetation management. Two other types of applications, right-of-way and vectored-disease pest control, may traverse over various agricultural and nonagricultural use settings.

Aircraft are also used to apply fertilizers and disperse crop seeds.

Pilots need a general understanding of the life cycles and habits of target pests and information about the damage these pests cause in order to communicate more effectively with pest management specialists and property managers. This also helps pilots better understand the pest management goals and constraints. A competent pilot should be familiar with the

- general classification of target pests
- vulnerable life stages of the pest

- location of the pest in the area being treated
- importance of application timing to achieving effective control
- vulnerable or sensitive life stages of the crop plants to be treated or other desired plants
- mode of action of the pesticides being used

The following sections provide useful information for pilots who will be making applications to manage vegetation and control weeds, insects and mites, and plant diseases. Pesticide labels provide additional information.

## VEGETATION AND WEEDS

Weed control methods include sanitation, cultural control, mechanical control, biological control, and chemical control, using herbicides. Aerial application may be appropriate when using herbicides in the vegetation and weed management program (Figure 2.2). Pilots making herbicide applications should be familiar with the various types of herbicides and have a general understanding of how they work. An understanding of plant growth stages and other factors that influence herbicide effectiveness is necessary.

### Weed Classification

Weeds and other soil inhabiting plants usually fall into one of two general plant categories—the *monocots* and the *dicots*. Monocots are the grasslike plants, such as wheat, grass, rice, and other grains. Dicots are broadleaved plants such as sunflowers, beans, alfalfa, and other crops.

One of the ways plant specialists classify plants is according to their life cycle. Therefore, weeds can be classified or identified as:

- **Annuals** complete their life cycle within one year. Plants having this life cycle are either summer annuals—they germinate in the spring, or winter annuals—they germinate in the fall. Most annual weeds produce many seeds.
- **Biennials** live more than one year but usually less than two years. These plants grow from seeds, which usually germinate in the spring. During the first year, they store food, commonly in short fleshy roots. During the following season, the plants use the stored food and grow vigorously, producing seeds in the summer or fall before dying.
- **Perennials** live more than two years, and some may live indefinitely. Most perennial weeds spread by seeds, and many spread vegetatively by producing creeping stems or roots, rhizomes, or bulbs. There are shallow-rooted and deep-rooted perennials.

Labels of some herbicide products used for weed and vegetation control recommend that applications be made at certain leaf growth stages of the plants because these herbicides may only be effective when weeds are at these stages of growth. If applied too early or too late, weed control may not be achieved, or the crop and other desirable plants may be damaged.

**Broadleaf Plants (Dicots).** Cotyledons are the seed leaves, and a pair of them is usually the first to appear in broadleaf, or dicot, plants that are just emerging from the soil.



FIGURE 2.2

Aerial application of herbicides is suitable for many types of weed control programs.

Cotyledons are usually a different shape than the true leaves and may dry up and disappear as true leaves begin growing. On a few plant types, the cotyledons stay beneath the soil surface.

Growth stages are usually determined by counting the number of true leaves (not including the cotyledons) on the newly emerged plants.

**Grasses (Monocots).** Grasses, or monocots, produce only one seed leaf. Weed managers count all the leaves on the main shoot of the grass plant to determine its growth stage.

## Herbicides

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Using aircraft is an effective way of making broadcast applications of pre- and post-emergent herbicides to unplanted fields and other large, open areas void of desired plants. However, aircraft fly too fast and are not designed to use dispersal systems that make strip spray applications or applications of nonselective herbicides near the bases of desirable plants. Many types of herbicides are available for weed management, and each type has certain characteristics to consider for a specific job. These characteristics include selectivity, mode of action, optimum plant growth stage, and residual effectiveness.

Many types of herbicides are available for weed management, and each type has certain characteristics to consider for a specific job. These characteristics include selectivity, mode of action, optimum plant growth stage, and residual effectiveness.

- **Selectivity.** *Selective herbicides* are effective for controlling only certain types of plants, while leaving other types of plants unharmed. *Nonselective herbicides* destroy all types of plants they contact. A few herbicides will be selective or nonselective depending on the application rate. Selective materials, such as phenoxy herbicides, are often aerially applied to grain and grass crops (e.g., wheat, oats, rice) to control broadleaved weeds because these herbicides do not damage grasses.
- **Mode of Action.** Mode of action explains how the herbicide affects plant growth. For example, *contact herbicides* damage plant parts (usually leaves and stems) contacted by the herbicide, and there is little or no movement of the contact herbicide throughout the plant. *Systemic herbicides* enter the roots or above ground parts and translocate internally to other parts of the plant. This results in the destruction of above ground and below ground parts of the plant. With systemic herbicides, effects on the plant may not be apparent for several days to several weeks after application.
- **Optimum Growth Stage.** Many herbicides are effective only on specific plant growth stages. *Preplant herbicides* are applied to the soil before seeding or transplanting crop plants into the area. *Preemergence herbicides* are applied to the soil after planting but before the emergence of the crop and weed plants. *Postemergence herbicides* are applied after the target weeds have emerged. Sidebar 5 describes various classifications of herbicides based on the plant growth stage.
- **Residual Effectiveness.** Residual effectiveness refers to how long the herbicide is biologically active once applied. Some materials lose their effectiveness within a few hours, while others may remain active for many months.





## Sidebar 5

## Herbicide Types

### Preplant Herbicides with Soil Incorporation

Preplant herbicide applications with soil incorporation are applied and incorporated into the soil before planting. Incorporation of these herbicides is required to prevent them from volatilizing (becoming a gas) or decomposing through ultraviolet light exposure.

Advantages of using preplant soil applications with incorporation include:

- early weed control reduces the number of weeds competing with the crop being planted
- weed control is not delayed by irrigation or rainfall that takes place after the crop is planted
- herbicide activation is less dependent on rainfall or irrigation than are preemergence herbicide applications

Some disadvantages or limitations of preplant soil applications with incorporation include:

- the possibility of incorporating the herbicide too deeply, which reduces effectiveness
- a “streaking” pattern of good and poor weed control resulting from incomplete or uneven soil incorporation
- a tendency to use these herbicides preventively, without identifying the weeds, because weeds have not yet emerged
- incorporation is not compatible with no-till systems

### Preemergence Herbicides

Preemergence herbicides are applied to the soil surface at the same time or after the crop has been planted but before weed seedlings emerge. Typically, preemergence herbicide applications require rainfall or irrigation within one week following the application to ensure that the herbicide moves through the soil.

Advantages of preemergence herbicides include:

- reduced weed competition for crop plants because of early weed suppression
- the ability to be used with all types of tillage systems
- planting and herbicide application may be done at the same time

Some of the disadvantages of using preemergence herbicides include:

- requiring rainfall or irrigation for activation
- being ineffective with inadequate rainfall or irrigation water
- risks, when applied to sandy soils, that excessive rain or irrigation water will move the herbicide down into the soil and injure the germinating crop seed
- a tendency to overuse these herbicides indiscriminately, without identifying the weeds, because weeds have not yet emerged

(Continued on next page)

(Sidebar 5, Continued)

### Postemergence Herbicides

Postemergence herbicide applications are applied to the above ground parts of weed plants **after** they have emerged. The two types of postemergence herbicides are **contact** and **systemic**.

Contact herbicides kill only the plant parts that they touch. Typically, the above ground parts of a weed, such as the leaves and stems, turn brown and die. Generally, the weed plants will then die but, in some cases, remaining vegetative plant parts may generate new growth. Contact herbicides are commonly used to control annuals.

Systemic or translocated herbicides are absorbed by the roots or leaves and moved throughout the plant. Translocated herbicides are more effective against perennial weeds than are contact herbicides because these herbicides affect all parts of the plant. However, translocated herbicides may take up to three weeks to kill the weeds.

Considerations in using postemergent herbicides include:

- applications should be timed to susceptible growth stages of the weeds for effective control
- sprays should not be applied to wet foliage
- weather conditions or cultural activities limit the requirement to apply the herbicide at the proper time

### Herbicide Application Considerations

Many factors at the time of application affect how well certain herbicides work and how they are applied. These include:

- **The Shape and Surface Structure of Leaves.** Thin, upright leaves are hard to cover with spray. Hairy or waxy plant surfaces may reduce herbicide contact. Herbicide labels may specify the use of surfactants to increase the coverage and wetting ability of the spray according to leaf characteristics of the plant.
- **Weather.** Temperature, humidity, rain, and wind may affect herbicide effectiveness. Weather may cause adverse growing conditions that slow weed growth activities. This slows the movement of nutrients through the plant and reduces the movement of systemic herbicides. Hot dry weather may make the herbicide evaporate quickly from the weed leaves and reduce uptake and effectiveness. Rain during or after an application may wash the herbicide off plant surfaces, although some soil-applied herbicides require irrigation or rain after application to activate them or move them into the soil. Wind can cause drift and prevent the herbicide from reaching the target.
- **Age of the Weed.** Postemergent herbicides are often more effective on young, rapidly growing weeds. Herbicides having systemic action can spread faster in rapidly growing younger weeds than in older plants. Many types of postemergent herbicides are less likely to kill plants that are in full flower or producing seed. Perennial weeds often become more resistant to herbicides as they grow older, but may become more susceptible again during the bud or early flowering stage.
- **Soil Type.** For soil active herbicides, the quantity of active ingredient applied may need to be increased for clay or silty soils or soils high in organic matter. This is because soil particles or organic matter adsorb and tie up the herbicide, reducing the amount available for weed control.

- **Soil Moisture.** Soil-applied herbicides generally work best in warm, moist soil. Moisture helps the herbicide move to the weeds.
- **Cultivation Status.** Cultivation of the soil before an herbicide application may influence the effectiveness of some herbicides. Cultivation weakens some types of weeds, making them easier to control, although cultivation may also break up and spread rooting structures of other types of weeds, making them more difficult to control.

## INSECT AND MITE PESTS

The aerial application of insecticides and miticides is effective in controlling widespread insect or mite infestations, especially when large acreages require treatment or damaging population levels increase rapidly. For densely foliated plants, such as fruit or nut trees, application speed and height must be adjusted to assure adequate coverage of the pesticide materials onto leaf surfaces. This is very critical in the lower or innermost portions of the tree canopies. Insect or mite pest outbreaks may be concentrated in certain areas of a field you are treating, so understanding the habits and distribution of these pests is needed to assure the application will achieve adequate control. For instance, mites are often most prevalent on crop plants that border dusty roads.

### Insect and Mite Characteristics

Like all organisms, insects and mites are classified taxonomically by kingdom, phylum, class, order, family, genus, and species. Of the many different insect and mite species, only a few are pests that have the potential to damage property, crops, food, feed, and livestock (Figure 2.3). A few others are threats if they can cause injury or transmit diseases to humans or animals. Many insect pests of plants are introduced species that have no natural enemies at their new location to suppress their populations.

**Life Cycles.** Insects and mites change in their size, shape, and appearance as they grow. Insects metamorphose or pass through several development stages that vary depending on the order that the insect belongs to. Two common insect growth stages are:

- **Gradual development or incomplete metamorphosis— egg, nymph, and adult.** The young, or nymphs, of insects in these orders are similar in appearance to the adults but are smaller, wingless, and lack the ability to reproduce. Examples include aphids and grasshoppers. Mites also pass through these stages.
- **Complete metamorphosis— egg, larva, pupa, and adult.** Larvae of insects in these orders are very different from the adults (e.g., caterpillars, loopers, grubs, maggots); the pupal stage is a non-feeding stage during which complete physical changes occur; the adults are usually winged. Examples include mosquitoes, moths, beetles, ants, and flies.

The most effective time to control insect and mite pests is usually during the nymph or larval stages. Most insecticides and miticides are not effective against eggs and pupa. The mouthparts of insects and mites are adapted to the methods they use to feed. When planning a management program for a particular insect pest, it is sometimes helpful to know what type of mouthpart the insect has. Sidebar 6 illustrates various types of insect mouthparts.

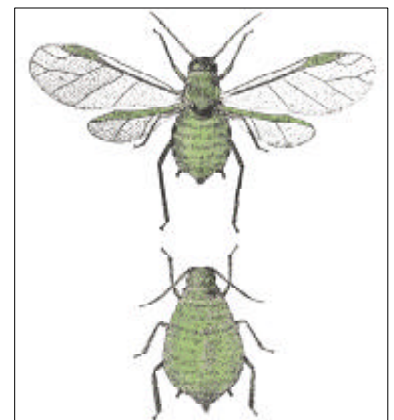


FIGURE 2.3

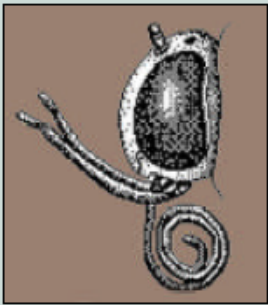
Insects, such as this aphid, become pests when they cause damage to property, crops, food, or livestock. Some insect pests transmit disease organisms to people or animals.



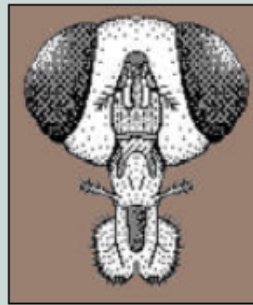
## Sidebar 6

## Insect Mouthpart Types

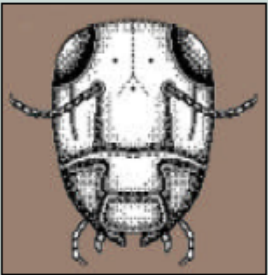
Insects and other invertebrates have various types of mouthparts that are suitable for the type of food they consume. Knowing the type of mouthpart is helpful in understanding the damage that specific insects or mites can cause and is helpful in selecting the appropriate control methods to use, including insecticides or miticides. Usually, insects that undergo complete metamorphosis exhibit different mouthpart types in the larval form than in the adult form, while those that undergo incomplete metamorphosis have the same types or mouthparts as nymphs and adults.



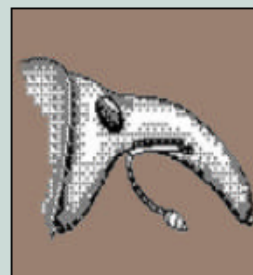
Adults of some insects such as butterflies and moths have coiled type mouthparts. The insect extends this coiled tube and uses it to suck nectar from deep within flowers.



Many flies have mouthparts modified into a flattened, rounded structure used for lapping or sponging liquefied food.



Larvae and adults of many types of insects have biting or chewing mouthparts. Often, these are very powerful, enabling the insect to bore into or crush and chew woody plants. Beetles, weevils, and termites have these types of mouthparts, as do larvae of beetles, moths, and butterflies.



The chewing mouthparts of adult weevils are attached to a prolongation of the head, forming a snout.



Many types of insects, such as aphids and true bugs, have mouthparts that are modified for piercing plant cells and then sucking up the liquid portions.



The mouthparts of mites and some insects are characterized by rows of teeth that the organism uses to rasp open the cells of plants and lap up the fluid from these cells.

## Insecticides and Miticides

Insecticides and miticides are often described according to their mode of action—how they act on or enter the pest:

- **Contact pesticides** must touch or contact the pest to be effective. They can be applied to the pest or on surfaces that pests touch. Some contact insecticides have a residual effect and can kill insects for some time after they are applied.
- **Systemic pesticides** enter plants and flow in the sap. These materials kill insects or mites that suck the sap. Some insecticides and miticides have both systemic and contact modes of action.
- **Stomach poisons** must be swallowed by the pest to be effective, and are applied to the foliage or other plant parts where the insects or mites feed.
- **Suffocating pesticides** (usually oils) clog the respiratory system of insects and mites and prevent respiration of some insect and mite eggs.
- **Growth regulators** affect the normal development of certain insects, so that they die before they become adults or before they can reproduce.
- **Microbial insecticides** contain bacteria, viruses, fungal spores, or the toxins produced by these organisms. After they are eaten, the microbe, or a poison the microbe produces, kills the insects.

## Factors Affecting Insecticide and Miticide Effectiveness

Pest managers must be aware of factors that can influence the effectiveness of insecticides or miticides used in a pest management program. These factors include:

- **Timing of Application.** Insects/mites need to be present and in a specific stage of development for the pesticide to be effective.
- **Resistance.** Some insects and mites have developed resistance to certain groups of insecticides or miticides, making these materials less effective for controlling the pests.
- **Weather Conditions.** Excessively high or low temperature, humidity, and rain can reduce the effectiveness of certain insecticides and miticides by accelerating their chemical breakdown or diluting the pesticide applied.
- **Adjuvants.** Materials added to the spray tank to enhance mixing, improve sticking to leaf surfaces, or reduce surface tension may also improve or reduce the insecticide or miticide effectiveness.
- **Mixing Water Quality.** The pH of the mixing water and the dissolved salts in the water can cause chemical reactions that reduce the longevity of the pesticide active ingredients as well as increasing or decreasing their effectiveness.
- **Spray Tank Contaminants.** Contaminants from previous pesticide mixtures in the spray tank can adversely react with another pesticide, reducing effectiveness or causing phytotoxicity.

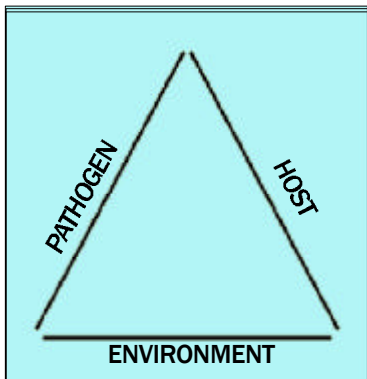


FIGURE 2.5

A *disease pathogen* must have a *suitable host* and the *proper environment* before it can infect. These factors are known as the *disease triangle*.

## PLANT DISEASE ORGANISMS—THE DISEASE TRIANGLE

A plant disease caused by a biotic agent requires the interaction of a susceptible host, a virulent pathogen, and an environment favorable for disease development. These three factors make up the *disease triangle* (Figure 2.5). Plant disease cannot occur if any one of these three components is eliminated or missing. The host cannot be eliminated in most cases, and in outdoor situations, the environment cannot be changed. Generally, the pathogen may be present on the host plant but not a threat or concern until there are favorable environmental conditions. In some cases, however, the pathogen may be eliminated, inactivated, or blocked from infecting the plant by certain types of pesticides.

Rainfall can cause unfavorable conditions for ground equipment while also providing a favorable environment for fungi or other pathogens to infect plants. A major advantage of using aircraft to apply fungicides and other materials to protect plants from disease is the ability to make these applications swiftly at critical times when the three disease factors are present, even when the soil is too wet or too muddy for ground application equipment.

### Fungi

Fungi cause a number of plant and animal diseases. Because fungi are more chemically and genetically similar to animals than other organisms, fungal diseases are very difficult to treat. Plant diseases caused by fungi include rusts, smuts, and leaf, root, and stem rots. These disease organisms may cause severe damage to crops.

### Bacteria

Bacteria are normally present on plant surfaces and will only cause problems when conditions are favorable for their growth and multiplication. These conditions include high humidity, crowding, and poor air circulation around plants. During this time, plants are not growing actively and are easily stressed. Common symptoms include leaf spots, blights, and wilting. Bacterial diseases restricted to the leaves of plants can often be controlled with pesticides.

Different species of bacteria affect plants in different ways. Plant symptoms include tip burns, leaf spots, blights, rots, wilts, or the total collapse of plant tissues.

### Controlling Plant Diseases

Two types of pesticide materials are used to manage plant diseases. These are *protectants*—materials that block the entry of the disease-causing organism into the plant, and *eradicants*—materials that destroy the infecting organisms as it infects the plant. Only a few materials are effective eradicants and these usually work only in the early stages of infection. Typically, protectant materials are applied when conditions that promote infection are approaching or have occurred, but before infection symptoms are seen.

Application timing and adequate coverage of susceptible plant parts with the pesticide are the critical factors needed to protect plants from disease infections. Most pesticides used for plant disease management are only effective for short periods, so repeated applications may be necessary when continuing environmental conditions promote infection.

## Chapter 2

## Review Questions

SEE PAGE 178 FOR ANSWERS

1. The level of selectivity of some herbicides to target plants is sometimes influenced by application
  - a. speed
  - b. height
  - c. rate
  - d. swath width
2. Generally, the most effective time to control insect and mite pests is during the
  - a. adult stage
  - b. pupal or resting stage
  - c. nymph or larval stage
  - d. egg stage
3. A pesticide that affects the normal development of an insect is a
  - a. systemic insecticide
  - b. microbial insecticide
  - c. contact insecticide
  - d. growth regulator
4. One factor that affects how well an insecticide application works is
  - a. application timing
  - b. soil moisture
  - c. cloud cover
  - d. temperature of the mix water
5. An integrated pest management program (IPM) emphasizes
  - a. chemical control of pests
  - b. use of organically approved pest control products
  - c. preventing pest damage by anticipating pest problems
  - d. applying control methods on a scheduled basis

6. Aerial application of pesticides is competitive with most other pest management methods because
  - a. other application methods are more expensive
  - b. other application methods are more hazardous
  - c. less skill is required than for other application methods
  - d. aircraft can spray larger swaths at higher speeds
7. What aspect of aerial application of pesticides can actually reduce the amount of pesticide needed to control pests?
  - a. the ability to reach areas that are inaccessible from the ground
  - b. the ability to more accurately time control sprays
  - c. the ability to fly low and close to the crop
  - d. better coverage of crop surfaces
8. A plant disease triangle includes which of the following factors?
  - a. virus, fungi, and bacteria
  - b. rainfall, pathogen, and warm temperatures
  - c. host, environment, and pathogen
  - d. host, moisture, and warm temperatures



# 3 Pesticide Safety

Understanding and following pesticide safety procedures is very critical when using any pesticide. Pesticides are poisonous and/or hazardous and must be handled safely and carefully to protect people and the environment. Components of pesticide safety that are discussed in this chapter include

- understanding how pesticides harm people
- knowing how exposure to some types of pesticides is monitored
- training employees to work safely around pesticides and around aircraft
- knowing how employer and employee habits and their attitudes affect pesticide safety
- selecting and using appropriate personal protective equipment (PPE) and its care
- managing the site where pesticides are stored and applied
- dealing with pesticide emergencies
- understanding aircraft and pesticide security

**Employer Responsibilities.** California pesticide worker safety regulations require that employers provide pilots and other agricultural pesticide handlers with pesticide safety and use information, changing and washing facilities, and protective coveralls. The requirements include providing

- handlers with specific information about pesticides being handled (see Sidebar 7)
- a clean, pesticide free change area where handlers can remove personal protective equipment as well as store personal clothing (see Sidebar 8)
- decontamination and eyewash facilities at the mixing and loading site as well as at other locations where handlers may work (see Sidebar 9)
- coveralls for employees who handle any pesticide with the signal word “DANGER” or “WARNING” on the label (see Sidebar 10)

## PESTICIDES AND HUMAN HEALTH

Pesticides injure people by damaging body tissues or interfering with the function of one or more of the body's systems, such as nerve signal transmission. The nature and extent of injury depend on the pesticide's toxicity and the amount of exposure. Some pesticides are so very toxic that even a minimal onetime exposure to these can cause serious illness or death. Other pesticides are less toxic, so that a person would have to receive a large single exposure or several exposures over time before experiencing any ill effect. However, it is usually impossible to predict what adverse health effects can result from long-term repeated exposures to even the least toxic pesticides. To avoid illness or injury, you need to handle all pesticides carefully and protect yourself from any amount of exposure.

### Health Effects of Pesticide Exposure

The illness or injury caused by a pesticide exposure may vary between classes of pesticides and pesticides within a class. The severity of illness is usually proportional to the amount (dose) of pesticide entering the tissues. In addition, people vary in their sensitivity to types and doses of pesticides and the impact may be even more pronounced in children, the elderly, and those individuals with a depressed immune system.

Common symptoms for many pesticides include skin rashes, headaches, and irritations of the eyes, nose, and throat. These symptoms may go away quickly and are sometimes difficult to distinguish from common ailments such as allergies, colds, or flu. Pesticides that are more toxic will cause various symptoms such as blurred vision, muscle pain or tightness, dizziness, heavy sweating, weakness, nausea, stomach pain, vomiting, diarrhea, extreme thirst, and blistered skin (Figure 3.1). Exposure to some pesticides will produce apprehension, restlessness, anxiety, unusual behavior, shaking, convulsions, or unconsciousness.

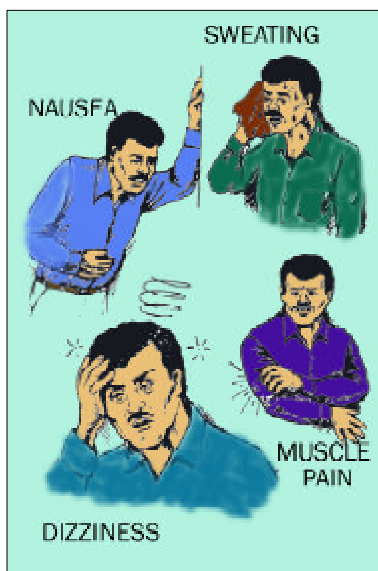


FIGURE 3.1

Some of the symptoms of serious pesticide poisoning include nausea, profuse sweating, dizziness and blurred vision, and muscle pain or cramping.

Exposure to a large dose will probably cause an injury. However, injury may also result from repeated smaller doses absorbed over time. Pesticide health effects may have a sudden onset and last a short while, or the illness may continue for a long time. Sometimes, the effects may not show up for weeks, months, or even years. Such delayed illnesses may either come on gradually or suddenly appear, and the illness may be difficult to associate with any pesticide exposure because of the lapse of time. Although it may be difficult to predict the negative health effects from exposure or to trace the cause of an illness under the circumstances described above, often the cause of a pesticide-related illness or injury can be determined through an investigation and chemical analysis of body tissue and fluids.

The seriousness of an injury depends on the toxicity and mode of action of the pesticide. In addition, the dose, or amount of pesticide absorbed, and the speed of absorption influences the extent of injury. Prompt first aid and medical treatment may greatly reduce the harmful effects.

Injuries caused by pesticides usually are **reversible**. Either the body repairs itself or medical treatment will help cure the damage. Exposure to a few types of pesticides may cause **irreversible** and serious impairment, such as permanent eye or nerve damage, lung disease, or some forms of cancer.

A number of people show signs of allergic reactions when exposed to some types of pesticides. The material causing the reaction may be the pesticide or one of the components



### Sidebar 7

## Application-Specific Information for Handlers

If the property is used for the commercial or research production of an agricultural plant commodity, the operator of the property shall display, at a central location, the following application-specific information while employees are employed to handle pesticides:

- identification of the treated area
- time and date of the application
- restricted entry interval
- product name, EPA registration number, and active ingredients

This information shall be displayed within 24 hours of the completion of an application and include all applications that have been made to any treated field on the agricultural establishment within one-quarter mile of where employees will be working. Once displayed, the information shall remain displayed until the area no longer meets the definition of a treated field or handler employees will no longer be on the establishment, whichever occurs earlier.



### Sidebar 8

## Employee Changing Area

Regulations require employers to provide a place for employees to change clothing and wash themselves if the following conditions apply:

- any employee who regularly handles pesticides\* with the signal word “DANGER” or “WARNING”
- all employees who handle any pesticides for the commercial or research production of an agricultural plant commodity

The changing area must be located where employees end their exposure period and remove their personal protective equipment. Clean towels, soap, and sufficient water shall be available to allow for thorough washing. The employer shall provide a clean, pesticide-free place where employees may store any personal clothing not in use while at work handling pesticides.

\*According to California regulations, **regularly handle** means that the employee is handling pesticides during any part of the day for more than six calendar days in any 30 consecutive day qualifying period, beginning on the first day of handling.



## Sidebar 9

## Handler Decontamination Facilities

The employer shall assure that sufficient water, soap and single use towels for routine washing of hands and face and for emergency eye flushing and washing of the entire body are available for handler employees.

- This water shall be of a quality and temperature that will not cause illness or injury when it contacts the skin or eyes or if it is swallowed, and shall be stored separate from that used for mixing with pesticides unless the tank holding water for mixing with pesticides is equipped with appropriate valves to prevent back flow of pesticides into the water.
- One clean change of coveralls shall be available at each decontamination site.

The decontamination site for employees handling pesticides for the commercial or research production of an agricultural plant commodity shall be at the mixing/loading site and not more than one-quarter mile (or at the nearest point of vehicular access) from other handlers, except that the decontamination site for pilots may be at the loading site regardless of distance from where the pilot is working. The decontamination site shall not be in an area being treated or under a restricted entry interval unless the

- handlers for whom the site is provided are working in that area being treated or a site that is still under a restricted entry interval
- soap, towels, and extra change of coveralls are in an enclosed container
- water is running tap water or enclosed in a container

One pint of water for emergency eye flushing shall be immediately available (carried by the handler or on the vehicle or aircraft the handler is using) to each employee handling pesticides for the commercial or research production of an agricultural plant commodity if the pesticide product labeling requires protective eyewear.



## Sidebar 10

## Employer Responsibility for Providing Coveralls

The employer shall provide coveralls for each employee who handles any pesticide with the signal word “DANGER” or “WARNING” on the label, and shall assure that

- employees start each work day wearing coveralls whenever they handle pesticides with the signal word “DANGER” or “WARNING”
- employees wear coveralls whenever they handle pesticides with the signal word “DANGER” or “WARNING”
- employees change out of their coveralls and wash at the end of the work day
- potentially contaminated coveralls removed at the worksite or headquarters are not taken home by employees

When employees do not return to their work headquarters at the end of the work day, they shall remove and store potentially contaminated coveralls in a sealable container outside of their own living quarters for later return to the employer

of the pesticide formulation. Allergic symptoms often include breathing difficulties, sneezing, eye watering and itching, skin rashes, apprehension, and general discomfort.

**Reporting Pesticide Injuries.** Pesticide exposure incidents involving any pesticide-related injury shall be immediately reported by the employer to the county agricultural commissioner in the county where the incident occurred. Medical personnel are required to report suspected or confirmed pesticide illnesses and injuries to the county health officer within 24 hours after seeing an injured individual. County agricultural commissioner staff investigate pesticide-related illnesses and injuries and report their findings to the Department of Pesticide Regulation. You may download yearly reports of pesticide illnesses and injuries occurring in California from the DPR website at <http://www.cdpr.ca.gov/docs/whs/pisp.htm>.

## First Aid for Pesticide Exposure

First aid is the help you give a person exposed to pesticides before they obtain professional medical help. However, first aid is not a substitute for medical care. The **precautionary statement** section of each pesticide label provides specific first aid information.

The type of exposure determines what first aid and medical treatments are required. Serious pesticide poisoning may cause breathing to stop or cause convulsions, paralysis, skin burns, or blindness. Immediately applying the proper first aid treatment may reduce the extent of injury and even save a life (Figure 3.2). To prepare yourself for such emergencies, enroll in an American Red Cross first aid course that includes **cardiopulmonary resuscitation** (CPR) training.

Protect yourself from exposure when administering first aid to a pesticide exposure victim. Protection is especially needed to prevent exposure to your lips if you perform mouth-to-mouth resuscitation. Avoid getting pesticides onto your skin, and do not inhale vapors. Never enter a confined area to rescue a person who has been affected by toxic pesticide fumes or the lack of oxygen unless you wear the proper supplied air respiratory equipment or breathing apparatus because you may also be affected, as was the injured person. You must act quickly and calmly to assure that

- the victim is quickly removed from danger and from further exposure
- the victim's contaminated clothing or personal protecting equipment is removed to prevent further exposure
- arrangements are made for calling professional medical personnel or transporting the victim to a medical facility

Get professional medical care **at once** for anyone who was exposed to a highly toxic pesticide or anyone who shows any signs of pesticide poisoning. Call an ambulance or transport the injured person to a nearby medical facility for treatment. In addition to performing one of the first aid measures listed below, quickly obtaining medical care often minimizes the extent of injury. Give medical personnel complete information about the pesticide suspected of causing the injury so they can provide the appropriate treatment. Providing a copy of the label or the manufacturer's **Material Safety Data Sheet** could provide them with the information they need.

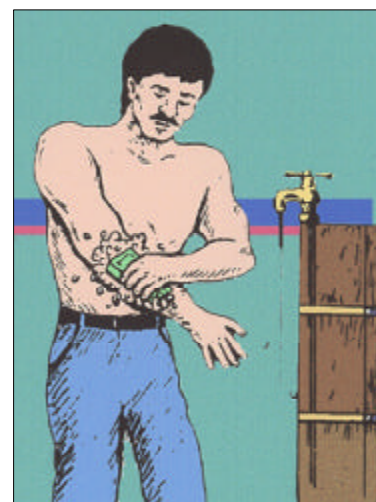


FIGURE 3.2

Immediate decontamination and other first aid measures should be taken whenever anyone contacts a pesticide on their skin or in their eyes.

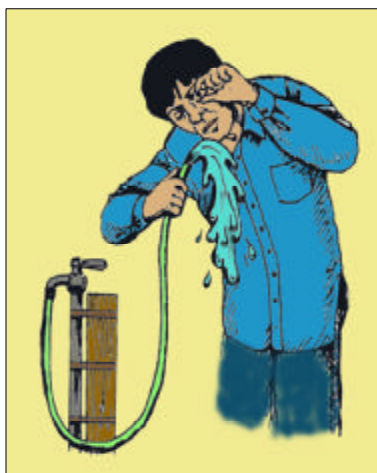


FIGURE 3.3

Pesticides can cause serious damage to the eyes. Immediate flushing with water will help to reduce the extent of injury. As soon as the eyes are flushed, get medical attention.

### Pesticides on the Skin or Clothing

Concentrated pesticides spilled on the skin or clothing can result in serious injury, often times within a matter of minutes depending on the level of human toxicity. Some pesticides may cause skin burns or rashes or, through skin absorption, produce internal poisoning or injury to organs. To reduce the severity of injury, follow this sequence of steps:

- **Leave the Contaminated Area.** As quickly as possible, remove any victims and get away from the fumes, spilled pesticide, and further contamination.
- **Restore Breathing.** If the person has stopped breathing, begin artificial respiration (rescue breathing) at once and continue until breathing resumes or until professional help arrives. If the person has stopped breathing *and* has no pulse, begin cardiopulmonary resuscitation (CPR) and continue until professional help arrives.
- **Prevent Further Exposure.** Remove the contaminated clothing and thoroughly wash the affected skin and hair areas with soap or detergent and large amounts of water.
- **Get Medical Attention.** Call or have someone else call for an ambulance or have someone transport the injured person to the nearest medical facility as quickly as possible. Provide medical personnel with the name of the pesticide.

### Pesticides in the Eyes

Many pesticides are caustic and cause serious damage if they get into the eyes. First aid for eye exposure includes:

- **Flushing the Eyes.** Immediately flush the affected eye or eyes with a gentle stream of clean, running water to prevent further damage (Figure 3.3). If running water is not available, slowly pour clean water from a glass, water cooler, or other container onto the bridge of the nose. Hold eyelids open to assure thorough flushing. Do not add any chemicals or drugs to the water, since this may increase the extent of injury. The water used for eye flushing should be close to body temperature.
- **Obtaining Medical Care.** Get medical attention soon after flushing. A medical professional should conduct an examination to assess any damage and prescribe any required remedial action. Provide medical personnel with the name of the pesticide that caused the injury.

### Inhaled Pesticides

Inhaled chemicals, such as fumigants, pesticide dusts, vapors from spilled pesticides, and fumes from burning pesticides, can cause serious injury to nasal and airway passages and the lungs. The inhaled chemicals may be absorbed into other parts of the body through the lungs. Wear a **supplied air respirator** when entering an enclosed area to rescue a person who has been overcome by pesticide fumes or suffered from oxygen deprivation. Cartridge respirators or dust masks are not suitable for high concentrations of pesticide vapors or deficient oxygen conditions because they do not provide air to breathe. You must use supplied air breathing equipment. If you do not have a supplied air respirator, call for emergency help. You will be of more assistance to the injured person by seeking proper emergency help than if you also become a victim of the pesticide fumes or lack of oxygen, and therefore cannot provide or obtain help.

Perform the following first aid measures immediately to reduce injury or prevent death:

- **Leave the Contaminated Area/Remove an Exposed Person from the Contaminated Area.** Anyone overcome by pesticide vapors must get to fresh air immediately. The affected person should avoid physical exertion because this places an extra strain on the heart and lungs.
- **Loosen Clothing.** Loosening clothing makes breathing easier and releases pesticide vapors trapped between clothing and the skin. Stay upwind or turn your face to keep from inhaling these vapors.
- **Restore Breathing.** If breathing has stopped, or is irregular or labored, begin artificial respiration (rescue breathing). Continue assisting until breathing has improved or until medical help arrives. If the person has stopped breathing *and* has no pulse, begin cardiopulmonary resuscitation (CPR) and continue until help arrives.
- **Treat for Shock.** Inhalation injury may cause a person to go into shock. Keep the injured person calm and lying down with their feet elevated. Prevent chills by wrapping the person in a blanket or clean clothing after removing contaminated clothing. Do not administer alcoholic beverages.
- **Watch for Convulsions.** If convulsions occur, protect the victim from falls or injury and keep air passages clear by tilting their head back.
- **Get Immediate Medical Care.** Call an ambulance or transport the person to the nearest medical facility. Provide medical personnel with the name of the pesticide.

### Swallowed Pesticides

Two severe consequences may result from ingesting pesticides. One is the poisoning effect it will have on a person's nervous system or other internal organs, which is affected by the toxicity of the pesticide. The second is the physical injury that the swallowed pesticide causes to the mouth, throat, and lungs. Corrosive materials, those that are strongly acid or alkaline, can seriously burn these sensitive tissues. Petroleum-based pesticides can cause lung and respiratory system damage, especially during vomiting.

Act quickly if someone has swallowed a pesticide (Figure 3.4). Follow these guidelines:

- **Contact the Poison Control System.** Call the Poison Control System anywhere in California by using a single toll-free number: 1-800-222-1222. These centers provide quick, lifesaving information on poisoning treatment. You can reach regional poison information centers, located in Sacramento, San Francisco, Fresno, and San Diego, by telephone 24 hours a day and 7 days a week.
- **Follow First-Aid Instructions on the Pesticide Label.** The *Statement of Practical Treatment* section of the pesticide label contains first aid instructions for swallowed pesticides.
- **Obtain Immediate Medical Care.** Call an ambulance or transport the poisoning victim to the nearest medical facility. Provide medical personnel with the name of the pesticide and as much information as possible about it.



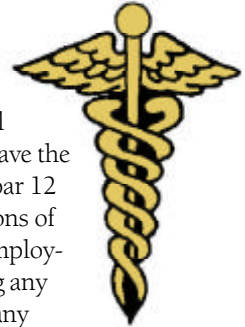
FIGURE 3.4

Immediate first aid and medical care is necessary if someone swallows any type of pesticide.



## MEDICAL MONITORING FOR CERTAIN OCCUPATIONAL PESTICIDE EXPOSURES

California's Pesticide Worker Safety Regulations require a series of special blood tests for employees who regularly handle any organophosphate or N-methyl carbamate pesticide when used for the commercial or research production of an agricultural commodity. This requirement is in effect when these pesticides have the "DANGER" or "WARNING" signal words on the label. (See Sidebar 12 "Training Employees to Handle Pesticides" for the legal descriptions of work activities of **pesticide handlers**). This test is mandatory if employees handle these materials for more than six calendar days during any 30 consecutive days. For this purpose, within a 24-hour period any amount of time spent performing handling activities counts as a day. Handling begins the moment you open a pesticide container for mixing or application and continues until you have bathed and changed clothing after completing the application. In case of a spill or other emergency, exposure begins at the onset of the incident and continues until you have bathed and changed clothing. Sidebar 11 describes an employer's responsibility for this handler medical monitoring program.



### Sidebar 11

#### Medical Monitoring Program

Whenever an employee mixes, loads, or applies an organophosphate or carbamate pesticide with the signal word "DANGER" or "WARNING", for the commercial or research production of an agricultural plant commodity, the employer must keep use records. These records must identify the employee, the name of the pesticide, and the date of use.

If an employee regularly handles these pesticides, the employer must have a written agreement signed by a physician, that includes the names and addresses of both the physician providing the medical supervision and the employer responsible for the employees. This agreement must state that the physician has agreed to provide medical supervision and that the physician possesses a copy of, and is aware of, the contents of the document ***Medical Supervision of Pesticide Workers-Guidelines for Physicians*** (available from the Department of Health Services and can also be downloaded from the Internet at [www.oehha.ca.gov/pesticides/pdf/docguide2002.pdf](http://www.oehha.ca.gov/pesticides/pdf/docguide2002.pdf)). A copy of this agreement must be given to the local agricultural commissioner by the employer before the employee begins to regularly handle the organophosphate or carbamate pesticides.

The employer's responsibilities for medical supervision for employees regularly handling pesticides must include the following:

- All covered employees must have a baseline red cell and plasma cholinesterase determination. Baseline values must be verified every two years. For new employees, the medical supervisor may accept previously established baseline values if they are obtained by the same laboratory methodology and are acceptable to the laboratory that will analyze the new employee's blood samples.
- The employer shall ensure that each employee, not previously under medical supervision associated with that employer, has red cell and plasma cholinesterase determinations within three working days after the conclusion of each 30-day period in which organophosphate and carbamate pesticides are regularly handled.



The blood test is a **red cell and plasma cholinesterase determination**. An initial test before using organophosphate and N-methyl carbamate pesticides establishes a baseline from which exposure can be measured. Subsequent testing provides for monitoring the level of exposure. These pesticides interfere with the body's nervous system by blocking the production of **cholinesterase**, an enzyme that helps to regulate nerve impulses and muscle activity. Cholinesterase normally balances the effects of another chemical, called **acetylcholine**, that transmits nerve signals between nerves and muscles.

Each person's blood and blood plasma has a unique baseline level of cholinesterase. The lowering of a person's cholinesterase usually indicates that exposure to an organophosphate or carbamate pesticide has occurred. If a person's cholinesterase level drops below the baseline level, a physician may advise the person to stop handling this group of pesticides awhile to avoid illness or injury. The physician may then prescribe additional tests to determine when the cholinesterase level returns to normal. This drop in the cholinesterase level also alerts the employer to find out how the exposure is taking place and take action to eliminate it, as required in regulation.

**Record Keeping.** California regulations require employers to keep several types of records pertaining to medical monitoring and organophosphate or carbamate pesticide use by employees. These include

- agreements to provide medical supervision
- detailed use records for employees handling organophosphate or carbamate pesticides
- recommendations received from the medical supervisor
- results of cholinesterase tests required to be made on his or her employees
- findings, any changes in equipment or procedures, and any recommendations made by a physician to an employee whose cholinesterase levels fall below 80 percent of the baseline

Employers shall keep these records for three years and make them available for inspection by the employee or the employee's representative, the Director of DPR, the local county agricultural commissioner, and county and state health officials.

Training that employers must provide to pesticide handlers and agricultural field workers is summarized in Sidebars 12 and 13.

## SAFETY PRACTICES AROUND AIRCRAFT

California prohibits pilots who are making aerial applications from handling category 1 or 2 ("DANGER" or "WARNING") pesticides containing organophosphates or carbamates except through a closed system. Therefore, pilots must depend on ground crews to perform various ground tasks associated with mixing and loading pesticides (Figure 3.5).



FIGURE 3.5

Ground crews assist the pilot by performing mixing and loading tasks.



## Sidebar 12

### Training Employees to Handle Pesticides

According to California regulations, a pesticide handler is any employee who

- mixes, loads, transfers, applies (including chemigation), or flags during aerial applications
- maintains, services, repairs, cleans, or handles equipment that may contain residues or that has been used in pesticide mixing or application activities
- works with opened pesticide containers, including emptied but not rinsed containers
- adjusts, repairs, or removes treatment site coverings, such as tarpaulins covering fumigated soil or agricultural commodities
- incorporates pesticides into the soil through mechanical means, or chemigation through an irrigation system
- enters a treated area during any application, or before the inhalation exposure level listed on pesticide product labeling has been reached, or before greenhouse ventilation criteria have been met
- performs the duties of a crop advisor, including field checking or scouting, making observations of the well-being of the plants, or taking samples during an application or any restricted entry interval listed on pesticide product labeling

California law requires all employers to have written training programs for pesticide handlers working in their operations. (Certified private and commercial applicators and licensed Pest Control Advisers are exempt from this training.) One part of this written program shall describe the materials used and information provided to the employees during training. Employers are responsible for either providing the training or arranging for someone else to provide it, and the records shall identify the person or firm actually conducting the training. Employers shall maintain a current copy of the training program while it is in use and for two years afterwards. All employers shall assure that their employee handlers are trained annually for each chemically similar family of pesticides or for each specific pesticide that they will handle. When pesticides are used for the commercial or research production of an agricultural commodity, trainers shall possess certain qualifications described below.

#### Trainer Qualifications

One or more of the following qualifications authorizes any person to train employees who will be handling pesticides for the commercial or research production of an agricultural commodity:

- possessing a valid California Qualified Applicator Certificate (QAC), Qualified Applicator License (QAL), or Pest Control Adviser License (PCA)
- possessing a valid California certified private applicator certificate
- holding a valid County Biologist License in Pesticide Regulation or Investigation and Environmental Monitoring issued by the Department of Food and Agriculture
- holding employment as a farm advisor employed by the University of California Cooperative Extension Service
- holding a certificate of completion from a DPR-approved instructor training program
- holding a valid California Registered Professional Forester license

(continued on next page)

(Sidebar 12, continued)

### The Training Program

The training program shall address each of the following topics as they apply to the pesticides that employees handle:

- understanding the format and meaning of information, such as precautionary statements about human health hazards, contained in the labeling of the pesticide products being handled
- understanding the hazards of the pesticides being handled, including acute and chronic effects, delayed effects, and sensitization, as identified in pesticide product labeling, Material Safety Data Sheets, or Pesticide Safety Information Series leaflets
- knowing the routes by which pesticides can enter the body
- recognizing the signs and symptoms of overexposure
- knowing specific emergency first aid for overexposure to the pesticides being handled
- knowing how to obtain emergency medical care
- knowing routine and emergency decontamination procedures, including spill clean up and the need to thoroughly shower with soap and warm water after the exposure period
- understanding the need for, limitations, appropriate use, and cleaning of any required PPE
- knowing the prevention, recognition, and first aid for heat-related illness
- understanding safety requirements and procedures, including engineering controls (such as closed mixing systems and enclosed cabs) for handling, transporting, storing, and disposing of the pesticides being handled
- recognizing environmental concerns such as drift, runoff, and wildlife hazards
- heeding warnings about taking pesticides or pesticide containers home
- knowing the requirements relating to pesticide safety, Material Safety Data Sheets, and Pesticide Safety Information Series leaflets
- understanding the purposes and requirements for medical supervision if organophosphate or carbamate pesticides with the signal word “DANGER” or “WARNING” on the labeling are mixed, loaded, or applied
- knowing the location of the written *Hazard Communication Information for Employees Handling Pesticides* (Pesticide Safety Information Series leaflet A-8), other Pesticide Safety Information Series leaflets, and Material Safety Data Sheets
- knowing the employee’s rights, including the right
  - to personally receive information about pesticides to which he or she may be exposed
  - for his or her physician or employee representative to receive information about pesticides to which he or she may be exposed
  - to be protected against retaliatory action due to the exercise of any of his or her rights

### Other Topics

The following topics should also be covered, if appropriate, during training. These are general pesticide handling procedures that apply to any pesticide product being handled:

- understanding the importance of wearing clean work clothing daily
- knowing how to handle, open, and lift containers

(continued on next page)

(Sidebar 12, continued)

- knowing how to properly pour pesticides out of containers
- knowing how to operate mixing and application equipment
- knowing procedures for triple rinsing containers
- knowing how to dispose of empty containers
- knowing how to confine spray to the target area
- knowing how to avoid contamination of people, animals, waterways, and sensitive areas
- knowing how and where to store containers that hold pesticides or are empty
- understanding procedures to follow when containers cannot be locked up
- understanding the importance of washing hands thoroughly before eating, smoking, drinking, or using the restroom

### Frequency of Training

Pesticide handlers shall be trained annually. Training does not have to correspond to the calendar year, but can take place at any time as long as pesticide handlers are trained annually. Pesticide handlers shall receive additional training on new pesticide products before they begin handling activities with them.



### Sidebar 13

## Criteria for Field Worker Training

Employers shall assure that their agricultural field workers are provided pesticide safety training before they enter treated areas within 30 days of completion of the application or expiration of a restricted entry interval. Field worker training also shall be performed by qualified trainers (as described in Sidebar 12).

This training shall be provided to any workers who enter pesticide-treated areas for the 30 days following expiration of a restricted entry interval. Training shall be provided to workers when an area has been treated with any type of pesticide, such as herbicides, fungicides, and insecticides. The current employer does not have to provide training if the worker or employer can verify such training has been provided within the past five years.

### Information that Shall Be Covered

- where and how workers may come in contact with pesticides or pesticide residues during work, including hazards from chemigation and drift
- the routes by which pesticides can enter the body (skin, mouth, inhalation, and eyes).
- symptoms of acute pesticide poisoning or injury, and long-term and delayed health effects from pesticide exposure, including sensitization
- first aid for pesticide injury and poisoning, and emergency decontamination

(continued on next page)

(Sidebar 13, continued)

- how workers can protect themselves from exposure, e.g., clothing; avoiding skin, eye, and mouth contact; personal hygiene
- obtaining medical help
- after-work storage, laundering, and decontamination of contaminated work clothes
- warnings about taking home pesticides or pesticide containers
- an explanation of the WPS entry restrictions, application limitations, posting, oral warnings, access to pesticide use information, and protection from employer retaliation

### Frequency of Training

Field workers shall be trained at least every five years after the date of the initial training. Training does not have to correspond to the calendar year, but can take place at any time.

There is evidence that direct eye contamination by organophosphates may cause contraction of the pupils for 7-10 days without any other symptoms. There have been several reports of fatalities when agricultural pilots were applying organophosphates. A *miosis* condition was discovered in some of the pilots following these fatal crashes.

While it is very difficult to assign “pilot error” crashes to pesticide exposure, all evidence suggests that pilots should keep their pesticide exposure to the minimum. If symptoms characteristic of pesticide poisoning occur, the pilot must seek examination and possible treatment by a medical professional. Following the examination and treatment, the pilot should not return to flight status without a doctor’s authorization.

## EMPLOYEE HABITS

All aspects of the aerial application of pesticides require alertness and attention to detail. This requires that the pilot and ground crew members not use alcohol or any drugs or medications that impair judgment or decrease mental alertness. Employees who must wear PPE must also take steps to avoid heat-related illnesses.

### Avoiding Use of Alcohol and Drugs

Alcohol, drugs, and certain over-the-counter and prescription medications cause drowsiness, impair judgment, and often influence your ability to handle an aircraft or apply pesticides safely (Figure 3.6). These substances may also alter the toxicity of pesticides in case of exposure. If you are taking any medication, consult a physician before flying an aircraft.

### Staying Alert

Anyone involved in the aerial application of pesticides must always be physically and mentally alert. This requires that the pilot and ground crew get sufficient sleep before an application operation. Pilots and ground crew must also not be fatigued from other activities prior to the operation. Stress from work or personal activities can be distracting and interfere with alertness, so individuals who experience high levels of stress should not participate in aerial application operations.



FIGURE 3.6

The consumption of alcoholic beverages before or during any pesticide handling activities can impair judgement and lead to accidents and serious injury.

### Preventing Dehydration and Heat-Related Illness

Drinking insufficient amounts of water coupled with wearing PPE during hot weather may lead to heat-related illness. Be sure to stay hydrated, drinking as much water as possible. Never wait until you are thirsty to have a drink of water, as thirst is an indicator that your body is already getting dehydrated. Heat-related illness may mimic certain types of pesticide poisoning. Symptoms of heat illness include tiredness, weakness, headache, sweating, nausea, dizziness, and fainting. Severe heat illness can cause a person to act confused, get angry easily, or behave strangely. People experiencing symptoms should be moved to a cool, shady, or air-conditioned area, provided cool, nonalcoholic, non-caffeinated beverages, and given adequate time to rest. California regulations require that pesticide handlers receive training on recognizing, avoiding, and treating heat stress along with training on recognizing pesticide illness. Sidebar 14 provides information on recognizing, preventing, and treating a heat-related illness.

## PERSONAL PROTECTIVE EQUIPMENT AND SAFETY EQUIPMENT

Personal protective equipment helps protect the person and the person's clothing from pesticide exposure. Some of this equipment is specific to protecting the wearer's head, torso, arms and legs, eyes, hands, and feet. Respiratory systems can also be protected by specific PPE. However, PPE is effective only if it fits correctly and is used properly. In addition, all PPE has limitations on the amount of protection from pesticide exposure it can provide. Safe work practices that help a pesticide handler avoid accidents and unnecessary exposure are still needed, even when wearing the correct PPE. Sidebar 15 describes the employer's requirements for providing PPE to pesticide handler employees. Sidebar 16 describes the respiratory protection program for pesticide handlers.

The greatest risk of pesticide poisoning comes from pesticides contacting the skin. Oil-soluble pesticides pass through skin faster than water-soluble pesticides. In addition, some areas of the body absorb pesticides more quickly than other areas.

**Selecting PPE.** Pilots are not required to wear the applicator PPE when they are inside the cockpit of the aircraft, unless required to do so by pesticide labels or state regulations. However, they shall always wear label- and regulation-required PPE for the pesticide being applied when entering and exiting the aircraft, cleaning windshields, making nozzle adjustments, and performing other tasks outside of the cockpit.

Follow the pesticide label instructions and California regulations for the PPE that pesticide handlers (including pilots) shall use. In most instances, using safer equipment than the label- and regulation-mandated equipment increases the amount of protection. In many instances, California regulations require additional PPE than pesticide labels prescribe. Sidebar 17 describes these California requirements.

PPE requirements for mixers and loaders may differ from required PPE for applicators, flaggers, or handlers who clean or repair contaminated equipment. Check the pesticide label for appropriate PPE for each handling task.



FIGURE 3.7

When working with pesticides, personal protective equipment provides protection against pesticide exposure.



## Sidebar 14

# Avoiding Heat Stress

Heat stress is the illness that occurs when the body builds up more heat than it can cope with. Heat stress is not caused by exposure to pesticides, but may affect pesticide handlers who are working in hot conditions. Wearing personal protective equipment—clothing and devices that protect the body from contact with pesticides—can increase the risk of heat stress by limiting the body's ability to cool down.

### Avoid Heat Stress

Several factors work together to cause heat stress. Before beginning a pesticide-handling task, think about whether any of these factors are likely to be a problem. Consider making adjustments in the task itself or in the workplace conditions, including:

- heat factors—temperature, humidity, air movement, and sunlight
- workload—the amount of effort a task requires
- personal protective equipment (PPE)
- drinking water intake
- scheduling

### Heat and Workload

High temperatures, high humidity, and sunlight increase the likelihood of heat stress. Air movement, from wind or from fans, may provide cooling. Because hard work causes the body to produce heat, a person is more likely to develop heat stress when working on foot than when driving a vehicle. Lifting or carrying heavy containers or equipment also increases the likelihood of becoming overheated.

### Signs and Symptoms of Heat Stress

Heat stress, even in mild forms, makes people feel ill and impairs their ability to do a good job. They may get tired quickly, feel weak, be less alert, and be less able to use good judgment. Severe heat stress (heat stroke) is a serious illness. Unless victims are cooled quickly, they can die. Severe heat stress is fatal to more than 10 percent of its victims, even young, healthy adults. Victims may remain sensitive to heat for months and be unable to return to the same work.

Learn the signs and symptoms of heat stress and take immediate action to cool down if they appear. Signs and symptoms may include:

- fatigue (exhaustion, muscle weakness)
- headache, nausea, and chills
- dizziness and fainting
- loss of coordination
- severe thirst and dry mouth
- altered behavior (confusion, slurred speech, quarrelsome or irrational attitude)

(continued on next page)



(Sidebar 14, continued)

Heat cramps can be painful. These are muscle spasms in the legs, arms, or stomach caused by loss of body salts through heavy sweating. To relieve cramps, drink cool water. Stretching or kneading the muscles may temporarily relieve the cramps. If there is a chance that stomach cramps are being caused by pesticides rather than salt loss, get medical help right away.

It is not always easy to tell the difference between heat stress illness and pesticide poisoning. The signs and symptoms are similar. Never waste time trying to decide what is causing the illness. Get medical help right away. Severe heat stress (heat stroke) is a medical emergency! Cool the victim immediately. Brain damage and death may result if treatment is delayed.

### First Aid for Heat Stress

- Get the victim into a shaded or cool area.
- Cool the victim as rapidly as possible by sponging or splashing the skin, especially around the face, neck, hands, and forearms, with cool water or, when possible, immersing in cool water.
- Carefully remove all PPE and any other clothing that may be making the victim hot.
- Have the victim, if conscious, drink as much cool water as possible.
- Keep the victim quiet until help arrives



### Sidebar 15

## Employer Requirements: Providing Personal Protective Equipment to Employee Handlers

California regulations require that employers provide all required PPE for employees who handle pesticides. Additionally, employers shall provide for the daily inspection and cleaning of all PPE according to pesticide labeling instructions. If labeling instructions do not address cleaning, the employer shall provide for the washing of PPE in detergent and hot water. Employers shall arrange to repair or replace any worn, damaged, or heavily contaminated PPE.

Other employer responsibilities for PPE include assuring that

- all clean PPE, when not in use, is kept separate from personal clothing and in a pesticide-free, specifically designated place
- appropriate measures are taken to prevent heat related illness of employees who wear PPE
- employees use PPE correctly for its intended purpose
- PPE made from absorbent materials that have been drenched or heavily contaminated with a pesticide with the signal word “DANGER” or “WARNING” is properly discarded
- potentially contaminated PPE is laundered separately from other clothing or laundry
- all clean PPE is either dried thoroughly before being stored or is put in a well ventilated place to dry
- PPE remains the property of the employer and that pesticide handlers are not allowed or directed to take potentially contaminated PPE into their homes
- any person or firm assigned or hired to clean or repair potentially contaminated PPE is protected and informed of the hazards of the pesticides and the methods of protecting against personal injury





## Sidebar 16

## Respiratory Protection Program for Pesticide Handlers

Employers shall assure that pesticide handler employees use approved respiratory protective equipment when pesticide product labeling or regulations require respiratory protection or when respiratory protection is needed to maintain employee exposure below the applicable exposure standard found in Title 8, California Code of Regulations, Section 5155.

The National Institute for Occupational Safety and Health (NIOSH) and/or the Mine Safety and Health Administration (MSHA) currently approve respiratory protection required by these regulations or pesticide product labeling. Proper selection of respirators shall be made according to pesticide product labeling, or absent specific instruction, according to the guidance of the National Standard Practices for Respiratory Protection: Z88.2-1980, or the American National Standard Practices of Respiratory Protection During Fumigation: Z88.3-1983.

Employees shall have written operating procedures for selecting, fitting, cleaning and sanitizing, inspecting, and maintaining respiratory protective equipment.

Employees with facial hair that prevents an adequate seal shall not be assigned work requiring them to wear a respirator unless they are provided a respirator that does not rely on a face to facepiece seal for proper operation.

Respirators maintained for standby or emergency use shall be inspected monthly or before use if occasions for possible use are more than one month apart. A record of the most recent inspection shall be maintained on the respirator or its storage container.

Employees shall be informed, prior to beginning work, that certain medical conditions may interfere with wearing a respirator while engaged in potential pesticide exposure situations. A statement in substantially the form shown in Figure 3.8 shall be on file for each employee assigned to work that requires wearing a respirator.

If an employee checks that he or she has such a condition, a physician's report of evaluation and approval for respirator use (Figure 3.9) shall be on file before work requiring respirator use is allowed. The following or substantially similar statement from a physician is acceptable.

Compressed air used in a Self Contained Breathing Apparatus (SCBA) or for airline type respirators shall meet or exceed the requirements for Grade D breathing air as described in the Compressed Gas Association Commodity Specification G-7.1 (ANSI Z86.1-1973).

When air purifying-type respirators are required for protection against pesticides, the air purifying elements or entire respirator, if disposable, shall be replaced according to pesticide product labeling directions or respiratory equipment manufacturer recommendations, whichever provides for the most frequent replacement. In the absence of any other in-

#### Employee Statement of Medical Condition

**To the best of my knowledge, I have \_\_\_\_\_, have no \_\_\_\_\_ medical conditions that would interfere with wearing a respirator while engaged in potential pesticide exposure situations. I understand that heart disease, high blood pressure, lung disease, or presence of a perforated ear drum are examples of conditions that require specific medical evaluation by a physician before safe use of a respirator can be determined.**

\_\_\_\_\_  
(Employee Signature)

\_\_\_\_\_  
(Date)

**FIGURE 3.8**

Example of a *Statement of Medical Condition* required to be completed by employees before performing handling activities that require the use of a respirator.

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(Sidebar 16, continued)

structions on service life, air-purifying elements shall be replaced at the end of each day's work period. At the first indication of odor, taste, or irritation, the wearer shall leave the area and check the respirator for fit or function concerns or air purifying element replacement.

<b>Statement of Medical Evaluation</b>	
On _____, I examined _____	
(Date)	(Patient's name)
At this time there is no medical contraindication to the employee named above wearing a respirator to allow working in potential pesticide exposure environments.	
Other comments: _____	
_____	
_____	_____
(Physician)	(Date)

FIGURE 3.9

If an employee indicates that he or she has a medical condition that would affect his or her wearing of a respirator, the employer must have the employee evaluated by a physician. The physician must complete a form with information on it similar to this example.

The application method, an applicator's technique, and equipment type also influences the exposure produced during an application. For instance, the exposure risk is greater with an air blast sprayer than with a low-volume boom sprayer. Applying pesticides in enclosed areas is usually more risky than applying pesticides outdoors. Aerial application has minimal risk of exposure to the pilot compared to most ground application operators when an aircraft with an enclosed cockpit shields the pilot from the spray.

## DEALING WITH PESTICIDE EMERGENCIES

Accidents may occur while you are handling or applying pesticides, even if you are working under the most careful conditions. Many pesticides diluted with water are hazardous, but undiluted pesticides are usually much more dangerous. Pesticide emergencies may be the result of

- leaks
- spills
- fires
- thefts
- misapplication
- lack of care in storage or handling

Material Safety Data Sheets (MSDSs) contain instructions on how to deal with many types of pesticide emergencies. Keep copies of the MSDSs at the storage, mixing, and application sites. In addition, whenever you use pesticides, regulations require that the names and locations of nearby medical facilities capable of treating pesticide-related injuries be posted in a conspicuous place on work vehicles used in the application operation. If an accident happens, and you or members of the ground crew have been exposed to pesticides, seek medical care.

Be prepared to offer first aid to accident victims who are exposed to pesticides. Then, insist they receive prompt medical attention. To help employees locate medical facilities, post the notice in a conspicuous place at the worksite.

## Pesticide Leaks and Spills

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Treat all pesticide leaks or spills as emergencies. Concentrated pesticide spills are much more dangerous than pesticides diluted with water, but both types should be dealt with immediately. Leaks or spills can occur during transporting, storing, or while using pesticides.

When spills occur on public roadways, immediately contact the California Highway Patrol and the Governor's Office of Emergency Services. Consult the Office of Emergency Services website at <http://www.oes.ca.gov/Operational/OESHome.nsf/1?OpenForm> for useful information on preparing for hazardous material spills. These agencies will take charge of coordinating the cleanup and protecting the public. For advice on cleaning up spills, emergency responders can contact CHEMTREC (Chemical Transportation Emergency Center) at 1-800-262-8200. This is a hotline for fire fighters, law enforcement, and other emergency responders to obtain critical information and assistance for emergency incidents involving pesticides and other hazardous materials.

When pesticides are spilled on public roadways, a report is required to be filed with the Office of Emergency Services. In addition, report all leaks or spills of pesticides, no matter where they occur, to the local county agricultural commissioner as soon as possible.

Put materials that have been cleaned up and anything that was contaminated by the spill into a sealable drum. Label the drum to indicate it contains hazardous waste. Include the name of the pesticide and the signal word ("DANGER", "DANGER/POISON", "WARNING", or "CAUTION").

Because local regulations vary, contact the county agricultural commissioner or Water Quality Control Board (phone 916-341-5250) for instructions on how to dispose of the sealed drum and its contents. Under most circumstances, you must send the residue from a pesticide spill to a Class 1 disposal facility.

Spills on cleanable surfaces, such as concrete, require thorough decontamination. Commercial decontamination preparations are available for this purpose, or prepare a solution, using 4 tablespoons of detergent and 1 pound of soda ash, dissolved in each gallon of water. Soda ash cannot be used for detoxification of a few pesticides, so check the label or MSDS before using this solution. Contact the pesticide manufacturer if you have any questions.

**First Aid.** If anyone has been injured or contaminated, administer first aid. Send for medical help if necessary.

**Barricade.** Rope off the area or set up barricades to keep everyone away from the contaminated site.



## Sidebar 17

## Minimum Required Personal Protective Equipment

California regulation requirements for PPE may be more restrictive than pesticide label requirements, so you must understand the California requirements. Regulation states that the employer shall provide the required PPE, and shall assure that it is worn. At the minimum, employers shall provide appropriate eyewear and chemical resistant gloves to pesticide handlers and assure that employees use them properly. In addition, employers shall follow certain requirements when the label requires using chemical resistant footwear, head covering, apron, or body covering.

### Eyewear

California regulations require employers to assure that their employee handlers wear protective eyewear

- when required by the pesticide product labeling
- during all mixing or loading activities (see Sidebar 18 for exceptions)
- while adjusting, cleaning, or repairing the mixing, loading, or application equipment that contains pesticide material in hoppers, tanks, or lines
- when making applications by hand or using hand held equipment, except when:
  - applying vertebrate pest control baits that are placed without being propelled from application equipment
  - applying solid fumigants (including aluminum phosphide, magnesium phosphide, and smoke cartridges) to vertebrate burrows
  - baiting insect monitoring traps
  - applying noninsecticidal lures
- while making ground application using vehicle-mounted or towed equipment, except when:
  - injecting or incorporating pesticides into soil
  - spray nozzles are located below the employee and the nozzles are directed downward
  - working in an enclosed cab
- while flagging, except when the flagger is in an enclosed cab

Whenever protective eyewear is required, one of the following types shall be worn:

- safety glasses that provide front, and supplemental brow and temple protection (common eyeglasses, including sunglasses, do not meet this requirement)
- goggles
- ace shield
- full face mask used in conjunction with respiratory protection
- visor (for aircraft operation only)

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(Sidebar 17, continued)

### Gloves

California regulations require employers to assure that their employee handlers wear chemical resistant gloves

- when required by the pesticide product labeling (unless the pesticide product labeling specifies that gloves shall not be worn)
- when employees are engaged in:
  - mixing or loading (pilots are not required to wear gloves while flying the aircraft during an application)
  - adjusting, cleaning or repairing contaminated mixing, loading, or application equipment
  - application by hand or using hand-held equipment, except when applying vertebrate pest control baits using long handled implements that avoid actual hand contact with the bait or potentially contaminated areas of the equipment

If the type of glove is not specified on product labeling for the pesticide being handled, gloves made of rubber, neoprene, or other chemical resistant material that provides equivalent or better protection shall be used. Pesticide handlers shall not wear gloves or glove linings of leather, cotton, or other absorbent materials unless expressly permitted by pesticide product labeling. If chemical resistant gloves with sufficient durability and suppleness are not available, leather gloves may be worn over chemical resistant glove liners. Once leather gloves have been used for this purpose, they shall not be worn in any other situation.

### Footwear

The employer shall assure that their employee handlers wear chemical resistant footwear when required by the pesticide product label. Chemical resistant footwear includes the following types of footwear:

- chemical resistant shoes
- chemical resistant boots
- chemical resistant coverings worn over boots or shoes

For aircraft operation, chemical resistant footwear need not be worn.

### Headwear

The employer shall assure that their employee handlers wear chemical resistant headgear when required by the pesticide product labeling. Either a chemical resistant hood or a chemical resistant hat with a wide brim will satisfy this requirement. For aircraft operation, a helmet may be substituted for chemical resistant headgear.

### Chemical Resistant Apron

Employers shall assure that their employee handlers wear a chemical resistant apron when required by the pesticide product labeling. It shall be a garment that covers the front of the body from mid-chest to the knees.

### Bodywear

Employers shall assure that their employee handlers wear chemical resistant body wear when required by pesticide product labeling or regulations. Chemical resistant body wear includes waterproof or impervious pants and coat, or a rain suit that covers the torso, head, arms, and legs.

Except for those conditions listed below, when the pesticide label requires chemical resistant bodywear, employees cannot handle the material if the outdoor temperature exceeds 80°F during daylight hours or 85°F during nighttime hours.

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(Sidebar 17, continued)

If outdoor temperatures exceed those maximums listed above, employees can only perform handling activities if employees are

- using cooled chemical resistant suits (mixers, loaders, other handlers, and applicators)
- working in an enclosed cab or cockpit (applicators)
- using a closed mixing system (mixers and loaders)
- handling pesticides packaged in water-soluble packets and the packets are not opened (mixers and loaders)



### Sidebar 18

## Exceptions and Substitutions to Required Personal Protective Equipment

The following exceptions and substitutions to PPE required by pesticide product labeling or regulations are permitted by California regulations:

- people using a closed system to handle pesticide products with the signal word “DANGER” or “WARNING” may substitute coveralls, chemical resistant gloves, and a chemical resistant apron for PPE required by pesticide product labeling
- people using a closed system to handle pesticide products with the signal word “CAUTION” may substitute **work clothing** for PPE required by pesticide product labeling
- anyone using a closed system that operates under positive pressure must wear protective eyewear in addition to other required PPE and they must have all the PPE required by pesticide product labeling immediately available for use in an emergency
- anyone properly mixing pesticides packaged in water soluble packets are considered to be using a closed mixing system
- anyone occupying an enclosed cab (including an aircraft cockpit) may substitute work clothing for PPE required by pesticide product labeling; if respiratory protection is required, it must be worn (except in an enclosed cockpit)
- anyone occupying an enclosed cab acceptable for respiratory protection may substitute work clothing for PPE required by pesticide product labeling
- anyone working in an enclosed cab, other than an aircraft cockpit, shall have all PPE required by pesticide product labeling immediately available and stored in a chemical resistant container, such as a plastic bag; labeling-required PPE shall be worn if it is necessary to work outside the cab and contact pesticide treated surfaces in the treated area; once PPE is worn in the treated area, it shall be removed and stored in a chemical resistant container, such as a plastic bag, before reentering the cab
- a chemical resistant suit may be substituted for coveralls and/or a chemical resistant apron
- pest control aircraft pilots are not required to wear gloves during operation but gloves shall be worn by any person entering or exiting an aircraft contaminated with pesticide residues; while in the cockpit, gloves must be carried in a chemical resistant container, such as a plastic bag

**Ventilation.** If the spill is indoors, open all doors and windows, set up a portable fan, if available, and get out of the building.

### Cleaning Up Pesticide Leaks or Spills

Cleaning up major pesticide spills requires the help of professionals. It is extremely difficult and costly to remove contaminated soil or to prevent or clean up ground water contamination. The most necessary things for you to do before professional help arrives are to contain the spill as much as possible and keep other people away.

The types of pesticide leaks and spills you will most likely encounter will be **control-lable quantities**—such as when a container is damaged or slips to the ground or when diluted pesticide leaks from application equipment. Proper and immediate response to even these types of small leaks and spills is necessary to minimize the threat to human and environmental health.

There are certain basic steps you should follow in cleaning up a pesticide leak or spill:

**Clear the Area.** Keep people and animals away from the contaminated area. Provide first aid if anyone has been injured or contaminated. Send for medical help if necessary.

Some liquid pesticide products or formulations are flammable. Pesticide powders are potentially explosive, especially if a dust cloud forms in an enclosed area. Do not allow any smoking near a spill. If the spill occurs in an enclosed area, shut off all electrical appliances and motors that could produce sparks and ignite a fire or explosion.

**Wear Personal Protective Equipment.** Before beginning any cleanup, put on the personal protective clothing listed on the label for mixing or loading the concentrated material. Check the pesticide label for additional precautions, but when uncertain what has been spilled, wear the maximum protection. This includes chemical resistant boots and gloves, waterproof protective clothing, goggles, and a respirator.

**Contain the Leak.** Stop the leak by transferring the pesticide to another container or by patching the leaking container (repair paper bags and cardboard boxes with strong tape). Use soil, sand, sawdust, or absorbent clay, such as cat litter, to form a containment berm around liquid leaks. If the wind is blowing pesticide dusts or powders, lightly spray the area with water or cover the spill with a plastic tarp to prevent offsite movement.

**Clean Up the Pesticide.** Proceed to clean up the spill or leak. Brush the containment dam of absorbent material toward the center of a liquid spill. Add additional absorbent material if necessary. If the spill is on soil, shovel out contaminated soil for disposal. Place the absorbent or spilled dry product, and any contaminated soil, into a sealable container. Containers for holding contaminated materials must be suitable for transporting. Label the container with the pesticide name and signal word.

**Clean Nonporous Surfaces and Safety Equipment.** If the spill occurred on a cleanable surface, such as concrete or asphalt, use a broom to scrub the contaminated surface with a strong detergent solution. Again clean this up with some absorbent material and place it in the container. Equipment such as brooms, shovels, and dustpans must be cleaned or disposed of.

**Properly Dispose of the Material.** Local regulations on disposal of hazardous materials may vary. Check with the local county agricultural commissioner or Water Quality Control Board for instructions on how to dispose of the container and its contents.

## Pesticide Fires

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Fighting pesticide fires requires special care because smoke and fumes generated by burning pesticides cannot be contained; areas endangered by these fumes must be evacuated. Toxic fumes hamper fire-fighting efforts and require the use of supplied air respirators and protective clothing. Water must be used with caution when fighting pesticide fires. Use it primarily to cool containers and prevent overheated chemicals from exploding. Do not splash or spread toxic chemicals with high-pressure water.

Once the fire has been brought under control, all hoses and equipment, including personal protective clothing, must be decontaminated. Residue remaining at the fire site must be removed and disposed of.

### How to Deal with a Pesticide Fire

Follow this sequence if a pesticide fire breaks out:

**Call the Fire Department.** Contact the nearest fire department as quickly as possible (call “9-1-1”). Inform them that it is a fire involving pesticides. Provide them with the names of the pesticides and other chemicals contained in the structure, vehicle, or aircraft. If possible, provide Material Safety Data Sheets to the arriving fire units.

**Clear the Area.** Get people out of the immediate area of the fire; there may be considerable risk of toxic fumes and the possibility of an explosion.

**Evacuate and Isolate the Area Around and Downwind of the Fire.** Protect animals and move equipment and vehicles that could be damaged by the fire or fumes or that would impair fire-fighting efforts. Keep spectators from being exposed to smoke from the fire and runoff from fire fighting. Contact the police or sheriff and have downwind residences, schools, and buildings evacuated until the danger has passed.

## MISAPPLICATION OF PESTICIDES

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Another form of emergency may exist when pesticides have been misapplied.

- **Intentional misapplication** involves intentional and illegal use of a pesticide on an unregistered site or knowingly applying pesticides in a manner inconsistent with label directions.
- **Accidental misapplication** involves unknowingly applying a pesticide to a site not on the label.
- **Negligent application** involves improper calibration of application equipment as well as improper use and disposal of the pesticide; it also involves applying pesticides at the wrong time, using the wrong type of application equipment, or in any other way making applications that are inconsistent with label requirements.

Making an application mistake is a serious problem; do not compound the damage by failing to take responsible, corrective action once the mistake is discovered. You may be financially responsible for damages, both physical and legal, caused by your misapplication of a pesticide. You may be able to reduce the amount of damage and liability by taking prompt action once you discover the error. Of primary importance is the protection of people, animals, and the environment.



### Incorrect Amount of Pesticide Used

Insufficient quantities of pesticides usually do not give adequate control of the target pest and waste time and money, but generally present no immediate problems to people or the environment. Excessive amounts of pesticide, however, can be an environmental threat as well as a danger to human health. This type of problem occurs because of:

- poor calibration of the application equipment
- faulty mixing of chemicals in the spray tank
- not understanding or following the label directions regarding application rates

Residues from the pesticide may last longer than expected, or a concentrated application may cause damage to the treated area.

**Correcting the Problem.** Once you discover an improper application, take immediate action. Notify the county agricultural commissioner of the problem and seek information and advice on what remedies to take. Contact the pesticide manufacturer to find out what corrective measures they suggest. Remember, speed is of the utmost importance when trying to reduce damage.

### Applying the Wrong Pesticide

Lack of attention to mixing or giving the wrong instructions to an employee may result in the wrong pesticide being applied. Besides possible damage to plants or surfaces in the treatment area, using the wrong pesticide exposes you and your ground crew to unanticipated hazards. Mixing and application might take place without the required PPE, resulting in possible injury to the handlers.

**Correcting the Problem.** When you discover that someone mixed or applied the wrong pesticide, contact the county agricultural commissioner for help, and then call the pesticide manufacturer. Notify people in the application area, and keep them away until the problem is resolved.

### Pesticides Applied to the Wrong Site or Crop

Another form of accident involves pesticides being applied to the wrong site. This can be a serious problem if the site (or crop) is not listed on the pesticide label or if there are workers at the site who are performing cultural operations during or after the application. Usually, this problem is caused by improper location instructions being given to the aerial applicator.

**Correcting the Problem.** Contact the county agricultural commissioner and the pesticide manufacturer for assistance. Keep people and animals out of the sprayed area until it has been determined that it is safe to return.

## AIRCRAFT AND PESTICIDE SECURITY

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Operations that handle pesticides are actively engaged in managing risks to ensure the safety of their workers and the community. Most of their efforts focus on ensuring that their facilities, mixing and loading equipment, and aircraft are designed and operated safely on a day-to-day basis, using preventive maintenance, up-to-date operating procedures, and a

well-trained staff. Because of today's increased concerns about terrorism and sabotage, companies must also pay more attention to the security of aerial application equipment, facility sites, and pesticide storage areas. All aerial operations should have some measure of site security in place to minimize crime and to protect company assets.

## Knowing and Understanding Potential Security Threats

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Businesses that transport, store, and apply pesticides have long known the importance of risk mitigation steps for the safety of their workers, their customers, and their communities. For the pesticide user community, safety efforts have focused on strictly reading and following all label directions. Today, these efforts are not necessarily enough.

While many of the steps to ensure an effective security program seem routine, they are **critical** to the health and safety of an aerial application operation and the surrounding community. Without effective security procedures, the business may be vulnerable to both internal and external threats, posing risks to pilots and other employees, facilities and equipment, stored pesticides, and even sensitive business information. Pest control operators need to take special precautions with aerial application equipment to protect both their equipment and the surrounding community.

### Evaluating Pesticide Security

Some of the security needs and critical control points for an aerial application operation include:

- **Securing Facilities, Storage Areas, and Surrounding Property.** One of the most fundamental security needs is the prevention of intrusion into areas used to store pesticides. Elements of an effective security plan can range from basic fencing, lighting, and locks, to intrusion detection systems and cameras.
- **Securing Pesticide Application Aircraft and Vehicles.** The operation should have appropriate security protections to prevent intruder access to equipment used in mixing, loading, and applying pesticides.
- **Aerial Application Equipment.** Security awareness is particularly necessary for large-scale pesticide application equipment such as aircraft. The FBI has requested that aerial applicators be vigilant to any suspicious activity relative to the use, training in, or acquisition of dangerous pesticide chemicals or airborne application of these materials. This includes threats, unusual purchases, suspicious behavior by employees or customers, and unusual contacts with the public. Report any suspicious circumstances or information to the FBI.
- **Employees.** Effective hiring and labor relations policies are needed to obtain and retain good employees who will support and follow safety precautions. For example, the hiring process should ensure that pesticide handlers have all requisite training necessary to handle pesticides safely. Background checks of staff who have access to secure areas, particularly those areas where pesticides may be stored, are also necessary.

- **Inventory Management** Inventory management policies can help limit the amount of potentially hazardous pesticides stored on site, reducing the risks of accidental or intentional release or theft.
- **Emergency Response.** Effective advance emergency response procedures can be critical, helping ensure that the operation manager and employees understand how to respond and whom to contact in the case of an emergency. Aside from accidents, such plans must also consider vandalism, bomb threats, and potential terrorist activity.

### Timely Coordination with Authorities

If a breach of security or suspicious activity does occur, timely cooperation with authorities is crucial. In addition to cooperation with the local police department, the FBI requests that operators expeditiously report any threats or suspicious behavior to the local FBI field office (Figure 3.10). Information on the location of the appropriate FBI office is available at [www.fbi.gov](http://www.fbi.gov).



FIGURE 3.10

The FBI requests that any suspicious behavior observed around aerial application equipment or facilities be reported to the local field office.

## Chapter 3

## Review Questions

SEE PAGE 178 FOR ANSWERS

1. One of the factors that determine the severity of a pesticide-related injury is
  - a. weather conditions at the time of exposure
  - b. how the exposure occurred
  - c. the dose to which the person was exposed
  - d. the type of work the person was performing
2. The type of first aid given to a pesticide exposure victim depends on the
  - a. type of exposure
  - b. age of the victim
  - c. training of the person administering first aid
  - d. work situation where the person received the exposure
3. If a person shows signs of pesticide poisoning, they should
  - a. stop working for the day
  - b. receive immediate medical attention
  - c. be assigned to another job not involving pesticides
  - d. be scheduled for a blood test
4. When medical care providers are treating a person injured by a pesticide, it is helpful to provide them with
  - a. a sample of the pesticide
  - b. an empty container that held the pesticide
  - c. the label and Material Safety Data Sheet for that pesticide
  - d. a copy of the DPR Pesticide Safety Information Series leaflet
5. If a person spills liquid pesticide onto his or her arm, the amount of exposure and injury can often be reduced by
  - a. removing any contaminated clothing
  - b. wiping the liquid off the person's arm
  - c. covering the exposed area with a damp cloth
  - d. washing the exposed area with soap and water

6. Medical monitoring is required by law for employees who regularly handle
  - a. all “DANGER” pesticides
  - b. “DANGER” phenoxy herbicides
  - c. “DANGER” organophosphate insecticides
  - d. “DANGER” fungicides
7. A pilot who is making an aerial application is prohibited by California law from handling Category 1 or 2 organophosphate or carbamate pesticides except when
  - a. using a closed mixing and transfer system
  - b. wearing an approved cartridge respirator
  - c. wearing the personal protective equipment required on the pesticide label
  - d. being supervised by a licensed operator
8. During an application operation, pilots must wear the label-required personal protective equipment for pesticide handlers
  - a. only while making an aerial application
  - b. anytime they are in the aircraft cockpit
  - c. while making nozzle adjustments
  - d. while calibrating an aircraft granule dispersal system
9. Information on how to deal with many types of pesticide emergencies is commonly found on
  - a. pesticide labels
  - b. Material Safety Data Sheets (MSDSs)
  - c. supplemental labeling
  - d. the Statement of Practical Treatment
10. An **accidental misapplication** of a pesticide is one that involves
  - a. improper calibration of the application equipment
  - b. knowingly applying the pesticide in a manner inconsistent with label directions
  - c. applying the pesticide at the wrong time
  - d. unknowingly applying a pesticide to a site not listed on the label
11. For protection of the surrounding community, a good reason for securing pesticide application aircraft and other equipment when not in use is to
  - a. prevent weather damage to the equipment
  - b. keep children from playing around the equipment
  - c. prevent intruder access to the equipment
  - d. comply with regulatory agency mandates



# 4 Safe Pesticide Handling Techniques

Pesticide handlers are responsible for the safe and proper handling and use of pesticides. Sidebar 12 on page 54 describes the duties performed by pesticide handlers. Pilots are considered pesticide handlers, and may supervise ground crews who are performing various handling activities (Figure 4.1). Pilots should know of the employer responsibilities to assure that ground crews

- are properly trained on the use of mixing and loading equipment
- receive annual pesticide handler training
- work safely and legally
- follow label and work order instructions
- understand emergency procedures

A large number of the reported pesticide illnesses and injuries in California occur during pesticide handling activities. Failing to follow the use requirements on the label or in the regulation, or to follow the basic principles of safe pesticide use, are the most common causes of pesticide injuries or illnesses. Mechanical problems or other causes also lead to pesticide related injuries or illnesses. Serious problems may occur if someone fails to

- use the required personal protective equipment
- use proper application methods and techniques
- immediately provide first aid or arrange for professional medical care after an exposure
- follow other requirements, such as for restricted entry interval, posting and notification of treated fields, or early entry
- take other appropriate action in response to pesticide-related emergencies

This chapter provides legal requirements and common sense methods for handling pesticides safely.



FIGURE 4.1

Pilots of application aircraft are considered pesticide handlers. Quite often, they are responsible for supervising the ground crew for an application operation.

## COMMUNICATING WITH THE GROUND CREW

Operational problems can result from poor communications or sketchy information about a job of which the ground crew is asked to perform. It is risky to assume that ground crew employees already possess vital information they need to perform their jobs safely. Job delays, having to return for forgotten materials, treating the wrong fields, or spraying the improper types or concentrations of materials are examples of accidents that can occur when ground crew employees are operating with incomplete information.

The pilot, supervisor, and the ground crew should be involved in

- developing maps of all areas to be treated and charting all hazards, adjacent crops, and environmental sensitive areas
- examining all new areas by ground and air and keeping maps up to date so that new obstacles or changes in conditions are identified promptly
- developing a system for accepting or transmitting information between the ground crew and the pilot on work order changes in the field
- filling out mix sheets and determining the order of mixing
- ensuring that mixer/loaders are trained in calculating tank batches, handling procedures, and personal protective equipment use and care
- providing ground crew with essential site-specific job information
- providing ground crew members with a checklist outlining the methods for them to comply with applicable regulations and company policies

## TRANSPORTING AND STORING PESTICIDES

A major part of the safe handling of pesticides involves proper storage and transportation of these hazardous materials. A spill, leak, or other accidental release of concentrated pesticides can seriously injure people and damage the environment.



FIGURE 4.2

Care must be used when transporting pesticide materials to avoid accidents that may lead to a spill.

### Transporting Pesticides

There is always a risk that an accident might occur while transporting undiluted or diluted pesticides in a vehicle or trailer (Figure 4.2). Spilled materials may cause serious human exposure and environmental damage if they flow into drainage or irrigation ditches, streams, or rivers. If not properly cleaned up, spilled pesticides also may wash into major waterways during a rainstorm or leach into the ground water.

If a spill occurs on a public road, passing vehicles may scatter the material and will increase the risk of human exposure and environmental contamination.

When transporting any pesticides

- never carry pesticides in the passenger compartment of the vehicle
- never carry passengers in the same area used for transporting pesticides
- secure all containers in the cargo area of the vehicle and protect them from rain and other potential damage



- never stack containers higher than the sides of the cargo area of the transporting vehicle
- never allow people to ride in the cargo area even when absent of pesticide containers, as the area may be contaminated
- never carry any other items in the cargo area
- do not leave pesticides unattended in a vehicle unless they are inside a locked compartment
- carry a manifest or list of the pesticides being transported to assist emergency workers in case of an accident

Obtain current information on the legal requirements for transporting pesticides on public roads from the California Highway Patrol, California and U.S. Departments of Transportation, or the Public Utilities Commission. Check with these agencies to find out what types and quantities of materials are subject to hazardous materials transportation requirements and what placards must be placed on the transporting vehicle.

### Storing Pesticides

If pesticides need to be stored for any purpose, put them into a separate, secure structure that has been designed just for this purpose and is located where it will not interfere with other activities. Post signs on the structure to warn people that it contains pesticides. Protect the pesticides in the storage area from extremes in temperature and do not allow any to become wet. Always check labels of the pesticide products for additional special storage precautions.

Maintain a current record of the pesticides being stored and keep a copy of this list in a separate location. Knowing the storage area's contents will help personnel responding to an emergency, such as a fire, and will often prevent injuries.

Keep the facility locked to prevent unauthorized access or theft. Regularly check the security of the storage facility and immediately correct any problems. Frequently inspect the condition of containers and look for leaks or spills. Clean up any spilled pesticides as soon as they are discovered.

## HANDLING PESTICIDE CONTAINERS

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Train anyone handling pesticide containers to follow these guidelines, including locating and following information that can be found in labeling or the manufacturer's Material Safety Data Sheet (MSDS):

- wear rubber gloves and personal protective equipment, such as an apron, when handling unopened pesticide containers or packages —the pesticide label will indicate the correct personal protective equipment (PPE) to wear (if a leak is present, eye protection is also needed, and respiratory protection may be required)
- do not eat, drink, or smoke while handling pesticide containers or while inside the storage facility
- check for contamination or leaks on all packages being handled
- never drop or throw containers or packages, because this may cause damage and leaks

- in case of a damaged and leaking container
  - check the label for all precautions and required safety equipment
  - do not let damaged packages or spilled pesticides contact skin or clothing
  - never walk through a spilled pesticide
  - transfer the pesticide to another container (use a container labeled for that pesticide or another properly labeled container—see the **Service Containers** section below)
- to prevent causing a danger to others or exposing containers to theft, never leave pesticide containers unattended or stored in unlocked areas
- always keep pesticide containers away from food and water and away from sources of heat and fire
- never allow paper or cardboard containers to get wet
- wash your hands and forearms immediately when finished handling containers and before eating, drinking, smoking, or using the restroom

### Service Containers

A service container is any container, other than the original labeled container that is being used for applying, storing, or transporting concentrate or diluted pesticides. Each service container and rig that is used to handle concentrate or diluted pesticides and draws water from an outside source shall be equipped to prevent backflow. The backflow prevention method or device must be acceptable to the water provider and the local health department, and it must effectively prevent backflow of any concentrate or diluted pesticide into the water source. Backflow prevention includes using an air-gap separation, a reduced pressure principle backflow prevention device, or a double check valve assembly. Service containers must carry the registrant's label(s) for each pesticide it holds. The service container shall also be labeled with the

- identity or identities of the pesticide
- signal word(s)
- name and address of the person or company responsible for the container



FIGURE 4.3

Pesticides must be mixed accurately and carefully loaded into the aircraft.

## MIXING AND LOADING

Pesticides must be mixed with water or other diluent as directed on the label (Figure 4.3), just prior to application and they should never be left in the mixing tanks for extended periods because they may degrade. The registered labels allowing the intended application method for all pesticide products being mixed must be available at the mixing site. Before mixing any pesticide or adjuvant, the pilot and ground crew must check the labels of all materials to assure they can legally be applied to the intended site by air. This step should also take place when the pesticide is selected for an application and is performed again at the mix/load site to assure there is no misapplication.

Main considerations for mixing and loading operations include

- legally and well trained pesticide handlers in the ground crew
- a carefully selected and well organized mixing and loading site

- a suitable mixing and loading system to ensure legal, safe, and efficient pesticide mixing and loading into the aircraft

Mixing and loading involves diluting the concentrated pesticide into a mixing tank according to label instructions and transferring this mixture into the aircraft tanks or hoppers. Each piece of mixing and loading equipment, service containers, and rigs that are used to handle concentrate or diluted pesticides and draws water from an outside source shall be equipped to prevent backflow. The backflow prevention method or device must be acceptable to the water provider and the local health department, and it must effectively prevent backflow of any concentrate or diluted pesticide into the water source. Backflow prevention includes using an air-gap separation, a reduced pressure principle backflow prevention device, or a double check valve assembly. Before beginning, the mixing crew should understand mixing directions on labels of all pesticides being used. When more than one type of pesticide formulation is mixed, add them to the mixing tank in the following order

- wettable powders
- flowables
- water-soluble concentrates
- emulsifiable concentrates

If the mixture needs adjuvants, add these before pesticide materials unless label instructions give a different order.

### Personal Protective Equipment

Check the labels of all pesticides being mixed to determine what personal protective equipment (PPE) is needed for mixing and loading. Some labels list different PPE for people involved in mixing than for other handling activities. When two or more pesticides are mixed, follow the label that requires the greatest amount of protection. In general, California regulations require that all handler employees shall wear eye protection and chemical resistant gloves when handling pesticides, even if this PPE is not required on the product labeling. Be sure that the PPE is clean and in good condition. Check the label and especially the California regulations for the PPE requirements or exemptions for specific handling tasks.

### Liquid Mixing and Loading Equipment

Mixing equipment must be capable of accepting and mixing any of the formulations that are handled by the pest control operation crew. These formulations include water-soluble liquids, emulsifiable liquids, dry flowables, wettable powders, water-soluble powders, or others that may require dilution with water or other diluent. The equipment must be able to effectively mix even non-liquid formulations and transfer these diluted, liquid spray mixtures. Equipment used for mixing and loading liquid pesticides must provide for safe handling and mixing of liquid materials and rapid loading of pesticide mixtures into the aircraft. This equipment must be able to prepare load sizes that are compatible with the aircraft being used. If loading of the aircraft does not take place at a regular base of operations, the mixing and loading equipment must also be transportable.

The components of a liquid mixing and loading system for aircraft generally include

- a clean water tank equipped with backflow prevention
- a pesticide concentrate tank or device that attaches to pesticide containers



FIGURE 4.4

Closed mixing systems prevent pesticide exposure to toxic materials.

- a mixing tank equipped with agitators
- pumps to transfer concentrated pesticides to the mixing tank and from the mixing tank to the aircraft
- an accurate metering system to measure amounts of pesticide or mixture transferred

**Closed Mixing System.** Legal requirements notwithstanding, the mixing and loading equipment should be designed as a closed system, where pesticides can be removed from their containers, the containers rinsed, and the mix transferred to the aircraft without exposing individuals to pesticide concentrate or dilutions (Figure 4.4).

California laws require that employees use a closed mixing system when mixing, loading, diluting, or transferring liquid formulations of pesticides with the signal word “DANGER”. They must also use closed systems when loading or transferring dry formulations of “DANGER” pesticides after mixing these formulations with water or other diluents.

Properly operating and calibrated closed mixing systems allow accurate and safe measurement of the pesticide being put into the mixing tank. The closed-system requirement does not apply when handling one gallon or less of “DANGER” pesticide per day and the liquid pesticide is in an original container of one gallon or smaller.

**Safety Features.** Liquid mixing and loading equipment must be equipped with the following safety features to protect the ground crew and to prevent backflow of concentrate or diluted pesticides into the water source:

- tanks, hoses, and couplings that are made of materials appropriate for the pesticides being used and of sufficient size or capacity to easily accommodate the pressure generated by the pumping system
- air gap or approved one-way valves in appropriate hoses or lines to prevent backflow from the mixing tank to the pesticide containers or the water supply
- a rinsing system for cleaning the interiors of pesticide containers
- sight gauges that are easily visible and located where they are protected from damage
- reliable metering units that can be calibrated and monitored for accuracy
- easily accessible and clearly marked valves and controls
- cleanable filters or screens located in appropriate places to prevent algae, sand, and other water contaminants from entering the mixing tank
- dry break couplings on hoses used to fill aircraft tanks to prevent leaks during connect and disconnect operations

### Dry Materials Loading Equipment

Equipment designed to load powders, dusts, or granules into aircraft hoppers should have the capacity to load the aircraft in a single operation. Dry material loaders should

- be of sturdy construction and be easily mobile
- provide good visibility for the operator during movement and loading
- be equipped with volume or weight measuring capability to ensure accuracy of loads

## Equipment Maintenance and Inspection

Inspect and service liquid and dry loading equipment on a regular basis according to the manufacturer's recommendations. Clean and lubricate mixing and loading equipment after each use. Repair or replace faulty hoses and other components immediately, and do not use the equipment unless all components function properly. Maintain records of all inspections, servicing, and repairs made on the mixing and loading equipment.

## Quality of the Mixing Water

If the water used for mixing is obtained from an unfamiliar source, check it carefully before using it. Whenever there is doubt about the water quality, locate another source. The water used for filling a mixing tank should look clean and be free of sand, dirt, algae, or other foreign matter. Sand or dirt accelerates wear of pumping systems on the mixing equipment and aircraft. In addition, dirty water will accelerate nozzle wear and clog filters, screens, and nozzles in the aircraft spraying system. Algae may clog the aircraft's filters and nozzles and can react with some pesticides to reduce their effectiveness. Chemicals in the mixing water may react unfavorably with some pesticides. For example, chlorine used in domestic water supplies for controlling bacteria reduces the effectiveness of some pesticides. High levels of dissolved salts deactivate certain pesticides and may even damage treated foliage. If possible, check the pH of the water. Alkaline water (high pH) causes hydrolysis, or breakdown, of many pesticides before they can be applied. Add a buffer or acidifier if the pH is too high.

## Measuring Pesticides

Read the pesticide label and the work order to determine how much pesticide to use. Measure pesticides carefully, accurately, and safely. Inaccurate measuring can cause serious problems because it may produce gross errors in application rates. Be sure the measuring device is properly calibrated.

## Mixing Procedures

Mixing begins by filling the mixing tank at least half full with clean water. To allow room for the pesticide, adjuvants, and residues from triple rinsing, avoid filling the tank more than  $\frac{3}{4}$  full. Start agitators if the equipment has them.

Open pesticide containers carefully to prevent spilling and to make resealing easier. Cut paper containers open with a sharp knife or scissors, rather than by tearing. Metal and plastic containers all have protective seals that must be broken before use. Most of these containers have screw caps that allow resealing.

After measuring or weighing the correct amount of pesticide, carefully transfer it into the partially filled tank. Rinse the measuring device and pour the rinse solution into the tank. Many closed mixing systems have built-in container-rinsing capability and the equipment pumps the rinse solution into the mixing tank. Unless rinsed automatically, drain liquid containers into the mixing tank for 30 seconds after they are emptied. Rinse and drain the containers three more times (triple rinse). After each draining, fill the container about  $\frac{1}{4}$  full of water, put the cap on, and shake the container for several seconds to mix the residue with water. Pour each of these rinse solutions into the tank.

For bags that hold dry pesticides, follow these emptying guidelines:

- open and empty the bag so that no pesticide material remains in the bag that can be poured, drained, or otherwise feasibly removed

- empty the pesticide bag completely and hold the bag upside down for five seconds after continuous flow ceases
- straighten out the seams to eliminate wrinkles or folds so that the bag is in its original “flat” condition
- again, hold the bag upside down for five seconds after continuous particle flow ceases—shake the bag twice and hold for five seconds or until continuous flow ceases

After adding the pesticide, fill the mixing tank to its final volume, avoiding overflow. Never let the outlet of the filling hose, pipe, or other filling device come in contact with liquid in the tank. For top opening tanks, leave an air gap between the surface of the liquid at its highest level in the spray tank and the fill pipe. This space should equal at least twice the diameter of the filling pipe to prevent siphoning of the spray mixture back into the water supply after positive water flow stops. Regulations require that side or bottom filling systems be equipped with a reduced pressure principle backflow prevention device or a double check valve to prevent backflow of pesticides into the water supply.

## CLEANING EQUIPMENT AND CONTAINERS

The mixing equipment and the aircraft become contaminated with residues of pesticides during an operation. Some pesticide materials can be corrosive to the surfaces they contact and residues in tanks and hoses can contaminate future mixtures. Residues on the outside of mixing equipment and the aircraft may be hazardous to people who work on or around this equipment, requiring aircraft and mixing equipment to be thoroughly cleaned at the end of each day and also when changing pesticides. The cleaning operation is a pesticide handling activity; for this reason, people involved in the cleaning activities must receive documented training as pesticide handlers and must wear label and regulation mandated personal protective equipment.

Cleaning involves

- draining and flushing tanks, lines, and hoses
- cleaning filters and screens (including nozzle filters)
- washing the exterior of the aircraft and all mixing and loading equipment

Prevent environmental contamination by containing all residues flushed from tanks and hoses and the wash water from washing the aircraft and mixing equipment (Figure 4.5). Perform the cleaning operations on a specially designed wash pad that drains the water used for flushing and washing into holding tanks. These holding tanks must be located within a secondary containment.

Liquid from washing and flushing activities may be treated through ozone ionization, ultraviolet light, or other means to break down pesticide residues and then reused for future washing activities. It may also be condensed through evaporation in specially designed evaporation ponds. Condensates and untreated residues must be transported to an appropriate Class 1 disposal site.

Properly rinsed pesticide containers may be transported to a Class 2 disposal site after being inspected by the local county agricultural commissioner’s office.



FIGURE 4.5

Washing an aircraft used for pesticide application must take place on a specially designed wash pad that is equipped with a system to confine the wash water.

## Chapter 4

## Review Questions

SEE PAGE 178 FOR ANSWERS

1. The training that ground crews must receive as pesticide handlers is required to be performed
  - a. at the beginning of each operation
  - b. annually, before performing handling activities
  - c. every two years, before performing handling activities
  - d. every five years, before performing handling activities
2. A large number of the reported pesticide illnesses and injuries in California occur
  - a. while performing cultural practices
  - b. during pesticide handling activities
  - c. during pesticide transporting activities
  - d. while cleaning application and mixing equipment
3. Chances of pesticide exposure greatly increases if a pesticide handler fails to
  - a. read the Statement of Practical Treatment on the pesticide label
  - b. take frequent breaks during handling activities
  - c. drink adequate water during handling activities
  - d. wear the required personal protective equipment
4. Good communication with the ground crew before and during an application operation may result in
  - a. greater chances of accidents
  - b. inability for the ground crew to perform their tasks properly
  - c. fewer job delays
  - d. improper spray mixes
5. California regulations require employees use a closed mixing system when
  - a. transferring one or more gallons of any concentrated liquid pesticide
  - b. diluting 2.5 gallons of a “DANGER” liquid formulation
  - c. pouring from a 1-pint original container of a “DANGER” liquid formulation
  - d. mixing 12 pounds of a “DANGER” wettable powder into water

6. The purpose of an air gap when filling a mixing or spray tank is to
  - a. observe the level of the liquid in the tank
  - b. prevent contamination of the water source
  - c. avoid overflow of the tank
  - d. assure proper functioning of the backflow valve
7. Many pesticides will break down rapidly if the mixing water is
  - a. too warm
  - b. too cold
  - c. alkaline
  - d. free of impurities
8. After an application operation, aircraft should be cleaned and the tanks, lines, and hoses flushed at
  - a. the edge of the runway where the base of operations is located
  - b. the application site, if possible
  - c. a pad specially designed for cleaning and collecting wash water
  - d. the mixing site



# 5

# Aerial Pesticide Dispersal Systems

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Pest control aircraft must be able to lift, transport, and disperse pesticides safely and enable the pilot to apply them to the target area in the proper quantities. Fixed wing and rotary wing aircraft are suitable for aerial application as long as they meet these criteria. Fixed wing aircraft are fast, maneuverable, and can carry heavier loads than rotary wing craft. Rotary wing aircraft are more maneuverable than fixed wing aircraft; they can be operated over a range of speeds and in almost any area because a landing strip is not needed.

Accurate metering and dispersal of the various pesticide formulations are the key functions of all aircraft dispersal systems. Metering and dispersal equipment must deliver the labeled rate of a liquid or dry pesticide formulation uniformly and in a short period.

## GENERAL REQUIREMENTS

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Equipment and components used in the aerial application of pesticides must be of high quality and be

- **corrosion resistant**—many pesticide materials are corrosive, so all the components of a dispersal system must be corrosion resistant. Stainless steel, fiberglass, polyethylene, and polypropylene are materials that exhibit this property, while steel, iron, and aluminum are subject to corrosion. In addition, acidic liquids may react with steel or iron to produce highly explosive hydrogen gas. While the application components are corrosion resistant, the rest of the aircraft is not and these parts need to be frequently cleaned, maintained, and kept painted with a protective material.
- **leak proof**—all components of pesticide dispersal systems must be substantial and durable enough to withstand the rigors of takeoffs, landings, and flight while remaining as much as possible free of leaks. This includes tanks, pumps, agitators, bearings and seals, hoses, and hose fittings. Pesticide leaks within an aircraft can endanger the pilot and permanently damage the aircraft and its parts. Exter-

nal leaks can contaminate people, runways, hangars, and other areas, while also damaging crops and other plantings outside of the treatment area.

- **able to make accurate volume measurements**— aircraft pesticide dispersal equipment must include a system that allows accurate measurement of the pesticide solution or dry material so that the correct amount of material can be applied to the treated area.
- **well ventilated**—adequate ventilation is necessary when applying liquids, dusts, or granules to prevent the buildup of hazardous fumes and explosive gases or dusts that could endanger the pilot and damage the aircraft. Tank vents are also necessary to prevent a vacuum from developing that would alter or stop the normal flow of liquids, thereby affecting calibration and the accurate delivery of the pesticide. In addition, ventilation is necessary in case a load must be dumped in an emergency.
- **equipped with a tank agitation device**— hydraulic or mechanical agitators in the liquid pesticide tank keep the pesticide mixture uniform and prevent some materials from settling out or separating. Many pesticide mixtures consist of insoluble solids kept in suspension by agitation. Others may be water-insoluble liquids, such as oils, that become emulsified when mixed with water. These mixtures require continual agitation to prevent separation.
- **able to produce uniform flow rates**— the dispersal system has to provide a uniform flow rate of the pesticide through the nozzles or spreader for an even distribution of liquid sprays or dry materials over the treatment area. Systems that adjust the flow rate according to the application airspeed (sometimes referred to as flow control) provide the greatest uniformity of application.

## DISPERSAL SYSTEM COMPONENTS

Dispersal systems have various components, and each must be designed for aerial application. These components should be dependable and durable, as well as being uncomplicated to service and repair.

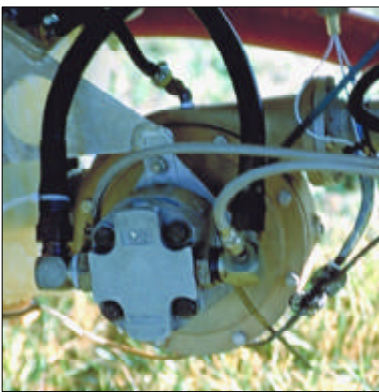


FIGURE 5.1

A main component of an aircraft pesticide dispersal system is the spray pump.

### Spray Pumps

The pump is one of the main components of liquid dispersal systems (Figure 5.1). A spray pump moves the liquid solution from the spray tank to the nozzles and maintains the pressure in the system to ensure a uniform flow rate and proper dispersal from the nozzles. The pump may also power the agitator that keeps the pesticide mixture in suspension. Various methods are used to power an aircraft pesticide pump. These include

- the aircraft's hydraulic system
- an electric motor
- on fixed wing aircraft, a fan mounted under the aircraft driven by the aircraft's propeller slipstream

Some fan-driven pumps have variable pitch blades so the pilot can change the pump speed as needed to accommodate different application requirements. Ultra low volume (ULV) applications may require modifications to the pumping system to make them suitable for low output.

The size of the pump is critical. Pumps must have enough power and capacity to meet the desired nozzle pressure and agitation requirements. The pump must have additional capacity to make up for pressure loss due to friction in the pressure lines and to operate nozzle anti-drip check valves. A pump with too little capacity will require reducing the swath width to assure adequate coverage. A pump with too much capacity may allow air into the system and interfere with even dispersal of the spray.

Centrifugal pumps commonly used on aircraft can produce high volumes of spray material (up to 200 gallons per minute or more, depending on the size of the pump) at low pressure, usually ranging between 5 and 200 pounds per square inch (psi). Besides bronze and steel, centrifugal pumps are made from high impact plastic, making them lightweight and suitable for aerial use. Centrifugal pumps have a high range of applications, including spraying of abrasive materials (wetttable powders and flowable formulations, for example) because there is no close contact between moving parts. These pumps usually require operating speeds between 1,000 and 5,000 rpm.

## Tanks and Hoppers

Tanks and hoppers must be corrosion resistant, made from materials such as fiberglass or high-density polypropylene or polyethylene (Figure 5.2). A disadvantage of fiberglass is that it absorbs pesticide liquids if interior tank walls are scratched or abraded, and this could contaminate future tank loads. However, small cracks or punctures in fiberglass tanks are easy to repair, while cracks or punctures in polypropylene and polyethylene tanks are difficult to deal with.

Some tanks serve a dual use: they can hold liquids for spraying and be used as hoppers for dispersing dry formulations, fertilizers, and seeds. Most tanks have top openings for filling, but it is preferable to fill liquids through a pipe that is equipped with a quick coupling disconnect that protrudes through the side of the aircraft fuselage. Hoppers, when filled with dry pesticides, fertilizers, or seeds, are filled through the top opening.

A gauge or visual level that measures the amount of material in the tank or hopper is necessary. This gauge should be easily visible to the pilot.

Interior baffles in tanks designed for holding liquids limit the sloshing of liquid during flight. A tank should have a large valve or port at the bottom through which the load can be dumped in a matter of seconds in case of an emergency.

On fixed wing aircraft, the tank or hopper is mounted in front of the cockpit and as close as possible to the center of gravity of the aircraft so that the trim will not be affected as the tank empties. On small rotary wing aircraft, tanks are usually mounted in pairs, one on each side of the fuselage. Connecting the two tanks with a pipe so that the spray is drawn equally from both keeps the aircraft balanced. Larger rotary wing aircraft have a tank mounted inside the craft. Tank or hopper size depends on the load capacity of the aircraft.

**Agitation.** Many pesticide formulations, such as emulsifiable concentrates, wetttable powders, and flowables, require agitation of the liquid mixture in the spray tank to maintain uniformity. Without agitation, the pesticide product may settle out from the water with which it is mixed. A common method of agitation is the recirculation of all or part of the



FIGURE 5.2

Tanks that hold the pesticide material in an aircraft must be made out of corrosion resistant material. Some tanks can also be used to hold granules.

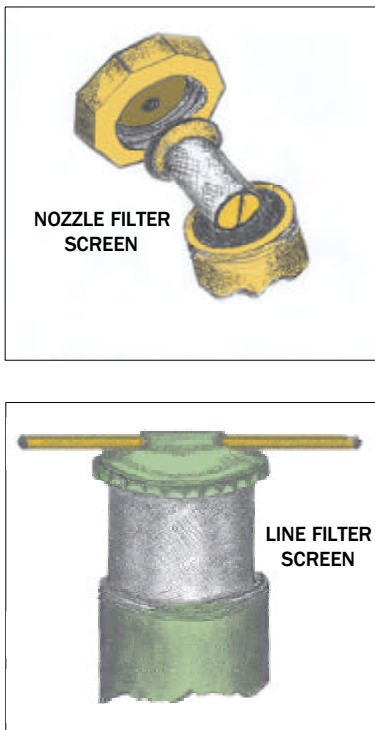


FIGURE 5.3

Nozzle and line screens are needed to prevent clogs in the spraying system and to protect the spray pump from damage.

pump output back into the tank (hydraulic agitation). Another type of agitator uses a propeller mounted inside the tank (mechanical agitation) that is powered by some external source. Mechanical agitation is not common on aircraft. Agitation should always occur during ferrying to the worksite and during turnarounds. If the pump has sufficient capacity, some of the pump output is recirculated back into the tank during spraying as well. Recirculated material enters near the bottom of the tank to prevent settling of pesticide residue.

## Screens

The purpose of screens in the dispersal system is to protect the pump from damage and to keep the nozzles from clogging (Figure 5.3). Screens require daily cleaning during spray operations and additional cleaning is needed any time that the flow rate or pressure indicates clogging. Filter screens range in size from 10 to 200 mesh. A 10-mesh size denotes 10 openings per inch, therefore the larger the mesh number the finer the screen.

**Nozzle Screens.** Nozzles require 20 to 100 mesh screens or a slotted strainer of equivalent size. The nozzle orifice size and the materials being applied dictates the nozzle screen size selection. A 20-mesh screen has the largest openings and would be the appropriate size for nozzles having large orifices. Nothing finer than 50-mesh screens should be used with wettable powders.

**Line Screens.** Line screens are always a coarser mesh than nozzle screens and should be located in the suction line between the tank and pump to protect the pump from damage. An additional screen may be used between the pump and the spray boom. This screen should have a smaller mesh than the one located in the suction line, but of a larger mesh than the nozzle screens.

## Pipes, Hoses, and Fittings in an Aerial Dispersal System

Main piping and fittings should be of a large diameter (up to 3 inches) to be able to apply high volumes of liquids. Smaller diameter pipes and fittings (approximately 1 inch in diameter) are suitable for low-volume applications. Smaller piping is also suitable for use with rotary wing aircraft because their slower speed makes it possible to use lower flow rates. Whatever the size, piping must be able to handle the maximum pump pressure.

**Hoses.** Hoses used in the dispersal system should be large enough to carry the desired flow and should be corrosion resistant. They are less likely to blow off if the ends of the connecting tubes are beaded or hoses are double clamped. Hoses must be positioned in such a way as to avoid sharp bends, and they must be replaced if they swell, develop surface cracks, or otherwise show wear and tear.

**Valves.** A positive cutoff valve, installed in the hose or line that delivers spray material to the nozzles, eliminates dripping when the spray is shut off. The most effective positive cutoff valve is one that incorporates a suck-back feature so that a slight negative pressure is applied to the material in the boom to aid the nozzle check valve in preventing any dripping.

This suck-back feature must not remove liquid from the spray boom, otherwise there will be a delay as the boom refills when starting a new spray pass.

## Spray Booms and Boom Couplings

The boom is the structure that supports nozzles and usually carries the liquid spray to the nozzles (Figure 5.4). It may be round, airfoil shaped, or streamlined. On fixed wing aircraft, booms are located behind and below the trailing edge of the wings to place the nozzles in cleaner airflow. For some configurations, drop pipes from the boom are used to keep nozzles in clean air. Research shows that this lower position is likely to give a better deposition pattern. Spray booms need to be attached securely to the aircraft to prevent bouncing and be durable enough to handle the output pressure of the pump.

Effective spray booms are approximately 75% as long as the wingspan for fixed wing aircraft and 90% of the width of the main rotor blade of rotary wing aircraft. Nozzles at the tips of longer booms will have a large amount of their output entrained in wingtip or main rotor vortices and contribute to drift problems. Nozzles positioned beyond these widths also contribute little toward increasing swath width because the spray droplets are trapped in the vortices.

Position the boom and nozzles so that the spray will not strike any part of the aircraft or boom attachments. If the spray does strike any structural part of the aircraft, it will likely

- collect and fall off in large drops
- distort the spray pattern
- waste material
- cause corrosion

Removable end caps on a boom facilitate flushing out and cleaning the inside of the boom. Ideally, the boom has an end nozzle. If the outermost nozzle is not at the end, install an air bleed valve to prevent pressurized trapped air from causing the spray to continue flowing after the spray valve is closed.

### Microfoil Boom

A microfoil boom is suitable for rotary wing aircraft because of its ability to control droplet size at slower speeds. This type of boom is most often used for applying pesticides to rights-of-ways. The boom consists of a series of 6-inch long, airfoil-shaped nozzles. A number of needlelike tubes project from the trailing edge of each nozzle. Spray pressure and orifice diameter control droplet size. Droplets form on the outlet end of the needlelike tubes and are pulled off by the airstream, where they enter the non-turbulent air behind the nozzle. The microfoil boom is specifically designed for rotary wing aircraft because fixed wing aircraft cannot fly at the reduced airspeed necessary for maintaining droplet size. The higher speeds of fixed wing aircraft causes atomization of the large droplets, making them prone to drift and eliminating any advantage to using nozzles and pressures that produce the large droplets for reducing drift. The microfoil boom is not suitable for high viscosity sprays or wettable powders because the orifices tend to clog.



FIGURE 5.4

Several types of spray booms are used in the aerial application of liquid pesticides.



FIGURE 5.5

Readings from a pressure gauge are most accurate when the gauge is connected to the spray boom.

## Flow Meter and Pressure Gauge

An accurate flow meter is an essential component of the spray dispersal system. It is a tool pilots use to calibrate the output of the pump and nozzles. The flow meter also alerts the pilot to changes in the spraying system such as clogged nozzles, clogged filters, leaks, and pump malfunction.

Like the flow meter, pilots use a pressure gauge to monitor the spraying system. A pressure gauge helps to determine the correct pump speed or spray valve opening in order to achieve the proper nozzle output. Changes in system pressure during a spray operation signal potential problems. Increase in pressure could indicate clogged nozzles or filter screens. A drop in pressure might indicate a broken nozzle, a disconnected line, another type of leak, or pump malfunction. When a pressure change occurs, inspect the system immediately to determine the cause and make necessary repairs.

Pressure gauges (Figure 5.5) need frequent calibration. Do this by comparing the gauge in the aircraft to another gauge known to be accurate. For most precise readings of pressure at the nozzles, connect the pressure gauge sensor line to the spray boom.

## Nozzles

Manufacturers produce many types of nozzles for various liquid pesticide application situations. Nozzles provide the primary means of controlling three factors that affect any application and possible offsite movement of the pesticide: the application rate, droplet spectrum, and spray pattern. However, in order to perform within the designed parameters for each of these factors, it is essential to operate the nozzles within a range of pressures, flow rates, and aircraft speeds prescribed by the manufacturers. Therefore, be sure that the spraying system is compatible with the specified pressure and flow rate ranges for the nozzles used and the speed of travel of the aircraft.

The aircraft's wake has a great influence on spray distribution across the swath. As a result, the overall pattern of all nozzles combined is very significant and any factor that affects spray droplet size, droplet size distribution, flow rate, and tendency to clog is more critical to aerial applications than to ground applications. Aerial application rates fall into three categories:

- conventional (5 to 15 or more gallons per acre)
- low volume (LV) (0.5 to 5 gallons per acre)
- ultra low volume (ULV) (less than 0.5 gallons per acre)

Traditionally, amounts less than 8 gallons per acre have been the norm for conventional rate applications. Although these applications are generally made with cone pattern nozzles, aerial spray drift studies indicate that spray output from cone pattern nozzles are likely to emit drift-prone spray droplets unless the cone pattern nozzles are configured to produce coarse spray droplets. Unfortunately, coarse droplet sprays require rates higher than 8 gallons per acre to achieve sufficient target site coverage.

Application rates in the low volume (LV) range are often suitable for certain situations, such as the application of particular fungicides. In such instances, cone pattern nozzles without cores may produce a useful droplet size spectrum with a lowered risk of droplets prone to drift. Flat fan or variable-orifice flood nozzles set to a low deflection angle may also



be used for LV applications. Drift studies show that properly installed straight-stream variable-orifice flood nozzles reduce the amount of small droplets that are prone to drift.

When vegetable oil carriers are used, or when concentrates are used in forest or public health pest control, such as mosquito abatement spraying, ULV application rates will range from less than one to a few ounces per acre. For ULV applications, rotary atomizers are sometimes used.

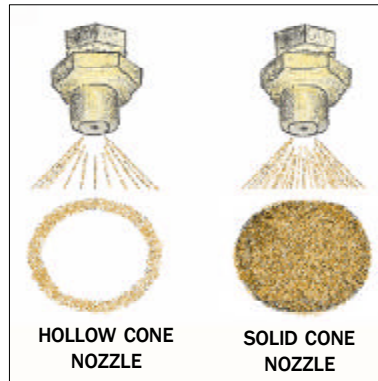


FIGURE 5.6

Cone pattern nozzles work well for high pressure and high flow rate situations. However, droplets formed by cone patterns are susceptible to drift because of their size.

### Cone Pattern Nozzles

Cone pattern nozzles (Figure 5.6) include the *disc-core* type and the *whirl-chamber* type. Under some conditions, cone pattern nozzles have a tendency to produce small droplet sizes prone to drift unless the spray is applied at high rates that allow for larger droplet sizes. The proper application speed reduces the number of small droplets.

A disc-core nozzle is comprised of a disc containing the orifice and a core (or spinner plate). Disc-core nozzles are suitable for high pressure and high flow rate applications. Standard disc-core nozzles produce a hollow-cone spray pattern, while full-cone spray patterns produce greater volume output. A disc with an orifice fits into the nozzle body. Discs are available in various orifice sizes to accommodate application needs. Located behind the disc is a *core* or *spinner plate* that puts a high rotation spin on the liquid passing through the orifice. The disc-core combination determines the gallons per minute (gpm) rating of the nozzle at a given pressure.

A whirl chamber nozzle consists of a specialized nozzle body and nozzle cap (Figure 5.7). When liquid enters a whirl chamber nozzle body, the interior structure of the nozzle body causes the liquid to whirl rapidly before exiting as a cone-shaped spray pattern. Whirl chamber nozzles are relatively free from clogging problems. However, recent spray drift research indicates that because the spray emerges in a conical pattern, using whirl chamber nozzles on an aerial spray boom yields a disproportionate amount of very fine, drift-prone droplets.

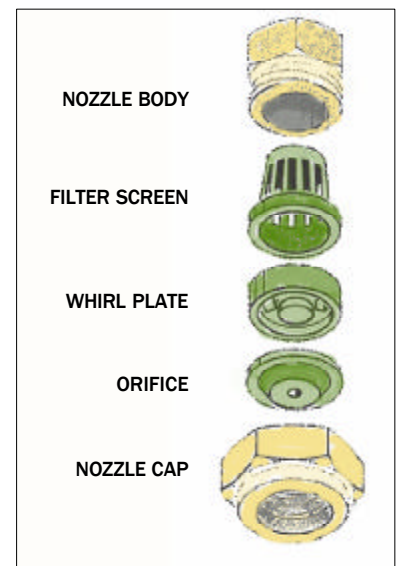


FIGURE 5.7

Components of a whirl chamber nozzle.

### Fan-Pattern Nozzles

Flat fan and even flat fan nozzle tips produce flat, fan-shaped spray patterns (Figure 5.8). The exact angle of the fan-shaped pattern produced by these nozzle tips depends on nozzle design, spray pressure, and characteristics of the pesticide spray mix. Nozzle tips designed to produce fan-shaped patterns have angles of 65, 80, or 110 degrees. In general, fan nozzle tips that produce wide angles tend to generate more drift-prone spray droplets. For this reason, fan nozzle tips designed to emit no more than an 80-degree spray pattern are better suited for aerial spray applications. Evenly distributed flat fan nozzles have little effect on the spray distribution applied by an aircraft. The more critical consider-

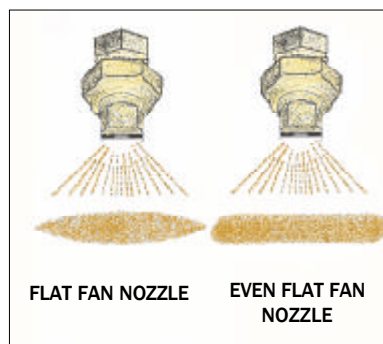


FIGURE 5.8

The angle of the fan produced by fan-pattern nozzles has a major influence on the size of droplets produced by the nozzle.

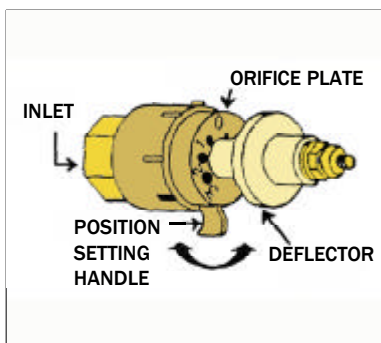


FIGURE 5.9

Variable-orifice flood nozzle.

ation when using flat fan nozzles on an aerial boom is that the nozzle tip produces a narrow spray angle.

Spray drift studies indicate that nozzles that emit fan-shaped spray patterns typically produce fewer small, drift-prone spray droplets than do cone-pattern nozzles.

### Variable-Orifice Flood Nozzles

The standard variable-orifice flood nozzle disperses liquid in a flood type of flat fan pattern (Figure 5.9). This type of nozzle utilizes a nozzle body that has two manual adjustments. The nozzle body governs nozzle flow rate in conjunction with the pump pressure. It contains four orifices of different sizes that can be selected or the nozzle can be turned off. Spray from the selected orifice hits an adjustable deflector that can be positioned to produce fine, medium, or coarse spray droplets.

### Rotary Atomizers

Rotary atomizers allow more control over the size of the droplets released. Spray droplets are formed after the spray solution flows through a screen cage or is deposited onto spinning toothed or grooved discs or cups. Centrifugal force generated by the spinning action causes the release of spray droplets. The speed at which the nozzle turns, combined with the liquid flow rate, controls the size of the droplets. Rotary nozzles reduce the range of droplet sizes, so very small and very large droplets are eliminated. Adjustments provide for a range of droplet sizes so it is possible to use the same nozzles for coarse or fine sprays. Control of droplet size with rotary atomizer nozzles is particularly significant when using oil carriers.

Rotary atomizer nozzles can apply a wide range of application rates. Because they have a relatively large metering orifice, these nozzles do not clog as easily as conventional nozzles when applying low-volume sprays containing a high concentration of chemicals in suspension.

Uniformity also depends on how fine the spray is and the spacing of the nozzles. For low-level work, six or more nozzles are required to provide a uniform swath. Typically, a single rotary atomizer can generate a swath of 10 to 15 feet.

### Nozzle Anti-Drip Devices

It is essential to equip all the nozzles on a spray boom with check valves to prevent dripping when the spray shuts off (Figure 5.10). These valves have spring-loaded diaphragms that stop the flow to the nozzles when spray pressure drops below a certain amount, usually about 7 psi. Use anti-drip check valves in combination with in-line valves that have the suck-back feature. In systems where suck-back is unavailable, such as in rotary wing aircraft, use a stronger diaphragm spring so the nozzles seal shut when pressure drops to about 15 psi.

Check and frequently clean spring-loaded diaphragms to assure they work properly. Replace diaphragms when they begin to wear out. It is possible to flush some types of anti-drip check valves without disassembling the nozzle.

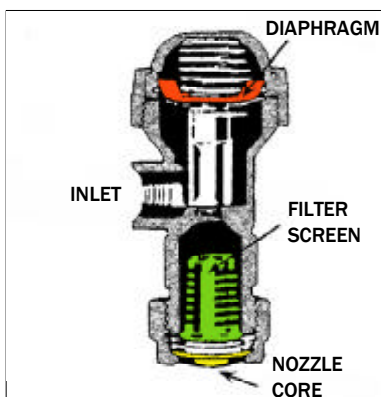


FIGURE 5.10

Nozzle anti-drip devices prevent nozzles from dripping when the spray shuts off.

## Spraying System Operating Pressure

The spraying system operating pressure should always be the lowest pressure needed for effective spray system function and minimization of droplets prone to drift. This usually



involves balancing the speed of the aircraft with the exit speed of the pesticide liquid from the nozzles. Typically, spray system pressure should be in the 15-35 psi range when using conventional (fan type) or variable-orifice flood nozzles.

When it is necessary to increase the output rate of the nozzles, very small changes can be made by increasing the system operating pressure, often done by increasing the pump speed. However, in order to double the spray output, the spray pressure must be quadrupled. Raising pressure significantly increases the number of small, drift-prone droplets. It also increases nozzle tip wear and power requirements.

In most cases, changing boom output rate is best achieved by changing nozzle tip size, nozzle orifice size, or by changing the number of nozzles in use. Typically, only change the spray system pressure to make minor changes (alterations of 10% or less) in boom output.

## Electronic Sprayer Rate Controllers

Electronic sprayer rate controllers allow very accurate metering of pesticide sprays. This equipment uses a microcomputer to monitor and regulate spray output and/or pressure. Some units even control output on individual nozzles. The equipment can warn of malfunction of nozzles or the pump. Electronic spray rate controllers allow application of consistent and precise amounts of pesticide spray even when the airspeed of the aircraft varies.

## Dry Material Spreaders

On fixed wing aircraft, ram-air spreaders disperse dry formulations, such as dusts, granules, or pellets. These spreaders are also used for applications of fertilizers and seeds. Rotary wing aircraft typically use a centrifugal spreader or a dusting blower to apply dry formulations.

### Ram-Air Spreader

Fixed wing aircraft fitted with a properly configured ram-air spreader (Figure 5.11) can apply dry formulation pesticides very uniformly. However, setup and operation may be more complex than that required for applying liquid pesticide products. General limitations imposed by ram-air spreaders include high aerodynamic drag and high power requirements.

Because of the considerable drag that results from their being placed in the high-speed airstream, ram-air spreaders always compromise aircraft performance. However, ram-air spreaders are comparatively simple, versatile, and reasonably priced. Typically, a ram-air spreader is secured beneath the fuselage in such a way that it can be removed so the liquid spraying capability of the aircraft can easily be restored.

An unsatisfactory distribution pattern of dry materials results when the material is applied at a feed rate greater than the flow rate of the spreader.

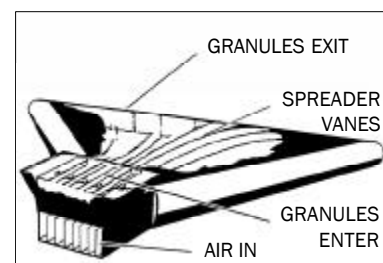


FIGURE 5.11  
Ram-air spreader.

## Feed Rate

In a ram-air spreader, the dry pesticide product drops from the hopper into a ducted airstream, where the airflow ejects it rearward and laterally. A metering gate situated between the hopper floor and the spreader throat governs the feed rate of pesticide granules or pellets. The hopper-to-spreader metering gate is usually hinged or is a sliding hatch.

On hinged metering gates, a pilot-controlled linkage cable rotates the trailing margin of the gate downward to open it to whatever setting is desired. Material escapes from the hopper by flowing over the lowered edge of the gate. Usually, hinged metering gates require more frequent calibration adjustment than do sliding hatch types. Some hinged metering gate units are capable of dispensing liquid materials.

Sliding hatch styles of hopper metering gates generally are easier to adjust, especially for low application rates. However, these units tend to be more prone to wear than hinged metering gates.

The hopper's metering gate must provide even feed of the pellets or granules across its opening; otherwise, it may cause an uneven swath pattern. It is unreasonable to expect any combination of other ram-air spreader adjustments to compensate entirely for swath pattern problems caused by improper gate adjustment.

Substantially increasing the hopper-to-spreader feed rate beyond its design maximum is a poor strategy for increasing application rate. When too much dry pesticide product is metered into the spreader, ducting becomes choked and less air is able to flow through the unit. Increasing the amount of dry pesticide entering the spreader requires more air to propel the material through the spreader.

## Spreader Vanes

The air channel of a typical ram-air spreader consists of 5 to 13 laterally adjacent, curved ducts. The partitions that form the walls of these ducts are the spreader vanes. Each spreader vane typically has adjustable sections located at its front and rear. These adjustable sections allow for lateral repositioning of the inlet and exit portions of a given vane within the spreader body. Vane adjustment enables fine-tuning of a ram-air spreader to a particular aircraft.

In a ram-air spreader, the material metered from the hopper flows through the ducts as a thin, sheet like layer of particles. This layer of particles flows along the internal upper surface (ceiling) of the spreader and is forced rearward by air entering the spreader inlet. Spreading of the particle layer is the main job of the spreader vanes. When functioning correctly, the vanes prevent air and particles from moving from one duct to another.

The top of each vane, including the movable sections, must be in close contact with the top of the internal surface of the spreader. If any air gap occurs between vane and duct ceiling, both air and particles can move from one duct to another during spreader operation. This will seriously affect the even distribution of the pesticide.

Adjusting the inlet vane positions help to make the swath uniform. Airframe-induced influences known to affect ram-air spreader performance, but that can often be compensated for by adjusting the spreader inlet vane, include

- aircraft oil-cooler-induced turbulence
- speed ring effects

- propwash effects
- turbulence caused by a flagging device air deflector

Propwash effect typically causes material released near the right of the fuselage to become displaced towards the left side of the fuselage. This results in a nonuniform swath where distribution of granules or pellets on the right side is sparse and too heavy on the left side. To correct a propwash-induced problem, configure a ram-air spreader to discharge more material from its right side than from its left. Do this by moving the spreader's inlet vanes toward the left, making the left discharge ports smaller than those supplying the right side.

Shifting inlet vanes too far laterally can cause problems, however. As an inlet vane is shifted laterally, the airstream attack angle (angle of incidence) of the duct wall increases. When the duct wall angle of incidence becomes too great, static air pressure increases inside the duct and impairs the hopper-to-duct flow rate. This causes an undesired reduction of spreader output. Lateral repositioning of an inlet vane should never exceed a 15-degree angle of incidence as measured in relation to the path of forward flight.

Altering the spreader's exit configuration requires repositioning the adjustable rear portion of one or more spreader vanes if the equipment is set up for this type of adjustment. Adjustment of rear vane sections provides a way to fine-tune overall swath pattern uniformity. This is because the position of the rear section of a vane mainly influences the exit direction of the particles passing through that duct.

Alignment of the rear section of a vane should, as much as possible, smoothly follow the arc formed by the vane's rigid internal curvature. For rear vane adjustment, the key concepts are smooth, non-obstructive, non-impeding, exit airflow changes. Generally, only small adjustments are needed. Over-adjustment will usually cause particles moving through the duct to slow down, resulting in excessive material in one part of the swath.

## Spreader Mounting

The best possible mounting configuration of a ram-air spreader is the one that causes the least turbulence. Having the smoothest airflow into, around, and out of the spreader improves spreader performance and provides good application results.

Relative to an aircraft's roll axis, a correctly mounted spreader hangs beneath the fuselage and is level with the fuselage from side-to-side and parallel to the bottom sides of the aircraft wings. Spreader mounting differs from airframe orientation only in pitch. The attack angle of a ram-air spreader directly influences the amount of airflow entering the spreader inlet. Spreader attack angle is set by establishing the pitch of the spreader body during mounting.

The forward mounting points of ram-air spreaders are usually nonadjustable. Therefore, change the attack angle by changing the distance between the aircraft fuselage and the rear part of the spreader. Typically, the lower skin of the spreader is the reference surface for measuring spreader attack angle. The attack angle of the lower surface should be approximately 1 to 3 degrees less than the attack angle of the lower surface of the aircraft wing. When a spreader attack angle is either too great or too small, the likely result is

- increased turbulence and drag
- increased deposition of the pesticide material on the tail gear of the aircraft

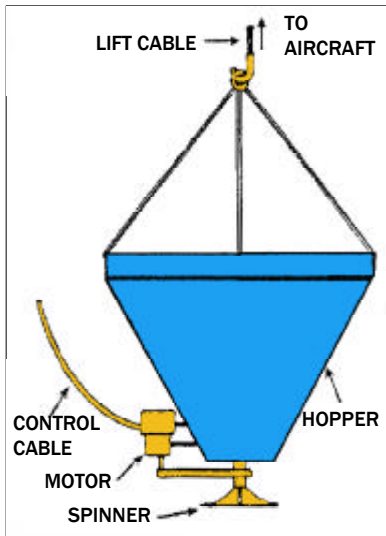


FIGURE 5.12  
Centrifugal spreader.

- a nonuniform swath pattern
- swath narrowing due to lowered exit speeds of particles

### Application Rate and Swath

Up to the point of its maximum material handling capability, changing the application rate of a spreader automatically changes its effective swath width. Increasing hopper feed to the spreader will cause a decrease in swath width because the particle stream exiting a spreader duct becomes heavier and less prone to being broken up. For high application rates such as jobs requiring more than 250 pounds of pesticide product per acre, the best strategy is to reduce the per-pass application rate, configure the spreader for a reduced swath width, and fly more passes per site.

## Centrifugal Spreader

The centrifugal spreader used by rotary wing aircraft is a self-contained unit having its own hopper (Figure 5.12). The entire unit is suspended on a cable and carried beneath the rotary wing aircraft. The pesticide granules or pellets are metered from the hopper onto a spinning disc that distributes the pesticide. A hydraulic motor or an integral gasoline engine controlled by the pilot via a hydraulic control cable or radio usually drives the spinner. Usually, two self-contained units are used so that the pilot can spread with one while the other is being refilled.

## Chapter 5

## Review Questions

SEE PAGE 178 FOR ANSWERS

1. Aircraft suitable for aerial application of pesticides must be
  - a. registered with the Department of Pesticide Regulation
  - b. constructed entirely of corrosion resistant materials
  - c. equipped with DGPS navigational equipment
  - d. able to lift, transport, and disperse pesticides safely
2. Iron or steel components in an aircraft dispersal system may react with acidic pesticide mixtures to produce
  - a. hydrogen
  - b. cyanide
  - c. bromine
  - d. oxygen
3. One of the reasons for an adequate vent in the aircraft pesticide tank is to
  - a. release excess pressure
  - b. allow the pump to function efficiently
  - c. prevent a vacuum from altering the normal flow of liquid
  - d. keep the pesticide mixture uniform
4. Proper agitation of the liquid in a spray tank is especially needed when applying
  - a. wettable powder formulations
  - b. soluble liquid formulations
  - c. soluble powder formulations
  - d. water miscible formulations
5. Even distribution of the pesticide mixture over the treatment area requires a
  - a. high system pressure
  - b. low system pressure
  - c. variable flow rate
  - d. uniform flow rate

6. On aircraft dispersal systems, the component that ensures a uniform flow rate is the
  - a. agitator
  - b. type of nozzle
  - c. control valve
  - d. pump
7. The purpose of baffles inside a liquid spray tank is to
  - a. assure even mixing of the spray material
  - b. prevent extreme pressure changes in the system
  - c. reduce sloshing of the liquid during flight
  - d. eliminate foaming of the spray mixture
8. Hydraulic agitation of the mixture in the aircraft spray tank requires
  - a. an external power source
  - b. sufficient pump output capacity
  - c. baffles mounted inside the tank
  - d. proper tank ventilation
9. A proper functioning positive cutoff valve with a suck-back feature will supply \_\_\_\_\_ pressure to the boom and nozzles when the spray flow is stopped.
  - a. high negative
  - b. low negative
  - c. high positive
  - d. low positive
10. The length of a spray boom on a fixed wing aircraft should be no more than \_\_\_\_\_ percent of the aircraft wingspan.
  - a. 75
  - b. 80
  - c. 85
  - d. 90
11. The length of a spray boom on a rotary wing aircraft should be no more than \_\_\_\_\_ percent of the width of the main rotor.
  - a. 75
  - b. 80
  - c. 85
  - d. 90

12. Spray that strikes a structural part of the aircraft during application will likely
  - a. have little effect on the spray pattern
  - b. break up into smaller droplets
  - c. increase offsite drift
  - d. collect and fall off in large drops
13. The purpose of bleed valves at the ends of the spray boom is to
  - a. prevent spray from continuing to flow from nozzles after the spray valve is closed
  - b. prevent pressure from building up from trapped air when the spray valve is opened
  - c. make cleaning the inside of the spray boom easier
  - d. reduce internal corrosion of the spray boom
14. To accommodate for the influence of the aircraft wake on spray pattern, it is necessary to
  - a. regulate the output flow to the nozzles
  - b. adjust the speed of the aircraft
  - c. reposition the nozzles on the spray boom
  - d. decrease the pump speed
15. A major disadvantage of cone pattern nozzles is that they
  - a. are more expensive than other nozzle types
  - b. are difficult to adjust in the airflow of the aircraft
  - c. tend to produce small droplet sizes prone to drift
  - d. clog easily
16. In order to double the liquid output of spray nozzles, the spray pressure must be
  - a. halved
  - b. doubled
  - c. tripled
  - d. quadrupled
17. The advantage of an electronic sprayer rate controller is that it
  - a. maintains the same spray output as airspeed changes
  - b. reduces or increases the spray output as airspeed changes
  - c. maintains the same spray output as altitude changes
  - d. reduces or increases the spray output as altitude changes

18. Ram-air spreaders can
  - a. compromise fixed wing aircraft performance
  - b. improve fixed wing aircraft performance
  - c. reduce aerodynamic drag on the aircraft
  - d. reduce the aircraft's power requirements
19. The purpose of adjusting ram-air spreader vanes is to
  - a. improve the performance of the aircraft
  - b. reduce the aerodynamic drag on the aircraft
  - c. improve the granule distribution pattern
  - d. change the swath width of the granule application
20. One way to overcome the problems associated with a ram-air spreader application of granules that requires more than 250 pounds of product per acre is to
  - a. fly at a slower airspeed
  - b. reduce the application rate and make a double application to the site
  - c. fly at a higher airspeed, but lower altitude
  - d. adjust the spreader vanes



# 6

# Aerial Application Guidance Systems

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Public concern about adverse effects from pesticides and pesticide applications, ongoing efforts to regulate pesticide applications, extensive plantings of high-value agricultural crops, and heightened concern over public and environmental health have spurred the evolution of aerial application technology. Problems of drift and uneven applications are greatly resolved through pilot skill and electronic assistance from navigational devices and variable rate application controllers.

## NAVIGATION METHODS

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The ability to navigate an aircraft accurately is an essential part of the piloting process. The ability to navigate to a certain point is one of the basic skills taught to pilot trainees. An additional amount of knowledge is necessary to find and identify a certain agricultural field and crop at the site to be treated. However, it is beyond the scope of this manual to cover all means of cross-country navigation available to the pilot.

For the purpose of the DPR Pest Control Aircraft Pilot examination, pilots must understand how to direct the flight of the aircraft across the field while applying the proper amount of material in each pass. The flight path must be accurately controlled to produce consistent swaths, ensure that buffer zones are not exceeded, and to prevent skips or double coverage.

## Global Positioning Systems

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One of the most accurate methods of navigation for aerial applicators is by the use of a global positioning system (GPS). The aircraft is equipped with a receiver that picks up signals from satellites that allow the pilot to know the velocity of the aircraft and its position in three dimensions. GPS equipment is, in most cases, an essential tool for aerial application. A recent study indicates that at least 92% of the agricultural pilots in the U.S. use GPS equipment. See Sidebar 19 for a description of how GPS systems work.



## Sidebar 19

## The Global Positioning System Program

The Global Positioning System program was created by the U.S. Department of Defense in 1973. Although various aspects of GPS technology are now readily accessible to the general public worldwide (Figure 6.1), the GPS program itself is exclusively funded and managed by the U.S. Department of Defense. The original intent of the GPS program was to provide a satellite-based system for military purposes.

The Global Positioning System is a satellite-sourced microwave-signal transmission system that can rapidly reference any specific location on earth. Functionally, the GPS system consists of three major components or **segments**:

- Space Segment—a constellation of 24 earth-orbiting satellites
- Control Segment—five earth-based satellite monitoring stations worldwide
- User Segment—individual GPS signal receivers owned and operated by users

**Space Segment.** Launching of the 24 earth-orbiting GPS satellites began in February 1989 and was completed in June 1993. Each satellite completes one orbit every 12 hours. Every GPS satellite flies in an assigned location in one of six orbital paths. Relative to the earth's surface, the six orbital paths are equidistantly spaced at 60-degree intervals. Relative to the earth's equatorial plane, each orbital path is inclined approximately 55 degrees. A practical consequence of the GPS satellite constellation is that the overall orbital path arrangement enables a GPS user to simultaneously access between five and eight GPS satellites from any point on earth.

**Control Segment.** This component principally consists of five earth-based tracking stations. Stations are located

- in Hawaii
- on Ascension Island in the middle of the South Atlantic Ocean
- on the island of Diego Garcia in the middle of the Indian Ocean
- on Kwajalein Atoll (2,100 miles southwest of Hawaii and 1,400 miles east of Guam in the Pacific Ocean)
- in Colorado Springs, Colorado

The station at Colorado Springs is the master station. Each tracking station checks the operational health of, and determines precise orbit location data for, the targeted GPS satellites. The master station sends corrections for orbital location and clock



FIGURE 6.1

Most aircraft used for applying pesticides are equipped with GPS systems.

(continued on next page)

(Sidebar 19, Continued)

data to all satellites in the system. This information enables a satellite to send an up-to-date subset of satellite location and time data to a user's GPS receiver.

**User Segment** The user segment is the worldwide total of all GPS receivers currently in service. This includes government, military, and civilian users. GPS receivers are installed and used on seagoing vessels, trains, trucks, mass transit busses, cars, farm equipment, motorcycles, commercial airliners, general aviation aircraft, and agricultural aircraft. GPS units provide useful data for many purposes other than navigation, such as

- a universal and instantly available global time reference having atomic clock accuracy
- a basis for precision map construction
- a way to precisely measure movements of geological formations
- the ability to track all of the individual vehicles within an entire fleet, such as with taxicabs or fire trucks
- the guidance needed for an aircraft to execute an accurate and safe landing when local conditions offer zero visibility
- the ability to provide aircraft speed and location at real time for parallel guidance of agricultural aircraft to automatically and continuously regulate spray output as a function of the actual travel speed and position of the aircraft

A GPS receiver uses data sent by orbiting satellites to calculate its own current location. In order to find its exact location, the receiver must simultaneously detect the identification signals from four different GPS satellites. The time it takes signals to travel from three of the GPS satellites form the basis of the calculations performed by the GPS receiver to determine its location in three-dimensional space. The signal from the fourth satellite serves to verify time signals from the three other satellites.

## Differential GPS

Each of the GPS satellites is configured to broadcast signals over two microwave frequency channels. One channel carries a strong signal that can only be used by the military. The second satellite signal is less robust and is known as the coarse acquisition (C/A) signal. This signal is available for nonmilitary GPS use, although calculations based on this C/A signal do not provide pinpoint precision of the GPS receiver location. It typically gives a location precision of  $\pm 30$  meters (roughly 100 feet) for horizontal accuracy. For some uses, such as aerial application, this lower level of precision makes C/A-signal-based GPS data too inaccurate for ultra-precise aerial application.

To improve accuracy of the C/A signal, a technology known as **Differential GPS** (DGPS) provides greater precision. DGPS technology reduces the horizontal error down to less than a meter and rarely more than three meters. DGPS systems are the type used by aerial applicators.

Regular GPS relies on only one receiver, but DGPS technology requires two receivers. One of these remains stationary at an accurately surveyed permanent location and acts as a

reference receiver. The other is mounted inside the aircraft. Both of these receivers detect the same C/A-signals from the orbiting satellites. The stationary receiver transmits data that refines the mobile receiver positioning information. Various governmental agencies and commercial providers operate stationary receiver signal transmission systems, thus enabling them to provide DGPS service to the public.

Because the location of the stationary receiver is precisely known and fixed, it can analyze the incoming timing signals from the satellites and compute a correction factor for the mobile receiver in the aircraft. Although the stationary receiver cannot determine which particular GPS satellites the mobile receiver is using, it detects all accessible satellites, computes the timing signal correction factor for each, and transmits the error corrections to the aircraft's mobile receiver, which then sorts out the data for the satellites being used.

DGPS providers transmit the correction signals from stationary GPS receivers to mobile receivers over a wide-range communication network. Two transmission methods predominate:

- FM radio tower beacon (e.g., U.S. Coast Guard Differential GPS Navigation Service; Nationwide Differential GPS Service)
- communication satellite relay (e.g., Wide Area Augmentation System (WAAS) and various commercial DGPS services)

### Wide Area Augmentation System

Because GPS alone did not meet navigation requirements of the Federal Aviation Administration for accuracy, integrity, and availability, the FAA and the Department of Transportation (DOT) developed the Wide Area Augmentation System (WAAS) for use in precision flight approaches. WAAS corrects for GPS signal errors caused by ionospheric disturbances, timing, and satellite orbit errors, and it provides vital integrity information regarding the status of each GPS satellite.

WAAS consists of approximately 25 ground reference stations positioned across the United States, covering a very large service area. These stations are linked to form the U.S. WAAS network. Two master stations, one located on the East Coast and the other on the West Coast, collect data from the reference stations and create a GPS correction message that is transmitted to a geostationary communication satellite (GEO). The satellite broadcasts the message on the same GPS frequency to receivers onboard aircraft that are within the broadcast coverage area of the WAAS.

The WAAS improves basic GPS accuracy to approximately 7 meters (28 feet) vertically and horizontally, improves the availability of the signals using *geostationary communication satellites*, and provides necessary integrity information about the entire GPS system.

For some users in the U.S., the position of the geostationary satellites over the equator makes it difficult to receive the signals if trees or mountains obstruct the view of the southern horizon. WAAS signal reception is ideal for open land areas and for marine applications.

### U.S. Coast Guard Maritime Differential GPS Navigation Service

The U.S. Coast Guard provides a Maritime DGPS service for the Harbor and Harbor Approach phase of marine navigation. The Maritime DGPS service coverage area includes the coastal United States, Great Lakes, Puerto Rico, and most of Alaska and Hawaii. It

consists of two DGPS control centers and about 65 DGPS reference stations. The reference stations transmit correction signals on U.S. Coast Guard radio beacon frequencies, and this service is available to the public.

Many GPS receivers are equipped with built-in radio receivers that accept and process GPS-satellite correction signal data. The position accuracy of the Maritime DGPS Service is within 10 meters (approximately 33 feet). If an aircraft is equipped with suitable DGPS receiving equipment, and is less than 100 miles from a reference station, its pilot may typically expect positioning accuracy of 0.75 meters (about 2.5 feet). For aircraft operating more than 100 miles away from the Maritime DGPS reference station, positioning accuracy decays at a rate of approximately 1 meter per 150 kilometers of distance (1 yard per 90 miles). Because of this distance-related decay in accuracy, aerial applicators who require accurate positioning data should obtain GPS satellite signal corrections from the closest Maritime DGPS reference station. The Maritime DGPS program is being incorporated into the Nationwide DGPS program.

### **Nationwide DGPS Service**

A federal law, enacted in 1997, directed the U.S. Department of Transportation to work with several other government entities to develop and operate a standardized Nationwide DGPS Service. The goal of this service is to provide reliable local-area GPS-satellite signal correction data to the public without charge.

This program involves the U.S. Air Force, U.S. Coast Guard, U.S. Army Corps of Engineers, the National Oceanic and Atmospheric Administration, the Federal Highway Administration, and the Federal Railroad Administration. When completed, the Nationwide DGPS Service expects to have approximately 80 DGPS radio beacon sites in place throughout the continental United States. The plan is to provide every area in the continental United States with double coverage DGPS correction data signals from two land-based radio beacon towers. The program will ultimately include all U.S. Coast Guard-operated DGPS reference stations. Each Nationwide DGPS System radio beacon site has a 300-foot tower antenna that substantially increases the effective range available for mobile DGPS user reception. The signal from each site covers a range of 250 miles with enough signal strength to provide positional accuracy of one meter (about 3 feet) or less.

### **Commercial DGPS Services**

Commercial DGPS services provide additional options for pilots making aerial applications in remote locations. These services fill in areas missed by the government systems. Most mobile DGPS equipment is compatible with the commercial DGPS services. Subscribing to one of these services provides pilots with a high degree of location accuracy suitable for precise aerial pesticide application.

## **Using DGPS for Aerial Application**

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The amount and kind of navigational information that aircraft-mounted DGPS equipment can provide depends on the features that are incorporated into the system installed on the aircraft. As with other avionic devices, an FAA-certified aircraft maintenance technician must install DGPS equipment and components.



FIGURE 6.2

An onboard DGPS system provides a visual representation of the position of the aircraft in relation to the swath being sprayed.

If you are planning to purchase mobile DGPS hardware and software for an application aircraft, be sure to find out if the equipment processes signals for the type of DGPS service that is available in the area where the aircraft is operating. In addition, find out what kinds of DGPS peripheral devices, such as light bars and flow controllers, the equipment can accommodate.

An aircraft fitted with *basic* DGPS components provides the pilot with the ability to perform DGPS-aided precision aerial swathing. A basic DGPS includes a

- DGPS mobile receiver
- GPS antenna
- light bar
- computer processor or CPU (in some units, the CPU and light bar are combined into one unit)

### Using the GPS Light bar

The GPS light bar is a linear array of light emitting diodes (LEDs) that produce a visual representation of the position of the aircraft in relation to the swath being sprayed. It enables the pilot to easily visualize off-track errors and quickly make flight-path corrections. Typically, the light bar is mounted at a location within the peripheral vision of the pilot.

The onboard DGPS receiver (Figure 6.2) continuously sends updated signals to the light bar, at about 5 per second. These signals activate specific LEDs on the light bar and represent the current position of the aircraft. The center of the light bar corresponds to the swath centerline. The other LEDs in the array located to the left and right of center represent a user-defined ground distance. This ground distance is usually 2 feet per LED, but can be set to as little as 6 inches per LED.

When the aircraft is exactly over the centerline of the swath, the center-most LEDs of the light bar illuminate. If the path of the aircraft shifts to the left of the swath centerline, the illuminated sector of the light bar shifts towards the right. The pilot corrects the flight course by steering toward the illuminated LEDs. The correct flight path is restored when only the centermost LEDs of the light bar glow.

When turning or lining up to begin a new swath, the pilot uses the light bar to get on course. Once the aircraft is lined up with the next swath centerline, the pilot uses traditional landmark navigation by selecting a distant visual object and flying toward it to begin and perform the spray pass. Occasionally checking the light bar during the spray pass will help the pilot fine tune the course of the aircraft.

## Computers, Spray Output Controllers, and Sensors

Positioning data can enhance accuracy of aerial application work. For this reason, many DGPS equipment manufacturers also sell onboard computers (or DGPS systems combined with a computer), spray output controllers and sensors, and computer software packages tailored to link DGPS data to aerial application needs.

An onboard DGPS computer enables aerial guidance, mapping, waypoint navigation, and spray operation recordkeeping. The pilot uses the computer to select a desired application pattern, such as racetrack. The onboard computer then uses DGPS positioning data to continuously calculate and display the aircraft location with respect to the target site and application pattern. This eliminates the need for human flaggers or flagging or marking devices.

The computer system records the precise in-field location of each spray swath. For jobs requiring multiple tanks of spray, a mapping system shows the pilot where to begin application of the next load. Throughout the spray operation, the computer system collects data and constructs records for customer billing, environmental reporting, GPS data analysis, and other custom needs.

Manufacturers of DGPS computer systems also offer software programs and computer hardware interfaces that enable precision spray boom operation. An electronically regulated flow controller receives continuously updated ground speed data from the onboard DGPS computer. The computer couples this data with the swath width of the aircraft and uses the result to regulate boom output. As a result, the spray can be delivered uniformly for the duration of the job in progress even if travel speed of the aircraft varies. Feedback data from the boom flow controller is used to construct an on-site record of the output performance of the spray boom.

## SMOKE GENERATORS

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Smoke generators on aerial aircraft are used to visualize air movement at the application site. A smoke generator is a device that injects oil into the exhaust system of the aircraft where it is burned, producing smoke. The pilot controls oil injection by a switch in the cockpit.

When the smoke generator is activated, the pilot can watch the smoke movement to determine the potential for drift of the spray being applied. In addition, some pilots use the smoke as a locator for the position of their previous pass in order to estimate where to begin the next pass. However, due to the movement of the smoke in the air currents, this method is less than reliable for swath marking.

Smoke generators are a common part of the onboard array of equipment found on most agricultural aircraft. One reason for this is that GPS systems have eliminated the need for human flaggers at the application site to position the aircraft for each swath. However, a flagger also typically provided information about wind speed and direction to the pilot. Since offsite pesticide drift is a major concern during aerial applications, a smoke generator can provide a better visual picture of wind direction and relative wind speed at the time of spray release. The use of a smoke generator allows the pilot to make immediate local wind condition evaluations without depending on someone on the ground.

Smoke generators have three major components:

- an oil tank (usually with a capacity of about two gallons)
- a pump (usually mounted on the top of the oil tank)
- a nozzle mounted in the aircraft engine exhaust stack



## HUMAN FLAGGERS

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With the advent of the GPS navigation system, the need for human flaggers has been drastically reduced. However, when a human flagger is assisting in an aerial application, of utmost importance is his or her safety because of their proximity to the spray. Flaggers should always wear label- or regulation-mandated PPE to protect themselves from pesticide exposure. They must clearly understand the application process the pilot will use and be in constant radio communication with the pilot. For additional safety, a pilot should begin application on the downwind side of the field and work into the wind to reduce the flagger's exposure to the pesticide. As the aircraft approaches, the flagger should move to the next swath so that he or she is not in the path of the spray.



## Chapter 6

## Review Questions

SEE PAGE 178 FOR ANSWERS

1. To produce consistent swaths and prevent skips or double coverage, the pilot needs to
  - a. accurately control the aircraft's flight path
  - b. carefully follow all pesticide regulations
  - c. pay special attention while ferrying the aircraft
  - d. avoid offsite pesticide drift
2. A differential global positioning system (DGPS) is
  - a. only used by commercial airline pilots
  - b. unsatisfactory for aerial application of pesticides
  - c. less accurate than wide area augmentation systems
  - d. powerful enough to provide positional accuracy for pesticide applications
3. Smoke generators are sometimes unreliable for swath marking because
  - a. the quantity of smoke cannot be calibrated
  - b. they are not compatible with GPS systems
  - c. the smoke moves in the air currents
  - d. smoke is an air pollutant
4. A DGPS system requires
  - a. two GPS receivers in the aircraft
  - b. a mobile (aircraft-mounted) receiver and a stationary receiver
  - c. permission from the federal communications commission to be operated
  - d. registration with the Federal Aviation Administration
5. The Wide Area Augmentation System (WAAS) may not be effective in some areas of the United States due to
  - a. weak radio signals
  - b. ionospheric disturbances
  - c. satellite orbit errors
  - d. obstructions such as trees or mountains



# 7

## Preparing for an Aerial Application

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Each pest control application can be unique for the aerial applicator because of differences between application site locations, obstacles, sensitive areas, weather, pesticide materials, crops or target areas, and other variables. Therefore, the pilot and ground crew must clearly understand the written pest control recommendation or work order, and the label. Before beginning the operation, the operator must arrange to scout the target site so the operation is carefully planned and scheduled. Reviewing the pesticide label is essential to understand application restrictions and precautions and to better prepare for emergencies or other problems. Some pesticide materials may have additional local application restrictions such as time of use, height of application, prohibitions due to nearby sensitive crops, and requirements for buffer zones.

### UNDERSTANDING THE RECOMMENDATION OR WORK ORDER

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Before a pest control business is allowed to conduct aerial pest control, it must have either a written pest control recommendation from a licensed Agricultural Pest Control Adviser or a grower's work order. It is crucial to review the recommendation or work order carefully to assure that the application can be made safely, correctly, and legally, according to the label and regulations. The requested work must be able to be performed with reasonable precaution and be within the expectations of the normal work procedures of both the pilot and ground crew. Take into account the following factors when evaluating the recommendation or work order:

#### Features and Limitations of the Aircraft

The aircraft used to conduct the application must be capable of safely delivering the appropriate amount of pesticide to the target site. The aircraft must



## Sidebar 20

## How to Reduce Drift During Aerial Applications

The following procedures help to reduce the potential for spray droplets to drift off the application site:

- use appropriate nozzles designed to produce larger droplets that are less prone to drift
- use a nozzle orientation that will maintain the desired droplet size
- be sure that positive shut-off valves are working properly.
- achieve good field-end coverage on initial spray runs—crossing the ends of fields that are bordered by trees or other obstacles usually means flying higher and increasing the chance of drift
- maintain applications at heights between 8 and 12 feet above crop canopy
- use a boom length that does not exceed 75% of the wingspan of fixed wing aircraft or 90% of the rotor diameter of helicopters in order to reduce drift caused by wingtip and rotor vortices
- consult the pesticide label for recommendations on boom type and setup requirements

- have the performance capabilities for the maneuvers needed to carry out the application
- have a maximum load capacity that will accommodate the weight of the pesticide and, if needed, be able to handle takeoffs and landings from short, rough, or temporary airstrips
- be properly equipped to discharge the recommended amount of pesticide product per unit of target site area
- be able to produce and deliver spray droplets that have minimal spray drift potential at the intended location (see Sidebar 20 and the spray drift section in Chapter 9)

## Pilot Qualifications and Limitations

The pilot's competence, alertness, and capacity for timely and accurate judgment largely determine the safety of the operation and the quality of the application. The pilot must be

- aware of his or her personal limitations in operating the aircraft and be fully aware of the features and limitations of the aircraft
- capable of safely maneuvering the aircraft when it is loaded to its maximum legal weight
- able to determine the best direction in which to apply the pesticide to reduce offsite movement
- capable of immediate and clear communication exchanges with on-site ground crew members and others

- sufficiently rested, and maintain a well-balanced diet, taking brief, scheduled breaks during every workday in order to avoid fatigue
- able to establish and follow realistic task deadlines and work patterns
- knowledgeable of weather factors and their influence on aerial application work
- able to correctly interpret and follow the pesticide label directions and written pest control recommendation or work order
- familiar enough with each pesticide product label to know
  - first aid measures in the event of accidental overexposure
  - special precautions required for aerial application
  - registered crops or sites
- able to recognize different types of crops from the air in order to insure the correct site is treated
- to delineate boundaries of adjacent nontarget areas

## Scouting the Target Site

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Each application site has a unique set of obstacles and hazards. Established aerial pest control businesses often have an extensive collection of maps and aerial photographs that identify such obstacles, hazards, and sensitive areas. In addition, the Agricultural Pest Control Adviser who provides the written recommendation or the grower who provides the work order are required to furnish information on susceptible surrounding crops or any sensitive areas. Prior to committing to make an application, the pest control business should have someone visit the target site to scout for obstacles, hazards, and sensitive areas. This can be done by ground, by air, or both. Afterwards, coordinate the visual observations with maps and photographs of the area.

Should the application site and surroundings be unfamiliar, seek advice regarding weather patterns, topography, and sensitive areas from people familiar with the area, such as staff at the local county agricultural commissioner's office or UC Cooperative Extension farm advisors.

The purpose of the scouting is to locate obstacles and other hazards and potential risks to the aircraft and pilot, people in the area, property, surrounding crops, and the environment. During scouting, collect information about the

- location of the site and the size and shape of the area to be treated
- proximity of the site to adjacent fields or other areas where field workers may be located
- general local weather conditions
- proximity of the site to areas used or inhabited by people, including residences, parks, schools, playgrounds, shopping centers, businesses, roadways, adjacent fields, work crews, and other areas

- proximity of the site to environmentally sensitive areas such as lakes, streams, ponds, irrigation canals, riparian zones, wildlife habitats, sensitive plants, nearby crops, and organic farms
- proximity of the site to farms, ranches, or other businesses with livestock or other domestic animals, such as dairies, beef feedlots, dog kennels, and horse stables
- proximity of the site to honey bee hives and other commercial pollinating insects
- safety hazards such as power lines, guy wires, vent pipes, antennas, towers, trees, and other obstacles adjacent to the site and within the site itself
- current cultural practices taking place at the site and other adjacent agricultural areas
- possible limitations to the operation, such as ground crew access to the site

Using a map or aerial photograph of the area, chart all sensitive areas and obstacles. This information will prove useful during the operation and for future reference. Prior to the actual application, make a final check to assure that there are no recent changes that would put the pilot, other people, the property, or the surrounding areas at risk.

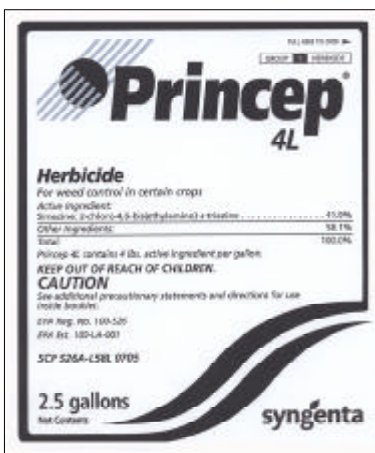


FIGURE 7.1

The pesticide label has important information, including certain use restrictions, that must be understood before making an application.

## Pesticide Label Restrictions

Review the pesticide label to understand the legal requirements and use restrictions for that material (Figure 7.1). If the recommendation or work order calls for a tank mix of two or more pesticide products, review the labels of all the products. Be sure you understand the following information:

- **Application Instructions.** Confirm that there are no prohibitions to applying the prescribed material by air.
- **Personal Protective Equipment Requirements.** Understand and have available the PPE required for mixers and loaders, for the pilot when outside of the aircraft cockpit, and other handlers.
- **First Aid and Decontamination Requirements.** Read the label for instructions on what type of first aid and decontamination procedures must be followed in case someone is exposed to the pesticide.
- **Environmental Hazards.** Check for precautions relating to environmentally sensitive areas, protecting natural enemies and beneficial insects, and other environmental hazards.
- **Sensitive Crop Restrictions.** Review the label precautions regarding applying the material onto or near sensitive crops or other plants.
- **Notification and Posting Requirements.** Understand the notification and posting requirements in labeling and in California regulations for the treated area and any other requirements for preventing entry by workers or people from the surrounding areas. Understand the requirements for informing people about the hazards associated with the application. Get assurance from the property manager that all notification, posting, and other requirements will be followed prior to the application.

## California State and Local Regulations and Restrictions

In addition to understanding the pesticide label, check state and local regulations and restrictions that may affect the use of the recommended pesticide. More restrictive regulations and conditions of the restricted material permit will supersede the pesticide label. The local county agricultural commissioner can provide information on these regulations and conditions.

**Personal Protective Equipment Requirements.** California regulations may be more restrictive for PPE requirements for pesticide handlers, including pilots, than the requirements listed on pesticide labels (see Sidebar 17 on page 64).

**Handler Training Requirements.** California regulations require that handlers receive annual pesticide class-specific training prior to handling activities (see Sidebar 12 on page 54). This requirement does not apply to certified pest control aircraft pilots because they must receive 20 hours of continuing education credit every two years in order to renew their certificates.

**Posting Requirements.** Posting requirements in California differ from federal regulations and may be more restrictive than the pesticide label requirements (Figure 7.2). In addition, some materials may require posting even when the pesticide label does not require posting. While the operator of the property has primary responsibility for posting the treated field to provide warning of hazards to workers and the public, it is in the interest of the pest control business to assure that posting has been taken care of by the customer or landowner. Therefore, before applying a pesticide to a field that must be posted, check to assure that the proper warning is displayed. If it is not, contact the customer and delay the treatment.

**Endangered Species and Other Sensitive Areas.** To protect endangered or threatened species and certain environmental areas, state or local regulations may prohibit or restrict the use of certain pesticides in defined areas. Check with the local county agricultural commissioner for any restrictions.

**Buffer Zones.** State regulations or conditions of the local restricted material permit may require unsprayed buffer zones of prescribed widths to protect sensitive areas. Check with the local county agricultural commissioner for this information.

**Beekeeper Notification.** California regulations require pesticide applicators to notify beekeepers if applying pesticides that are harmful to honey bees to blossoming plants within one mile of apiaries. See Sidebar 21 for information about beekeeper notification.

**Notification of Application.** Before making any application, the pest control business is required to notify the person who is responsible for the property to be treated. See Sidebar 22 for information that must be included on this notification.

**Age Limitations for Handlers.** Minors under 18 years of age are prohibited from mixing or loading any pesticide that requires the use of air supplied respiratory protection, closed systems, or full-body, chemical-resistant protective clothing during handling activities.



FIGURE 7.2

Posting is required when certain pesticides are applied. The purpose of posting is to warn people to keep out of a treated area. California posting requirements may be more restrictive than federal laws for some pesticides.



### Sidebar 21

## Notifying Beekeepers Before an Application

Before making an application to a blossoming plant, anyone intending to apply a pesticide that is moderately toxic or toxic to bees should check with the local county agricultural commissioner (or a notification service designated by the commissioner) to find out if any beekeepers with apiaries within one mile of the application site have requested notice of the application.

If any beekeeper has requested notification, you must notify the beekeeper at least 48 hours in advance of the application.\* The notification shall include

- the time and location where the application is to be made
- the crop and acreage to be treated
- the method of application
- the identity and dosage rate of the pesticide to be applied
- how the person performing pest control may be contacted by the beekeeper

\* The amount of time that notice must be given to beekeepers before the application may be increased or decreased by the county agricultural commissioner or by an agreement between the beekeeper and the person performing the pest control work.



### Sidebar 22

## Notice of Applications

Anyone performing pest control must give notice to the operator of the property to be treated before any pesticide is applied. The notice has to be in a manner that the person receiving it can understand. This notice must include:

- the date of the scheduled application
- the identity of the pesticide to be applied by brand or common chemical name
- precautions to be observed as printed on the pesticide product labeling or included in applicable laws or regulations

If the scheduled application is for the commercial or research production of an agricultural plant commodity, the notice must also include the

- time of the scheduled application
- location and description of the area to be treated
- applicable restricted entry interval
- product name, EPA registration number, and active ingredient
- pesticide product labeling requirements for posting of the treated area





## Sidebar 23

## Notice of Intent

The local county agricultural commissioner must be notified at least 24 hours before the application of any pesticide that requires a restricted material use permit. The notice of intent to apply a pesticide may be submitted to the commissioner by the operator of the property to be treated, by an authorized representative of the operator, or by the licensed pest control business hired to apply the pesticide.

The commissioner may allow less than 24 hours notice if it is determined that because of the nature of the commodity or pest problem, effective pest control cannot be attained if there is a delay, or when 24 hours are not necessary to adequately evaluate the intended application. The commissioner may also require more than 24 hours notice under permit conditions.

The following information must be provided in the notice of intent:

- restricted material use permit number
- name and address of permit holder and applicator
- location of areas to be treated and name of the farm operator
- crop or commodity, or if there is no crop or commodity, the site to be treated
- approximate acres or other units to be treated
- method of application
- pesticide(s) to be applied
- dilution, volume per acre or other units, and dosage
- pest(s) to be controlled
- date intended application is to begin
- location and identity of areas adjacent to the intended treatment site that have changed since the permit was issued and that may be adversely impacted; a map or aerial photograph may be used for designating such locations

**Notice of Intent.** Users of restricted use pesticides are required to notify the local county agricultural commissioner at least 24 hours prior to the application. See Sidebar 23 for information that must be provided with the notice of intent.

**Sensitive Crop Restrictions.** State or local regulations may restrict or prohibit the application of certain pesticides within specified distances of sensitive crops. Check with the local county agricultural commissioner for any restrictions.

### Resolving Conflicts

If the recommendation or work order appears to be in conflict with any of the factors listed above and you have a concern, delay the application until a revised recommendation or work order can be agreed upon. Resist pressure to perform an aerial application that presents high levels of risk and refuse any job that is clearly unsafe or illegal.

## PLANNING AND SCHEDULING THE APPLICATION

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Planning for and scheduling the application can begin once the recommendation or work order, pesticide label, and state and local restrictions have been reviewed and the application site and surroundings have been scouted. Both a congested area plan and an operations plan may be needed.

### Congested Area Plan

If the pest control job requires flying over a congested area, the pest control pilot, in accordance with FAR, Title 14, Part 137, needs to obtain written approval by the jurisdictional authority of that area and give public notice of the intended operation. A congested area plan must be submitted for approval to the appropriate FAA Flight Standards District Office (FSDO).

Part 137 of Title 14 was specifically instituted to provide relief for aerial applicators from the more stringent Part 91 general aviation requirements. If it were not for Part 137, almost all aerial applications (and especially those in congested areas) would be in violation of the other FAA Regulations.

If the pest control pilot does not comply with this standard when operating in congested areas, he or she does not qualify to be covered by the other provisions of Part 137. This automatically removes the exceptions provided by Part 137 and places the operator in jeopardy of violating Part 91. This consequence holds true even if the pilot complies with the other provisions of Part 137. In such case, the operator can be cited for violation of both Parts 91 and 137.

In addition to avoiding violation of the FAR, following the Part 137 standard provides the commercial applicator with help in accomplishing two objectives—reducing the number of public complaints and building better community relations. Local authority approval and public notification of impending operations reduce the number of complaints received. The involvement of FAA inspectors in responding to individual complaints and explaining how unusual aircraft maneuvering is both safe and legal can assist in building better community relations.

See Sidebar 24 for steps to take in filing a Congested Area Plan under FAR Part 137.

### Operations Plan

Commercial pest control businesses should use an operations plan to reduce the risk of errors that could lead to lowered efficiency or costly accidents. Plans should be in writing and made available to all employees. The plan should include:

- management policies and expectations
- work procedures
- individual employee job responsibilities
- requirements stipulated by regulatory agencies
- procedures for the proper storage, transportation, handling, and disposal of pesticides and pesticide containers

- how to deal with emergencies such as a pesticide spill, pesticide fire, or aircraft crash
- emergency procedures for protecting workers, the public, and the environment in case of an accident, pesticide release, or incident such as a major spill or leak

Insure that employees understand their job responsibilities and can demonstrate their ability to put into operation any part of the plan in which they have a role. For each job, the operator must provide the pilot and ground crew with the information, training, and tools necessary to assure their own safety as well as safety of others and the protection of the environment.

Operational problems frequently result from poor communication or sketchy information about a job on which employees are assigned to perform. It is risky to assume that employees already possess all the information they need, so review this information before each new operation. Job delays, having to return for forgotten materials, treating the wrong fields, or applying the improper types or concentrations of pesticides are examples of what can happen when employees operate without all the information or training they need. Operators must provide essential site-specific job information to employees and job briefings for each application. For example:

- develop and maintain an inventory of maps of all areas to be treated; chart all hazards, adjacent crops, and environmentally sensitive areas onto these maps
- scout all new areas by ground and air and keep maps up to date so that new obstacles or changes in conditions are identified promptly
- construct maps of the various operational areas to orient crews on the location of areas to be treated
- provide written directions to the application site and take new employees to job sites that they are not familiar with
- develop a system for accepting and transmitting information on recommendation or work order changes in the field; when something comes up, make sure that the field scout or customer talks directly to the pilot or supervisor rather than office staff or members of the ground crew



## Sidebar 24

### Congested Area Plan

Where necessary, file congested area plans with the appropriate FAA Flight Standards District Office (FSDO) to insure that the operation is covered by FAR Part 137 rather than Part 91.

Public notice of the intended operation can be legally given through the daily newspapers, radio, television, or door-to-door notification. Door-to-door notice is usually the most effective procedure. This is especially true for operations close to small rural communities.

Plan flight patterns that avoid passes or flying over residences, schools, communities, animals, or field workers.

Establish a reporting mechanism to address local complaints or concerns when operating in congested areas.

- insure that the pilot or supervisor prepares mix sheets and determines the order of mixing and the proportions of pesticides in a tank mix; the supervisor or pilot should also train the mixers and loaders in calculating tank batches, pesticide handling procedures, and personal protective equipment use and care
- give each employee a checklist that outlines the procedures they need to follow to comply with applicable regulations and company policies

## Plans for Managing Offsite Pesticide Drift

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Having information about the prevailing wind direction and locations of sensitive areas will assist in developing an application pattern and other procedures that will minimize offsite pesticide drift into these areas (see Sidebar 20 on page 112). Setting up the nozzles and spray boom and making applications as described in the following two chapters will result in larger, heavier droplets that are less prone to drift. Scheduling the application during times when there is minimal wind and no inversion conditions will help in keeping spray droplets confined to the application site.

## Planning for Emergencies

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A vital part of the application planning includes being prepared for any emergency that might occur during the operation. Having a written emergency response plan and sharing and discussing this plan with the ground crew will help everyone know how to respond and will reduce the chances of injury or death.

**Emergency Information.** All members of the application operation should be equipped, by cell phone or radio, to call for emergency help or to transport an injured person to a medical facility. Part of the emergency planning should be to locate the nearest medical facility to the application site and be sure each crewmember knows how to get there. Operators should also arrange with the medical facility for possible emergency medical care. All members of the ground crew should be trained to direct emergency responders to the application or mixing/loading site.

**Flight Hazards.** To assist the pilot during an application, a ground crew member should be present at the application site and be equipped to communicate with the pilot. This person can warn the pilot of hazards and notify him or her if there is a problem on the ground that requires stopping or delaying the application. This person should have a map of the application site that shows the hazards and sensitive areas within the application site and in surrounding areas.

**Plans In Case of Engine Failure.** Plans should also be made for catastrophic events such as aircraft engine failure leading to a forced landing or crash. This requires that every member of the ground crew be prepared to respond immediately to an aircraft crash. Ground crew members responding to a crash should act promptly, stay calm, and focus on helping the pilot. They should get to the crash site immediately with a fire extinguisher and communicate the exact location of the crash site to emergency responders and others by cell phone or radio. Sidebar 25 provides the steps that should be taken for assisting the pilot in a crashed aircraft.



## Sidebar 25

### Rescuing the Pilot from a Crashed Aircraft

If the aircraft crashes and is on fire, rescuers must stay out of the smoke. Call for help immediately. Use the fire extinguisher to help get the pilot out and moved to safety, upwind and upslope of the wreckage. When pesticides are onboard, check the pilot to see if he or she has been contaminated. If there is contamination and he or she is not seriously injured, remove all pesticide-contaminated clothing and use the nearest water to wash his or her contaminated body areas. Avoid becoming contaminated while assisting the pilot.

If the pilot appears seriously injured, loosen any restrictive clothing, ensure his or her airway is clear, and use direct pressure to stop any profuse bleeding. Either take the pilot to a medical facility or call an ambulance. Tell medical personnel what pesticide was being used and arrange to provide them with a copy of the pesticide label.

If the plane is not on fire and the pilot is not seriously injured, take him or her to a medical facility for checkup and treatment. Tell medical personnel what pesticide was being used and arrange to provide them with a copy of the pesticide label.

If the pilot is seriously injured or unconscious, do not move him or her from the aircraft, unless the pilot's life is threatened as a result of the crash. Remove any restrictive clothing and make sure his or her airway is clear. Apply direct pressure to restrict any bleeding. Call 9-1-1 for an ambulance and clearly identify the exact location of the crash.

Follow the ambulance to the medical facility, inform the health care providers which pesticide the pilot was applying, and arrange to provide them with a copy of the pesticide label. Contact the main pest control business office and let them know which medical facility will be receiving the pilot.

**Application Equipment Malfunction.** Application equipment malfunction could include ruptured lines, a tank leak, pump failure, or electronic controller failure. Any of these problems could result in contamination of areas outside of the target area and may require a load jettison before the aircraft can return to an airport for repairs. The pilot should prepare for this type of emergency by locating possible places to jettison the load or to set down the aircraft. Any route taken by the aircraft having a pesticide leak should be over areas that are unoccupied by people or animals.

## Ground Crew Emergencies

Ground crew emergencies include leaks and spills of concentrated pesticides or diluted spray materials and splashes and spills that contaminate one or more of the ground crew members. It could also include a fire involving pesticides. These are serious problems that require immediate action to protect people and the environment. California regulations require that pesticide labels be at the use site, which include the treatment site in addition to the mixing-loading site. There is an exemption for aerial applications if the pilot maintains radio contact with the mixer/loaders and any flaggers. These labels serve as references for accidents involving spills and for first aid information when someone is exposed to a pesticide.

Spills or leaks must be contained and cleaned up immediately to prevent further contamination of the mixing and loading area. Planning for a leak or spill emergency should



## Sidebar 26

## Contents of a Pesticide Spill Kit

A pesticide spill kit should always be available at the mixing and loading site. The kit should be a container with the spill control materials stored inside. Label the container “For Pesticide Spills Only”. Include a list of the contents inside the container. To make it easy to see if the contents have been used or disturbed, tape the spill kit container closed (lightly, but visibly) after checking the contents.

The following items should be included in a pesticide spill kit:

- waterproof or chemical resistant gloves, goggles, a respirator, and disposable coveralls
- chalk or grease pencil (for marking a spill area on a nonporous floor) and permanent marker (for labeling the spill container after cleanup)
- dust pan or small shovel (plastic preferable)
- small broom
- spray bottle (for wetting down small spills of dry materials)
- paper towels
- 30 to 50 gallon polyethylene chemical resistant drum with sealable lid
- 20-gallon heavy duty plastic storage bags
- sorbent pillows and tubes
- loose absorbent
- roll of “Caution” tape

include having an adequately equipped spill cleanup kit at the mixing-loading site at all times. Sidebar 26 describes what should be included in the spill kit. The operator should train handlers performing the mixing and loading jobs on the proper ways to clean up a spill. They should also be provided with a cell phone or radio for use to summon help for major spills or in case of a pesticide fire or other emergency. Operators responding to major spills or major emergencies such as a pesticide fire should provide an instruction sheet at the mixing and loading site that gives the steps handlers should take for cleaning up a spill (see Sidebar 27).

Handlers should follow the first aid information on the pesticide label when someone involved in the mixing or loading activities is exposed to a pesticide. The decontamination facility must have sufficient clean water for emergency decontamination of the entire body as well as soap and single use towels. In addition, a change of clothing for each crewmember shall always be available at the mixing and loading site and be stored in a pesticide free, clean location. See pages 49-51 in Chapter 3 for additional first aid information.

**Overspray, Drift, and Other Misapplication.** Serious environmental contamination can result from overspray, offsite drift, and other types of misapplication. There also may be serious financial liability due to the damage caused by any type of misapplication. Ground crews can assist a pilot in preventing such problems by being alert during an application

and quickly communicating with the pilot when problems are spotted. The **Misapplication of Pesticides** section in Chapter 4 (page 68-69) outlines steps to take if a misapplication should occur.

**Spray or Dust Contacting Bystanders or Vehicles.** It is illegal to apply any pesticide in a manner that causes people, livestock, vehicles, and other objects to be exposed to the spray or dust. Unfortunately, farm workers, joggers, trespassers, and others may not recognize the hazard of entering an area until an aircraft making an application flies over them. Weather patterns can also change rapidly, causing pesticide from the application to drift off site and possibly onto workers or other people nearby. Therefore, you need to develop a plan to keep people out of the area during an application and only make applications when workers and others are not in adjacent areas where they might be subject to drift. It is essential to check the site and adjoining areas before beginning an application to be sure no one is around. Having one or more ground crew members in the area during an application to keep people out is also essential.

The application plan should include procedures to follow in case a bystander does contact spray or dust. This should include decontamination and assistance in obtaining medical care for anyone who is exposed to the pesticide.



#### Sidebar 27

### Steps in Cleaning Up a Pesticide Spill

Cleaning up major pesticide spills requires the help of professionals. It is extremely difficult and costly to remove contaminated soil or to prevent or clean up ground water contamination. The most crucial things to do before professional help arrives are to contain the spill as much as possible and keep other people away.

Follow these steps to clean up a small pesticide leak or spill:

**Clear the Area.** Keep people and animals away from the contaminated area. Provide first aid if anyone has been injured or contaminated. Send for professional medical help and an ambulance if necessary.

**Wear Personal Protective Equipment.** Before beginning any cleanup, put on the personal protective clothing listed on the label for mixing or loading the concentrated material or follow directions listed on the pesticide product MSDS. Check the pesticide label for additional precautions, but when uncertain what has been spilled, wear the maximum protection. This includes chemical resistant boots and gloves, chemical resistant protective clothing, goggles, and a cartridge respirator.

**Contain the Leak.** Stop the leak by transferring the pesticide to another container or by taping and patching the leaking container. Use sorbent pillows, soil, sand, sawdust, or absorbent clay, such as cat litter, to form a containment berm around liquid leaks. If the wind is blowing pesticide dusts or powders, lightly spray the area with water or cover the spill with a plastic tarp to prevent offsite movement.

**Clean Up the Pesticide.** Proceed to clean up the spill or leak. Brush the containment berm of absorbent material toward the center of a liquid spill. Add additional absorbent material if necessary. If the spill is on soil, shovel out contaminated soil for disposal. Place the absorbent or spilled dry product, and any contaminated soil, into a sealable container. Containers for holding contaminated materials must be suitable for transporting. Label the container with the pesticide name and signal word.

**Dispose of the Material.** Local regulations on disposal of hazardous materials may vary. Check with the local county agricultural commissioner for instructions on how to dispose of the container and its contents.

## Chapter 7

## Review Questions

SEE PAGE 178 FOR ANSWERS

1. Before a pest control business can perform an aerial application of a pesticide to a particular site, it must have a
  - a. valid permit from the county agricultural commissioner
  - b. written pest control recommendation or work order
  - c. letter of authorization from DPR
  - d. bill of lading for the material
2. Any aircraft used to apply a pesticide must
  - a. be inspected and approved by the Department of Pesticide Regulation
  - b. comply with U.S. EPA standards for aerial application aircraft
  - c. be certified to apply spray droplets larger than 200 microns
  - d. be airworthy enough for the maneuvers needed to carry out an application
3. Factors that largely determine the safety and quality of an aerial application include the
  - a. pilot's alertness, competence, and accurate judgment
  - b. age and development stage of the targeted crop
  - c. methods used to prepare and mix the pesticide
  - d. training and experience of the ground crew
4. Decisions relating to suitable weather conditions for application and the direction to fly to avoid sensitive areas during an application should be made by the
  - a. ground crew
  - b. manager of the property being treated
  - c. pest control operator
  - d. pilot
5. Scouting an area before making a pesticide application by air is needed because
  - a. pesticide labels require this
  - b. it is a condition of the operator's liability insurance policy
  - c. it helps to identify obstacles, hazards, and potential risks to the pilot and aircraft
  - d. it provides a service to the client and is a good business practice



6. Information about hazards and sensitive areas within an unfamiliar application site can often be obtained from
  - a. most local businesses
  - b. the county planning department
  - c. UC Cooperative Extension farm advisors
  - d. regional FAA offices
7. Specific information about environmental hazard precautions relating to the pesticide product being applied should be obtained from the
  - a. product label
  - b. manufacturer's sales literature
  - c. Internet
  - d. U.S. Environmental Protection Agency
8. Notification of field workers about a pesticide application and posting a treated field is the responsibility of the
  - a. pilot working for the pest control operator
  - b. ground crew working for the pest control operator
  - c. pest control operator
  - d. owner or manager of the property being treated
9. Application of restricted materials require that a Notice of Intent be filed with the county agricultural commissioner's office at least \_\_\_\_\_ hours prior to the application.
  - a. 8
  - b. 12
  - c. 24
  - d. 48
10. Information about local requirements for leaving unsprayed buffer zones adjacent to sensitive areas can be obtained from the
  - a. pesticide label
  - b. Material Safety Data Sheet
  - c. DPR Website
  - d. county agricultural commissioner

11. If any beekeeper has requested notification of the application of pesticides harmful to bees within one mile of the apiaries, this notification must be given at least \_\_\_\_\_ hours before the application takes place.
  - a. 12
  - b. 24
  - c. 48
  - d. 72
  
12. You must file a Congested Area Plan for approval by which of the following?
  - a. county agricultural commissioner
  - b. Department of Pesticide Regulation
  - c. FAA Flight Standards District Office
  - d. local control tower authority

# 8

# Calibrating Aerial Application Equipment

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Applying liquid or dry pesticide products uniformly and at the proper rate per unit of area is crucial for a legal, safe, and effective application. This is because manufacturers and/or regulatory agencies establish proper application rates and safety precautions through research that involves testing for efficacy and safety. Pesticide product labels list maximum rates, so exceeding these rates constitutes a conflict with the label directions, which violates federal and state laws. There can be numerous adverse results from exceeding the maximum label rate, including

- increased exposure to concentrated pesticide by handlers, especially mixers and loaders
- increased levels of pesticide residues on the treated crop or commodity and other surfaces within the treated site, increasing the risk of exposure to field workers and other workers that may enter the treated field or other site
- increased levels of pesticide residues on the treated crop or commodity, possibly exceeding legal tolerances
- potential phytotoxic effect on treated desired plants (injury to plants caused by the pesticide)

Applying less than the minimum recommended rate is usually legal, but may result in inadequate management of the pest, wasting time and resources.

The success of each aerial pesticide application depends on accurate calibration. The term calibration refers to setting up and adjusting the application equipment to ensure that the correct amount of pesticide active ingredient is properly diluted and applied according to label instructions. This chapter discusses the steps to take to calibrate, test, and adjust fixed and rotary wing aircraft pesticide dispersal systems.

Once the aircraft system is calibrated, check and test the equipment periodically to be sure the calibration stays accurate. Many operators fail to understand how rapidly equipment becomes maladjusted or worn. As a result, application equipment is usually not calibrated often enough.

Advances in electronic technology in the form of DGPS systems, flow rate controllers, and direct injection spraying systems provides more accurate tools to assist pilots in precision applications. These tools reduce calibration errors and automatically adjust the spraying system to accommodate for changes in pump output and nozzle wear, as well as variations in application speed. Operation manuals for these electronic devices are the best resources for setting up and adjusting these systems. As a result, this chapter does not cover any methods of calibrating or adjusting electronic devices.

## WHY CALIBRATION IS ESSENTIAL

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The main reason for calibration is to figure out how much pesticide to put into the tank or hopper of the aircraft to apply to a determined area. This assures that the correct amount of pesticide is applied to the target site when the aircraft is flown at a determined speed and altitude. Accurate calibration is necessary for

- assuring compliance with the requirements in labeling, law, or regulation
- effective pest control
- protecting human health, the environment, and treated crops or surfaces
- preventing waste of resources
- controlling the volume of water (for liquid applications) applied to a given area

**Effective Pest Control.** Manufacturers of pesticides spend millions of dollars researching ways to use their products effectively. Their research includes determining the correct amount of pesticide to apply to control target pests. Using less than the labeled amount of pesticide may result in inadequate control, wasting time and money. Inadequate amounts of pesticide may also lead to problems such as pest resistance and resurgence. Using too much pesticide may have adverse effects on natural enemies, targeted plants, and the environment, and may result in residues on crop plants that exceed the legal tolerance level. Higher than label rates are *illegal* and waste pesticides.

**Human Health Concerns.** Pesticides applied at higher than label rates could endanger the health of pesticide handlers, field workers, and other people working in or visiting an area where they are applied. In addition, if over-application results in illegal residues on plant surfaces, regulators have the authority to confiscate and destroy an entire crop to protect consumers.

**Environmental Concerns.** Pesticide concentrations higher than label recommendations may cause serious environmental problems. Calibrating equipment to maintain application rates within label instructions will help to protect beneficial insects and wildlife. It also reduces the potential for contaminating surface water, ground water, and the air.

**Protecting Treated Plant Surfaces.** Certain pesticides are phytotoxic (injurious to plants) and damage treated desired plant surfaces when used at higher than label-prescribed rates. Manufacturers evaluate these potential problems while testing the products so they can determine safe concentrations. Using too much pesticide increases chances of building up excessive residues in the soil. This buildup sometimes seriously limits the types of future crops that people can grow in the treated area.

**Preventing Waste of Resources.** Using the improper amount of pesticide wastes time and adds unnecessary costs to the application. Pesticide materials are expensive, and the fuel, labor, and equipment wear and tear required to make extra applications are costly.

**Managing the Amount of Water Applied Per Acre.** For the greatest application efficiency, the amount of water used per acre of application must be the smallest amount that is legal and will still give adequate results. Specific pesticide product labels often prescribe a range for water per acre to use for aerial applications.

**Legal Aspects.** An applicator who applies pesticides improperly is subject to criminal and civil indictments, resulting in possible loss of his or her journeyman or apprentice pilot certificate, fines, imprisonment, and lawsuits. All applicators are legally liable for injuries or damage caused by improper pesticide application.

## EQUIPMENT CALIBRATION METHODS

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Liquid application equipment and granular application equipment require different calibration techniques that are discussed in the following sections.

### Calibrating Liquid Sprayers

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Calibration involves determining how much area each tank of spray covers when the aircraft travels at a known speed and the system operates at a known pressure. To do this, measure these four factors:

- tank capacity
- application airspeed
- flow rate
- effective spray swath width

Spray pressure is a component of the flow rate because as the pressure increases or decreases the flow rate increases or decreases as well. Spray pressure must never exceed the recommendations of the nozzle manufacturer. The spray pressure must also be the same as the pressure used for calibration and be consistent throughout the entire application operation.

Check liquid spraying equipment frequently when applying abrasive pesticides, such as wettable powders, because these materials wear out pumps and nozzles. Pump wear decreases the amount and pressure of fluid output, while nozzle wear increases the volume of output. This usually lowers the output pressure and may produce a poor spray pattern.

#### Tank Capacity

You need to know exactly how much liquid can be put into the tank in order to determine how much area the aircraft can spray with each load. This requires measuring the capacity of the spray tanks, usually *one time only*. If the tank is modified or if sprayer components inside the tank are removed or added, you will have to re-measure the capacity. Never rely on tank size ratings provided by the manufacturer because these may be

approximate volumes, they may not take into account fittings installed inside the tank, and they do not account for the attitude of the aircraft while it is on the ground. In addition, the capacity of the spray lines, pump, and filters influences the total tank volume.

Position the fixed or rotary wing aircraft on a level surface and make sure there is no liquid in the system. Drain the system if necessary, then close any open valves to prevent water leaks and start adding measured amounts of clean water with the pump running to circulate the liquid. Using a flow meter, bring the water level to the maximum operating fill point. This is the level to which the tank will always be filled whenever applying a full load. Once the actual capacity of the tank or tanks is known, paint or engrave this amount onto a prominent place for permanent reference.

While filling the tank, also calibrate the tank sight gauge, or make marks on the tank as measured volumes of water are added. Once the sight gauge or tank is calibrated, it is easy to see how much liquid is in the tank when it is not entirely full. Always return the aircraft to a level surface when reading the sight gauge or tank marks. The sight gauge readings while the aircraft is in flight will differ from readings taken when the aircraft is on the ground due to flight attitude.

### Application Airspeed

Measure airspeed under actual working conditions, with the aircraft spray tank fully loaded with water, and flying at the same altitude as an actual spray application. If the aircraft spraying system is equipped with a flow rate controller, the controller will calculate the proper flow rate and make adjustments if airspeed changes. For it to make these adjustments, you must enter the application rate and the size of the effective swath width into the unit.

### Flow Rate

If the aircraft is not equipped with a flow rate controller, measure the actual output of the system when nozzles are new, then periodically thereafter to accommodate for nozzle wear. Manufacturers provide charts showing the estimated output of given nozzle sizes at specified spray pressures. Manufacturer charts are most accurate when using new nozzles—used nozzles may have different output rates because of wear. Even new nozzles may have slight variations in actual output. Additionally, the pressure gauge in the aircraft system may not be accurate, which further adds error to the output estimate determined from manufacturer charts. The flow rate is expressed in

gallons per minute, which you can then convert to gallons per linear mile at the prescribed swath width.

**Rotary Wing Aircraft.** To find out the combined flow rate for all nozzles on a helicopter spray boom, collect liquid from each nozzle over a known time (such as 30 seconds) and add together these amounts (Figure 8.1). Use a calibrated container that measures liquid ounces. Once the total amount of output is determined, convert the ounce measurement into gallons and then determine the gallons per minute output.



FIGURE 8.1

Since spray pumps on rotary wing aircraft are not wind powered, it is possible to collect liquid from individual nozzles while the aircraft is not in flight. Adding the volumes collected from individual nozzles over a measured period will provide the information needed to calculate the spray flow rate.

**EXAMPLE:** A helicopter spray boom is equipped with 50 nozzles. Liquid has been collected from each nozzle for 30 seconds. When combined, the total amount of liquid collected is 1,293 ounces.

- Convert the 1,293 ounces per 30 seconds into gallons per minute using this formula:

$$\frac{\text{TOTAL OUNCES COLLECTED} \times 60 \text{ SECONDS/MINUTE}}{\text{SECONDS OF COLLECTION TIME}} = \text{total ounces/minute}$$

$$\frac{1,293 \text{ OUNCES COLLECTED} \times 60 \text{ SECONDS/MINUTE}}{30 \text{ SECONDS}} = 2586 \text{ OUNCES/MINUTE}$$

- Next, convert the total ounces per minute into gallons per minute:

$$\frac{2586 \text{ OUNCES/MINUTE}}{128 \text{ OUNCES/GALLON}} = 20.2 \text{ GALLONS/MINUTE}$$

In this example, the helicopter discharges 20.2 gallons of liquid per minute. This result can be converted to gallons per mile by dividing the airspeed in miles per hour by 60 minutes per hour and then dividing the result into the gallons per minute.

**EXAMPLE:** Assume the helicopter is traveling at 80 miles per hour.

$$\frac{80 \text{ MPH}}{60 \text{ MINUTES/HOUR}} = 1.33 \text{ MILES/MINUTE}$$

$$\frac{20.2 \text{ GALLONS PER MINUTE}}{1.33 \text{ MILES PER MINUTE}} = 15.19 \text{ GALLONS PER MILE}$$

**Fixed Wing Aircraft** Most fixed wing aircraft use air driven spray pumps, so the aircraft must be airborne or have the engine running at high speed while on the ground. Due to the air blast from the propeller, you cannot collect spray from the nozzles (Figure 8.2). Therefore, find the output of the sprayer over time by measuring how much water is used during several test flights. Each time you fill the tank you will make a run operating the sprayer for a timed period

Start by moving the aircraft to a level surface and fill the tank to a known amount with clean water. Fill the tank to a level that you can duplicate when refilling. A convenient technique is to fill the tank with clean water to the point just before it begins to overflow. Use a low-volume, low-pressure water source, such as from a garden hose, for topping off the tank. Check for leaks around tank seals, hoses, and hose fittings. All nozzles must be clean and operating properly or the results will be inaccurate.

Take off and fly to an area where you can release the spray water. Operate the sprayer at its normal operating speed and pressure. Open the valve to the spray boom, starting a stopwatch at the same time. Continue to run the sprayer for several minutes, and then close the valve. Record the elapsed time, return to the ground, and park the aircraft at the same spot where the tank was filled, and refill it. For more accuracy, repeat this process two more times to get an average of sprayer output.



FIGURE 8.2

Air driven spray pumps require the fixed wing aircraft engine to be running at high speed to test the flow rate. This makes it impractical to collect fluid from individual nozzles when measuring flow rate.

Attach a flow meter to a low-pressure filling hose and refill the tank to the original level. Record the gallons of water used; this volume is the amount of liquid sprayed during the timed run. Determine the gallons per minute output of the sprayer by using the calculations shown below. This result can then be converted to gallons per mile as shown here.

**EXAMPLE:** For this example, the aircraft's spray tank was filled with water to its top mark. After takeoff and leveling off, the pilot made four runs at 120 MPH and opened the spray valve for 30 seconds for each run. After landing, the aircraft was returned to the same location where the tank was originally filled. Using a flow meter attached to a water hose, the tank was refilled to the top mark. It took 15.2 gallons of water to refill the tank.

- Calculate the gallons per minute output of the sprayer

$$\text{TOTAL SPRAYING TIME} = 30 \text{ SECONDS} \times 4 \text{ RUNS} = 2 \text{ MINUTES}$$

$$\frac{15.2 \text{ GALLONS}}{2 \text{ MINUTES}} = 7.6 \text{ GALLONS PER MINUTE}$$

- Convert the gallons per minute into gallons per mile

$$\frac{120 \text{ MILES PER HOUR}}{60 \text{ MINUTES PER HOUR}} = 2 \text{ MILES PER MINUTE}$$

$$\frac{7.6 \text{ GALLONS PER MINUTE}}{2 \text{ MILES PER MINUTE}} = 3.8 \text{ GALLONS PER MILE}$$

### Effective Swath Width

A crucial step in the calibration of an aircraft liquid dispersal system involves determining the *effective swath width*. Although the actual swath width may be wider, the effective swath width includes overlaps made with each pass to achieve a more even application. The amount of overlap leading to the effective swath width produced by an aircraft is measured by pattern testing. Whenever the spray boom is altered in any way, or application height is changed, you must repeat this pattern test and recalculate the effective swath width. Application height affects the effective spray swath, so the application height used during pattern testing must be the same as the height flown during an actual application.

**Application Height.** Application height describes the distance between the nozzle tips and the target, be it the plant canopy or open ground at the target site. The effective swath width usually increases as the application height increases due to air movement. Spray drift management studies indicate that application height can affect the amount of offsite drift of the spray, depending on the spray droplet size. Therefore, in order to minimize offsite drift risk, small droplet sprays require lower application heights. The greater the application height, the more time it takes for spray droplets to reach the target and so they are subjected to evaporation and other forces that create offsite drift. With larger spray droplets, application height can increase. An application height of 8 to 10 feet is usually the maximum suitable for applying 150–200  $\mu$  spray droplets. For application heights greater than 8 to 10 feet, larger spray droplets are needed to reduce drift. Application height limits or a range of application heights for a particular product is usually given on the pesticide label. Flying too low can cause additional drift issues because of air turbulence hitting the ground (ground effect).



Arrange nozzles on the boom in such a way as to produce the desired deposition pattern with the material being applied from the application height selected. Keep application height constant during each swath run to obtain uniform coverage of the target site. Avoid adjusting application height to either change the swath width or spray pattern uniformity. Swath width and pattern uniformity are best corrected with nozzle adjustments.

**Pattern Testing a Spray Boom.** When evaluating the spray pattern and determining the effective swath of an aircraft, application height, speed, power setting, spray pressure, and nozzle location need to duplicate field conditions. The best time for spray pattern testing is early in the morning before the sun heats the ground and causes thermal turbulence. During testing, fly the aircraft directly into the wind. However, conduct pattern test flights only when ambient wind speed is less than 10 mph.

One method for spray pattern testing consists of a detector that reads the intensity of fluorescent dye deposited on a string or tape positioned across a flight line test site. Following a spraying pass made by the aircraft, special computer equipment scans the string or tape and measures the deposition of the dye-containing spray. The computer then produces a graph of the actual spray pattern. This graph is used to assess nozzle positioning along the boom, determine spray deposition uniformity, and measure the effective swath width.

If computerized pattern testing equipment is not available, a pilot can determine the spray pattern by another means. Figure 8.3 shows a suitable test layout for spray pattern evaluation. Determine the wind direction and place several flags about 100 feet apart along the centerline of the direction of travel. Paper clip squares of water sensitive paper to small blocks of wood and arrange these along an 80- to 100-foot line that runs perpendicular to the flight line. You can substitute plain white cards for the water sensitive paper if you add dye to the spray tank to visualize the droplets.

When flying a spray pattern test, make sure that the nozzle tips, filter screens, and check valves are clean. Put about 30 gallons of water into the spray tank. Before takeoff, operate the pump and briefly engage the boom to check for leaks.

After takeoff, purge the boom and make sure that water from the system reaches the end nozzles. Align the aircraft with the flags on a spray run that duplicates an actual field application. Operate the boom for at least 100 yards both before and after passing over the line of water sensitive paper or cards. To minimize control-surface-induced air disturbance, maintain straight and level flight during spray boom operation—this will help assure a representative pattern. After the pass, have a ground crew member collect and number the sprayed cards in the order they were laid out. Put new cards on the wood blocks and repeat the test to make sure the run was representative of typical spray deposition.

Visual evaluation of treated cards reveals common problems with spray uniformity and swath width. Especially look for

- a region of light spray density near the flight centerline
- uneven spray densities toward the wingtips

Effective swath width is less than the distance between the outermost cards where spray droplets are evident. Figure 8.4 simulates a graph of a spray pattern test result. The amount of spray per card is reasonably constant for some distance on each side of the centerline path and then gradually diminishes until no spray is evident. The typical pattern forms a trapezoidal shape. The effective swath is the distance between the midpoints on the sloping ends of the pattern. Each midpoint corresponds to a spray deposition that is approximately one-half the average amount of spray deposited in the more uniform portion of the spray pattern.

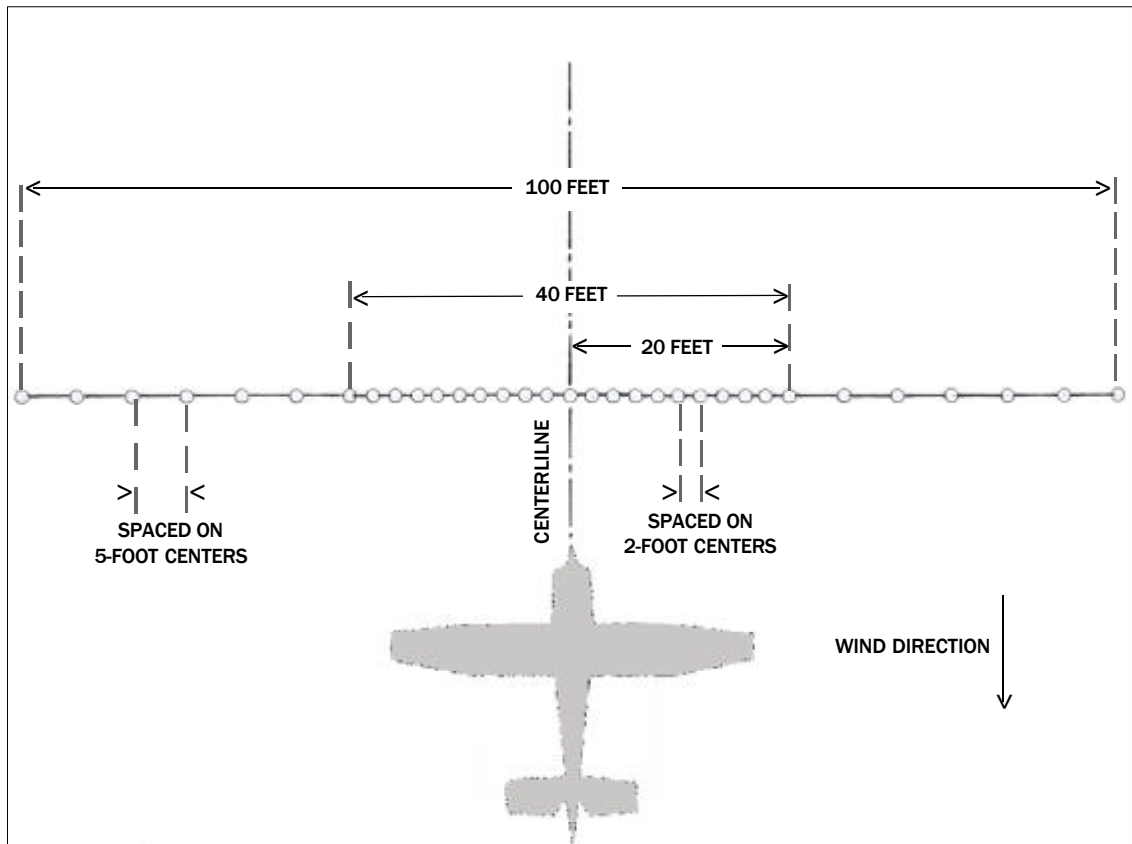


FIGURE 8.3

Example of a layout to test spray deposition.

Typical problems that spray pattern testing can help detect include:

- **Leaks.** Sometimes the pilot or the ground crew is unaware of system leaks. Water sensitive paper or dye helps to visualize leaks. For example, if very large drops are visible, the spray system should be thoroughly checked for leaking components.
- **Nozzle Problems.** The presence of a range of sizes of spray droplets on the sampling paper is normal. This is because all nozzle types actually generate a range of droplet sizes. However, large variations in the average spray droplet size along the spray swath would indicate different size nozzles on the spray boom, badly worn nozzle tips, or both.
- **Incorrect Droplet Spectrum.** The sampling paper will not accurately measure the spray droplet size spectrum produced by the nozzles. The sampling paper will instead show a relative comparison of droplet sizes being generated by a given set of nozzle tips. The result is a rough estimation of sizes of the spray droplets being produced. This can provide information about the suitability of the droplet size for the job to be done. Generally, coarse droplets are best suited for herbicide applications, small to medium droplets are best suited for insecticide sprays, and smaller droplets are best for fungicide applications. Analyzing the droplet size spectrum will also provide information about drift potential, since very small droplets are prone to drift.

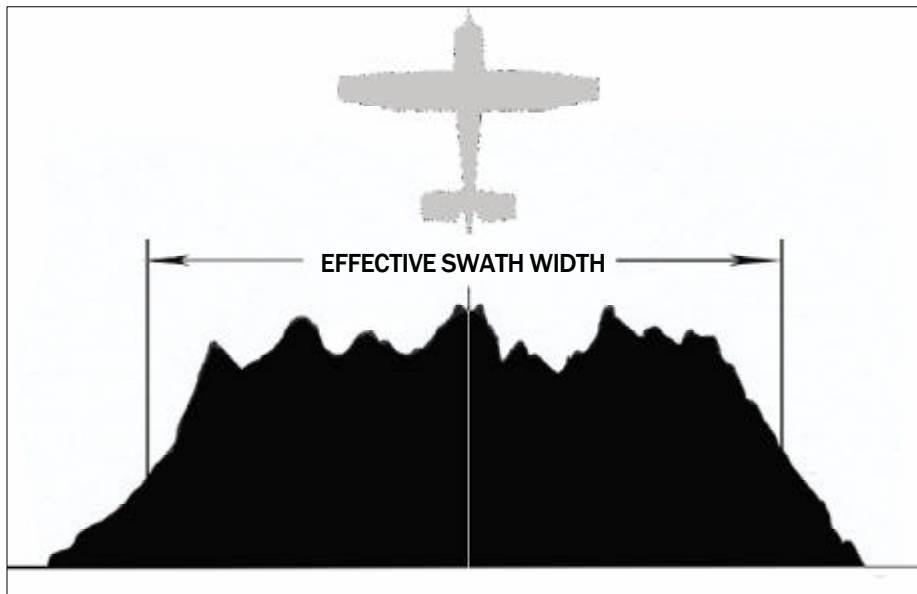


FIGURE 8.4

A graphical representation of a typical spray droplet deposition across a spray swath.

- **Prop Wash Displacement.** On fixed-wing aircraft, propeller rotation produces a slipstream that spirals about the fuselage. This spiral slipstream moves spray particles from right to left under the aircraft. The result is usually a reduced application rate under the right wing and a higher application rate under the left wing. Figure 8.5 (upper image) shows a typical spray pattern created by the prop wash effect. This problem is most evident on aircraft fitted with spray booms that have a symmetrical nozzle arrangement. The conventional correction for prop wash displacement is to add nozzles to the right side of the boom and remove nozzles from the left side of the boom. The number and location of the nozzles to be altered is determined by trial and error. Generally, the nozzles that need alteration are those positioned within 3 to 6 feet of the fuselage.
- **Prop Wash Overcompensation.** Spray pattern distortion due to prop wash has been emphasized so much that some operators actually overcompensate for propeller-induced effects. The resulting pattern is shown in Figure 8.5 (center image). Often, a pronounced spray peak developing on the left of the fuselage can be corrected by turning off one or more nozzles mounted within 3 to 6 feet of the right side of the fuselage.
- **Wingtip Vortex.** A wingtip vortex is generally characterized by a pattern with high peaks at its edges (Figure 8.5—lower image.) This pattern can occur on either fixed or rotary wing aircraft. Spray emitted from the outermost nozzle tips on the boom is captured by the wing tip (or rotor) vortex and propelled upward. Spray droplets so captured do not contribute to the effective swath width, but are a significant source of spray drift droplets. In almost every case, wingtip vortex induced spray pattern problems can be overcome by keeping the spray boom length at approximately 75% of the wingspan for fixed wing aircraft or 90% of the rotor span for rotary wing aircraft.
- **Rotor Distortion.** Rotary wing aircraft may display a spray pattern having a low application rate in the middle of the swath and heavier patterns at each end of the spray boom. Normally, this can be corrected by adding extra nozzles under the aircraft between the skids.

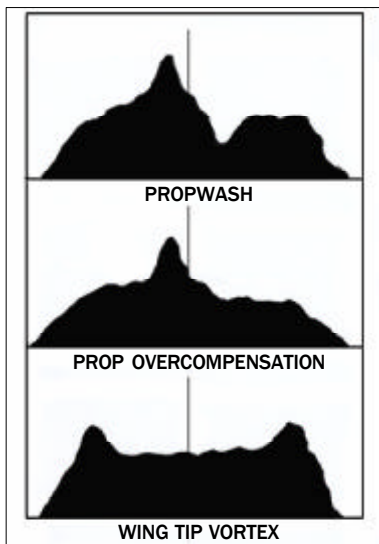


FIGURE 8.5

Typical patterns of spray droplet deposition showing a propwash problem (top), overcompensation for propwash (center), and effects of wingtip vortices (bottom).

### Determining the Acres per Minute Treated

To calculate the number of acres treated in one minute, use the airspeed and the effective swath width measurements in the calculations shown here.

**EXAMPLE:** Convert the airspeed from miles per hour to feet per minute using this formula:

$$\frac{\text{MPH} \times 5,280 \text{ FEET/MILE}}{60 \text{ MINUTES/HOUR}} = \text{FEET/MINUTE}$$

- Assume for this example that the aircraft travels at 100 miles per hour. Convert this speed to feet per minute:

$$100 \text{ MPH} \times 5,280 \text{ FEET/MILE} = 528,000 \text{ FEET/HOUR}$$

$$\frac{528,000 \text{ FEET/HOUR}}{60 \text{ MINUTES/HOUR}} = 8,800 \text{ FEET/MINUTE}$$

- Next, multiply the effective spray swath width by the feet per minute airspeed to determine the area, in square feet, covered in one minute. The effective swath width has been determined to be 50 feet and the travel speed is 8,800 feet per minute.

$$\text{FEET/MINUTE} \times \text{EFFECTIVE SWATH WIDTH} = \text{SQARE FEET/MINUTE}$$

$$8,800 \text{ FEET/MINUTE} \times 50 \text{ FEET} = 440,000 \text{ SQUARE FEET/MINUTE}$$

Convert this area into acres by dividing the square feet/minute by 43,560 square feet/acre:

$$\frac{440,000 \text{ SQUARE FEET/MINUTE}}{43,560 \text{ SQUARE FEET/ACRE}} = 10.1 \text{ ACRES/MINUTE}$$

Therefore, an aircraft traveling at 100 miles per hour and producing a 50 foot effective swath will have an application rate of 10.1 acres in one minute.

### Determining the Per Acre Application Rate

In the “Flow Rate” section on pages 130-132, the example calculations showed that a boom with 50 nozzles was discharging 20.2 gallons per minute. As shown below, dividing this figure by the calculated acres per minute being treated results in the amount of liquid being applied per acre.

**EXAMPLE:**

$$\frac{20.2 \text{ GALLONS/MINUTE}}{10.1 \text{ ACRES/MINUTE}} = 2 \text{ GALLONS/ACRE}$$

Therefore, the aircraft in this example will be spraying 2 gallons of liquid per acre when traveling at 100 miles per hour and spraying a 50 foot effective swath.

## Determining the Amount of Pesticide to Put into the Tank

The label, job order, or written pest control recommendation prescribes how much pesticide to apply per acre. Be sure to check that the job order or recommendation does not exceed the legal rate given on the label. It may be necessary to adjust nozzle output or modify the application pattern to achieve this desired rate. For example, more than one pass may be needed to apply the total number of gallons of spray or pounds of granules per acre as required by the label, job order, or recommendation application rate.

Use tank volume and the gallons per minute figure to calculate how much time it will take for the liquid in the tank to be sprayed out. Once this time is known, the total area covered with each tank of material can be calculated. The result will be the actual acres of treatment site that can be sprayed with one tank of pesticide mixture. Knowing this value and the recommended rate of application (units of pesticide per acre of treatment area) makes it possible to determine how much pesticide to put into the tank.

**EXAMPLE:** The aircraft is equipped with a spray tank with a measured capacity of 67.5 gallons. The aircraft spraying system will discharge 2 gallons per minute when flown at 100 miles per hour. Divide the tank capacity by the gallons per minute to determine how many minutes it will take to spray 67.5 gallons, the tank's capacity.

$$\frac{67.5 \text{ GALLONS/TANK}}{20.2 \text{ GALLONS/MINUTE}} = 3.34 \text{ MINUTES/TANK}$$

- Next, calculate the number of acres that can be sprayed with one tankful of liquid. To do this, multiply the minutes per tank figure by the acres per minute figure computed above.

$$3.34 \text{ MINUTES/TANK} \times 10.1 \text{ ACRES/MINUTE} = 33.7 \text{ ACRES/TANK}$$

- In this example, the aircraft can treat 33.7 acres with one tank of spray mixture. Assume the recommendation or job order prescribes 2 pints of pesticide per acre. Knowing that one tank can cover 33.7 acres, the total amount of pesticide to put into the tank can be calculated by multiplying the acres by the 2 pints.

$$\frac{2 \text{ PINTS/ACRE} \times 33.7 \text{ ACRES/TANK}}{8 \text{ PINTS/GALLON}} = 8.43 \text{ GALLONS/TANK}$$

These calculations show that 8.4 gallons of pesticide must be mixed with 59.1 gallons of water to fill the tank with 67.5 gallons of spray mixture.

To prevent waste of pesticide material, you must accurately know the size of the area to be treated. Then, mix only the amount of pesticide needed. Multiply the total acres in the application site by the application rate to find out how much pesticide will be required for the complete job. See Sidebars 28 through 31 for instructions on measuring sizes of various shaped treatment areas if the actual size of the treatment site is unknown.

## Changing Sprayer Output

Once calibrated, the output rate of the aircraft spraying system *for a specific speed, altitude, and pump pressure* is determined. However, there may be times during an operation when the output rate may need to change slightly. These include:

- accommodating variations in foliage density
- different plant spacing within the same field
- special requirements of the treatment area such as obstacles or sensitive areas
- compensating for nozzle or pump wear

The adjustments discussed below, either alone or in combination, can be made to effectively increase or decrease sprayer output, but only within a limited range.

**Changing Speed.** Application speed adjustments are not recommended for fixed wing aircraft. However, the simplest way for a rotary wing aircraft to adjust the volume of spray (and amount of pesticide) being applied is to change the speed of the aircraft. A slower speed results in more material applied, while a faster speed reduces the application rate. Changing the travel speed eliminates the need for altering the concentration of chemicals in the spray tank if there is a valid reason for increasing or decreasing the application rate. However, there are limits to the amount of speed change that can be made. Flying too fast is a common error and will increase the wind shear effect on spray droplet sizes, increasing atomization of the spray droplets. Flying too fast may reduce the application rate so much that it results in poor coverage and ineffective pest control. Flying too slow may possibly result in over application by exceeding the maximum label rate. At the very least it would increase the amount of pesticide applied, causing runoff and waste, increasing application time and cost.

**Changing Output Pressure.** As nozzles begin to wear, the spray volume will increase from the orifice getting larger. However, when a pump begins to wear, it becomes less efficient and it moves less volume of spray. As a result, the nozzle output drops off. Adjusting the pump speed to increase or decrease output pressure will change the spray volume slightly. Increasing pressure increases the output, while decreasing pressure lowers it. Although, in order to double the output volume, the pressure must be increased by a factor of four. This is usually beyond the capabilities of the spraying system. The working pressure range of the sprayer pump also limits this adjustment.

**Changing Nozzle Orifice Size.** The most effective way to change the output volume of the aircraft spraying system is to install different sized orifices on nozzles. Larger orifice sizes increase volume, while smaller ones reduce spray output. Changing orifice sizes usually alters the pressure of the system and requires an adjustment of the pressure regulator or pump speed. Be aware that changes in orifice size will also change the droplet size and spray pattern and will affect drift potential. A major factor in reducing drift is to produce larger spray droplets that are less prone to offsite drift. Considerations must include the effect of airspeed on droplet atomization as well as the effect of air shear across the nozzle face. Use tables included in nozzle manufacturer catalogs as a guide for estimating output of different nozzle and orifice size combinations. Whenever nozzle orifices are changed, remeasure the output rate.

## Calibrating Granule Applicators

---

The techniques for calibrating granule applicators are similar in many ways to those used for liquids. However, granules vary in size and shape from one pesticide to the next, influencing their flow rate from the applicator hopper and spreader. Temperature and humidity may also influence granule flow. Due to their lower drift potentials, pesticides for-



## Sidebar 28

## Calculating the Area of a Rectangular or Square Application Site

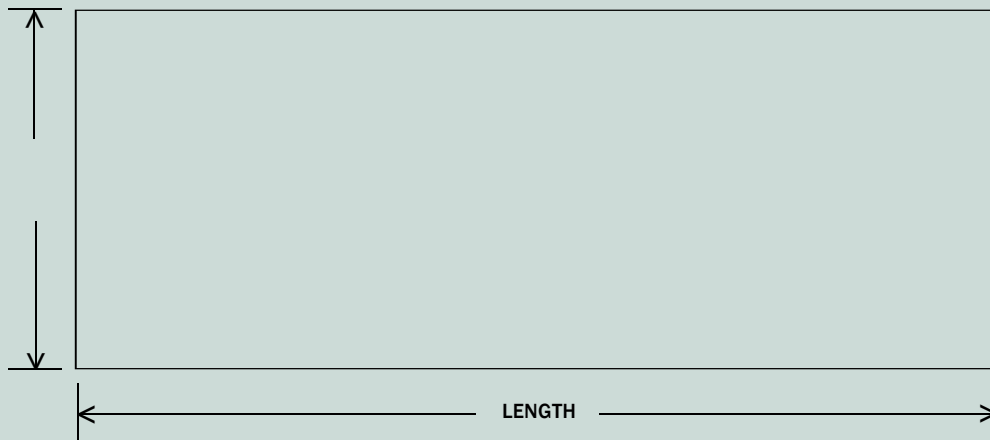
- To calculate the area of a rectangular (or square) site, you must know the
  - length of the longest side (in feet)
  - width of one adjacent side (in feet)
- Next, multiply the length by the width.

**EXAMPLE:** A rectangular field is 800 feet long and 250 feet wide. To find the area of the field (in square feet), multiply the length times the width

$$800 \text{ FEET} \times 250 \text{ FEET} = 200,000 \text{ SQUARE FEET}$$

- To convert the 200,000 square feet to acres, divide by the number of square feet in one acre (43,560)

$$\frac{200,000 \text{ SQUARE FEET}}{43,560 \text{ SQUARE FEET PER ACRE}} = 4.59 \text{ ACRES}$$





## Sidebar 29

## Calculating the Area of a Triangular Application Site

- To calculate the area of a triangular site, you must know two dimensions:
  - the length of the longest side of the triangle (its BASE)
  - the width of the triangle at its widest point (its HEIGHT)

Make sure that both measurements are in feet

- Next, multiply the BASE by the HEIGHT, and then divide by two

$$\text{AREA OF A TRIANGLE} = \frac{(\text{BASE} \times \text{HEIGHT})}{2}$$

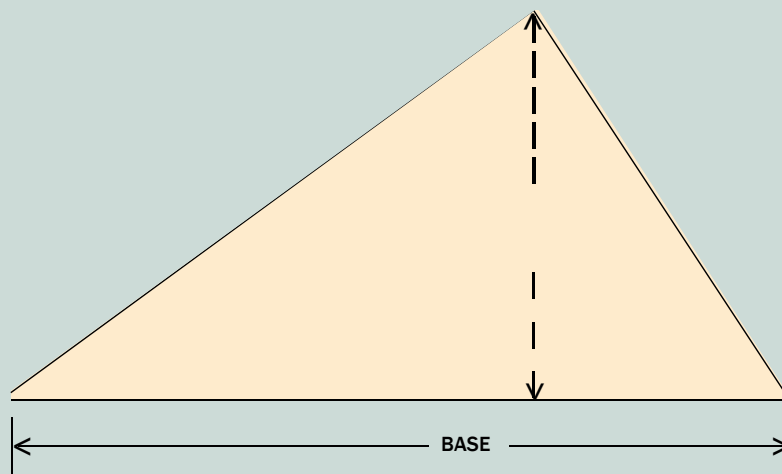
**EXAMPLE:** In the diagram shown here, a triangular field measures 650 feet along its longest side (the BASE) and 300 feet wide at its widest point (the HEIGHT).

- To calculate the area of the triangle, multiply 650 feet by 300 feet, then divide by 2.

$$\frac{650 \text{ FEET} \times 300 \text{ FEET}}{2} = 97,500 \text{ SQUARE FEET}$$

- To convert the 97,500 square feet to acres, divide the square footage of the triangular field by the number of square feet contained in one acre (43,560).

$$\frac{97,500 \text{ SQUARE FEET}}{43,560 \text{ SQUARE FEET PER ACRE}} = 2.24 \text{ ACRES}$$







## Sidebar 30

## Calculating the Area of a Circular Application Site

To calculate the area of a circular site, you must know two values

- the radius of the circle (see diagram below)
- the value of the constant ***pi***, which has the value of approximately 3.14

The radius is the length of the straight-line distance from the center of a circle to any given place on the circle's edge. The radius is equal to one-half of the diameter. A diameter is the length of the longest possible straight-line distance across a circle, passing through the center of the circle. ***Pi*** is a ratio of the circumference of a circle to its diameter. It is used to determine areas or volumes that involve circles, spheres, and other curved objects.

The area of any circle is determined by multiplying ***pi*** times the square of the radius of the circle, where the square of the radius means multiplying the length of the radius by itself. This formula is written as

$$\text{AREA} = \pi \times r^2$$

where ***r*** is the radius and ***pi*** = 3.14

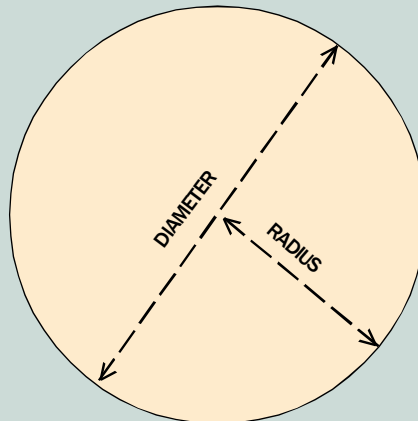
- ! Before making any calculations, make sure the length of the radius (or the diameter) is known in feet. If only the diameter is known, divide this by 2 to get the radius.

**EXAMPLE:** the diameter of the circular field is 400 feet. This means that the radius is 200 feet. To calculate the area, multiply ***pi*** (3.14) times the square of the radius (200 feet × 200 feet)

$$\text{AREA} = 3.14 \times (200 \text{ FEET} \times 200 \text{ FEET}) = 125,600 \text{ SQUARE FEET}$$

- To convert this area to acres, divide the 125,600 square feet by 43,560 square feet per acre

$$\frac{125,600 \text{ SQUARE FEET}}{43,560 \text{ SQUARE FEET PER ACRE}} = 2.88 \text{ ACRES}$$





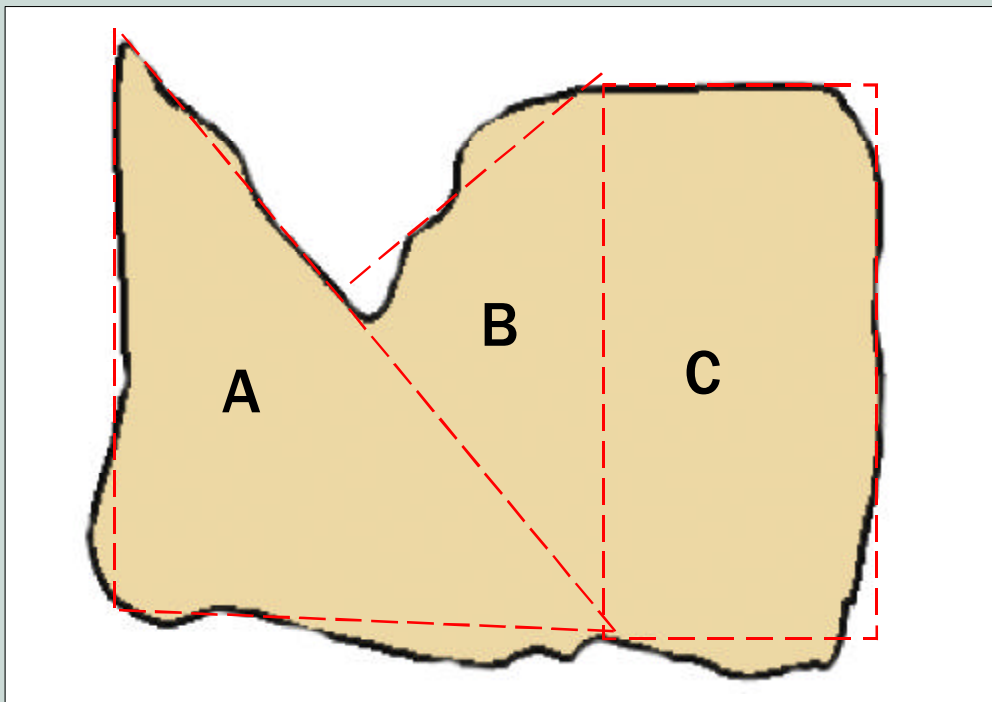
## Sidebar 31

## Calculating the Area of an Irregularly-Shaped Application Site

Many sites are not perfect circles, rectangles, or triangles. Often, agricultural sites have curved corners, have a bulge along one or more sides, or, have a notched area because an obstacle does not allow cultivation or spraying. It is difficult to make an accurate area calculation. Here are some guidelines on how to proceed.

- First, sketch a general map of the site. This is a key step, yet, in most cases, you do not need very many measurements to make a good general map. The main purpose of the map is to let you clearly identify the number and kinds of shapes that together make up the site.
- Next, identify the kinds and number of shapes such as triangles, circles, and rectangles that together form the irregular shape. Return to the field and place marker stakes to identify the boundaries of each identified shape or subsection. Record the location of each marker stake on a map.
- Take in-field measurements to determine the dimensions of each regularly shaped subsection. Record these measurements on the map.
- Calculate the area (in square feet) of each regularly-shaped subsection, following the procedures for calculating the areas of a rectangles, circles, and triangles.
- Finally, add together the square feet calculations from all the subsections. This will give you the total size, in square feet, of the irregularly shaped site. This square foot measurement can then be converted to acres.

**EXAMPLE:** In the example shown here, based on the general map of the site, three regularly shaped subsections (Triangle A, Triangle B, and Rectangle C) can be identified and measured.



mulated as granules can generally be delivered from greater application heights than those suitable for liquids. Higher application heights can also produce more uniform deposition patterns.

Before beginning to calibrate a granule applicator, be sure that it is clean and all parts are working properly. Three variables should be measured when calibrating a granule applicator:

- application airspeed
- output rate
- swath width

### Application Airspeed

Always measure airspeed under actual working conditions with the aircraft loaded and at the altitude that a granule application will be made.

### Output Rate

To determine the rate of output, follow the manufacturer's guidelines and set the ram-air spreader gate or centrifugal spreader gate to the desired rate per acre. Place a series of at least 13 collection pans at 5-foot intervals in a straight line on the ground perpendicular to the flight line. The footprint shape of the collection pans is unimportant, but the pans should be approximately 4 inches deep and have an area of at least 1 square foot. All of the collection pans must be exactly the same size. Pad the bottom of each pan with a thin layer of foam to help prevent granules from bouncing out.

Fly a swath test along a centerline oriented at a right angle to the line of collection pans. If ambient wind speed is greater than a sustained 8 mph, orient the line of pans at a right angle to the prevailing wind and fly directly into the wind.

After the swath test flight, collect the granules from each pan. Use a small graduated cylinder to collect and measure the granules in each individual pan, progressing from left to right. Record the quantity of granules from each pan on a graph in the exact order of collection. When plotted on paper, as in Figure 8.4, a graph of the volume distribution of granules across the swath is obtained. Finally, combine the granules from all the pans into another container, weigh, and record this weight. Calculate the total area of the 13 pans. For example, if each pan is exactly one square foot, the total area would be 13 square feet.

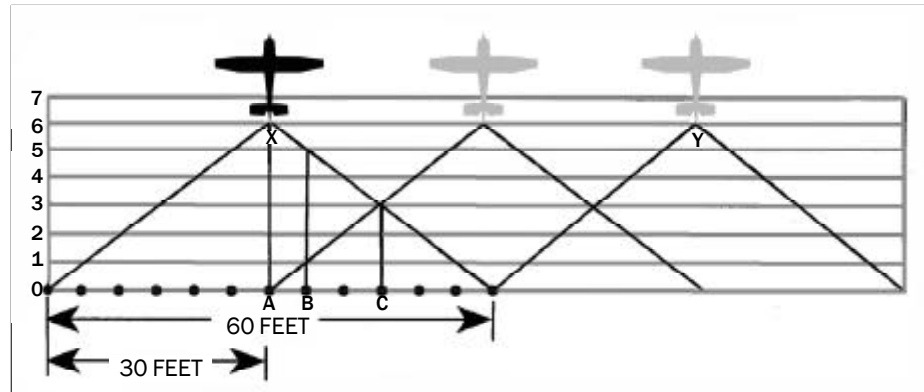
**EXAMPLE:** In this example, assume that the weight of the granules collected in all 13 pans is 2 ounces. Compute the pounds of granules being applied per acre as follows:

$$\frac{2 \text{ OUNCES} \times 43,560 \text{ SQUARE FEET/ACRE}}{13 \text{ SQUARE FEET} \times 16 \text{ OUNCES/POUND}} = 418.85 \text{ POUNDS/ACRE}$$

The distribution shown in Figure 8.6 is an idealized plotting of the amounts caught in 13 pans laid out 5-foot apart across the 60-foot swath. Another pass centered 30 feet to the right of the first pass would result in a 50% overlap of the swaths and produce an ideal, even distribution of granules. This would represent an *effective* swath width of 30 feet.

FIGURE 8.6

This is a graphical representation of the volume distribution of granules across a 60-foot swath, resulting in an effective swath width of 45 feet..



Examination of Figure 8.6 shows that at point A, six units (these could be pounds, ounces, or any other unit of weight) were collected in the pan. At point B, five units in the pan were applied by the first swath and one by the second swath for a total of six. At point C, each swath applied three units for six units in the pan.

The pattern shown in Figure 8.7 is a more typical trapezoidal pattern generated by granular spreaders. The effective swath width of a pattern having this shape is determined by adding the distances AD and BC together and dividing by 2, as shown in this example.

**EXAMPLE** (refer to Figure 8.7 on the next page): If distance AD (the distance between the two end pans containing zero granules) is 60 feet, and distance BC (the distance where granule catch per pan is relatively constant) is 30 feet, the effective swath width is:

$$\text{EFFECTIVE SWATH WIDTH} = \frac{60 \text{ FEET} + 30 \text{ FEET}}{2} = 45 \text{ FEET}$$

In this situation, application passes should be made 45 feet apart.

Once the effective swath width is known, the amount of granules, in pounds per acre, can be estimated. The example above is not an ideal method of calibrating a granule applicator because of the large difference in weight between the granules caught in the pans and those deposited onto the actual application swath. Unfortunately, it is often impossible to accurately calibrate dry materials unless the actual materials are being used. Spreading pesticide granules onto an area not designated for the application of a pesticide is dangerous and irresponsible. If possible, obtain “blank” granules (granules of the same size, shape, and weight as the pesticide product, but without the pesticide active ingredient) from the manufacturer to use for calibration. If this is not possible, the only alternative is to rely on the equipment manufacturer recommendations for setting and adjusting the ram-air spreader gate or centrifugal spreader gate to the desired rate per acre. This setting should result in accurate initial application rates. This rate can be fine-tuned to be even more precise by calculating the amount of pesticide that was applied to a known area and comparing that to the desired rate.

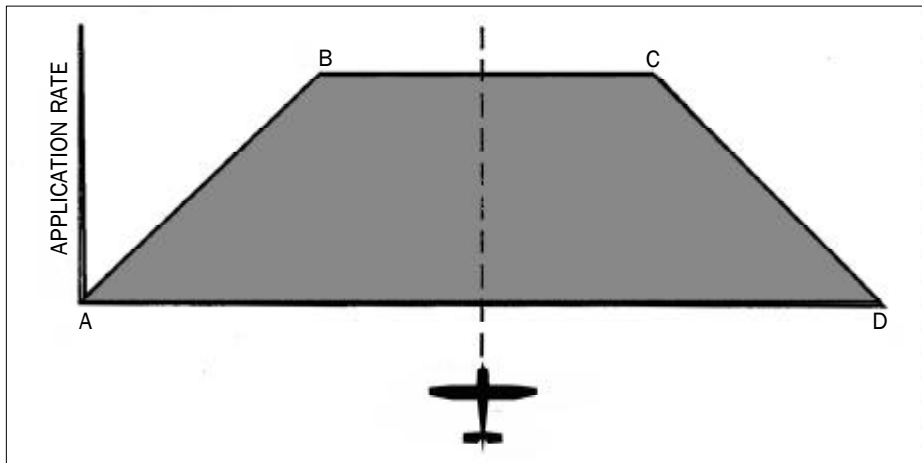


FIGURE 8.7

A typical trapezoidal pattern generated by granular spreaders.

## Chapter 8

## Review Questions

SEE PAGE 178 FOR ANSWERS

1. The most serious effect of over application as a result of poor calibration would be
  - a. poor control of the target pest
  - b. a reduction in the restricted entry interval
  - c. a phytotoxic effect on treated plants
  - d. a waste of time and resources
2. The purpose of calibration is to
  - a. determine the capacity of the spray tank(s)
  - b. prevent offsite pesticide drift
  - c. apply the correct amount of pesticide
  - d. protect the environment
3. Applying a pesticide at a rate that is higher than the pesticide label rate is
  - a. often necessary
  - b. careless
  - c. illegal
  - d. useful
4. Pest resistance may be caused by using
  - a. the labeled rate of pesticide
  - b. less than the labeled rate of the pesticide
  - c. more than the labeled rate of the pesticide
  - d. the wrong combination of pesticides
5. Which of the following formulations is most abrasive to spray nozzles?
  - a. soluble powders (SP)
  - b. wettable powders (WP)
  - c. emulsifiable concentrates (EC)
  - d. solutions (S)
6. Knowing the accurate volume of the spray tank is necessary to determine the
  - a. flow rate of the material being sprayed
  - b. pressure at the spray boom
  - c. swath width and swath overlap
  - d. area that can be treated in a single load

7. Increasing airspeed without changing the spray output will result in
  - a. more pesticide active ingredient applied per acre
  - b. less pesticide active ingredient applied per acre
  - c. an increase in the pesticide flow rate
  - d. a decrease in the pesticide flow rate
8. If 1700 ounces of material is collected from nozzles on a helicopter spray boom in 90 seconds, what is the total flow rate in gallons per minute?
  - a. 4.42
  - b. 8.85
  - c. 13.28
  - d. 17.70
9. An aircraft spraying system has an output rate of 8 gallons per minute. How many gallons are sprayed per mile when the aircraft travels at 130 miles per hour?
  - a. 3.7
  - b. 4.5
  - c. 5.8
  - d. 6.5
10. An **effective swath width** is the
  - a. total swath made by two passes
  - b. total swath made by a single pass
  - c. width of a single pass that includes portions of overlaps from other passes
  - d. distance between the outermost or widest points of application across the entire swath
11. Propwash displacement would be characterized by a spray pattern that is heavier
  - a. at both outside edges of the swath
  - b. directly in the middle of the swath
  - c. on the right half of the swath
  - d. on the left half of the swath
12. How many acres per minute will be treated by an aircraft traveling at 135 miles per hour and producing a 47-foot effective swath?
  - a. 10.1
  - b. 12.8
  - c. 15.2
  - d. 20.2

13. If an aircraft treats 10.1 acres per minute and has an output of 19 gallons per minute, what is the rate of application per acre (in gallons)?
- 1.53
  - 1.75
  - 1.88
  - 1.97
14. An aircraft sprays 20.2 gallons per minute. How many minutes of spraying time are needed to spray out 147 gallons of spray mixture?
- 6.8
  - 7.3
  - 8.5
  - 9.0
15. At 11.3 gallons per acre, how many acres can be sprayed with 147 gallons of spray mixture?
- 11
  - 12
  - 13
  - 14
16. If an aircraft treats 14 acres per tank of spray mixture, how many pints of pesticide liquid should be put into the spray tank to apply at a rate of 1.5 pints per acre?
- 11
  - 15
  - 21
  - 24
17. To increase the per acre application rate, the best method would be to
- use smaller sized nozzles
  - use larger sized nozzles
  - decrease the pump pressure
  - increase the pump pressure
18. How many acres are in a rectangular field that measures 620 feet by 1280 feet?
- 16.1
  - 18.2
  - 22.8
  - 28.8



19. How many acres are in a triangular field that measures 7,800 feet at its base and has a height of 1,564 feet?
- a. 96
  - b. 128
  - c. 140
  - d. 180
20. A circular field with a radius of 296 feet contains how many acres?
- a. 3.9
  - b. 6.3
  - c. 10.2
  - d. 14.0



# 9 Aerial Application Technology

The reasons for understanding aerial pesticide application technology is to use methods and develop skills that allow for consistently precise, safe, and legal aerial applications. Application technology includes

- minimizing offsite pesticide drift and other offsite movement
- understanding the factors and conditions that lead to and that can be used to minimize offsite pesticide drift
- ferrying the aircraft between home base, the loading site, and the application site
- inspecting the application site and surrounding areas for hazards before beginning the application
- watching for hazards throughout the application operation
- flying an effective application pattern and making safe and efficient turns and passes
- understanding factors that influence the stability and maneuverability of the aircraft
- understanding and using DGPS or other guidance systems

Because of public perception and because agricultural aircraft are highly visible and noisy, some people view aerial applications as nuisances or hazards. Even the sight of the aircraft may seriously frighten a few people. Pilots making aerial applications must acknowledge that some members of the public have concerns. Notifying people in the area about a planned application and making efforts to mitigate noise in areas where people live and work during ferrying or application operations will foster better relationships with the public.

**Checklists.** Preflight, departure, and application checklists are useful tools for pilots, ground crew members, and others involved in an aerial application operation. These checklists assist anyone involved in the operation to organize and manage their responsibilities

and they help to assure that the operation is safe and effective (See Sidebars 32 and 33 for examples of items that might be included in pilot and ground crew checklists)

**First and Last Runs of the Day** For the pilot and ground crew, the first and last runs of the day often call for extra attention. The first flight of the day requires that the pilot and ground crew be alert and mentally adjusted to and prepared for the complexities of the operation—there is no time to bring the operation up to maximum performance gradually. Likewise, the last flight of the day must not be rushed or compromised in any way in order to finish quickly—it requires the same attention and care as every other flight during that day.

## FERRYING



FIGURE 9.1

While ferrying, fly at an altitude of at least 500 feet above the surface and avoid flying over sensitive areas and keeping at least 500 feet away from people, personal property, and sensitive areas.

When traveling with an empty or full aircraft between the loading area and the application site, fly at an altitude of at least 500 feet above the surface and keep at least 500 feet away from people or personal property (Figure 9.1). Make every effort to avoid flying over buildings, residential areas, parks or playgrounds, penned animals, and other areas where people or livestock may be present. If the operation requires many trips back into an area, avoid taking the same route each time. Instead, vary the flight route by one-eighth to one-fourth mile during each trip to avoid repeated passes over the same surroundings.

## CHECKING THE APPLICATION SITE

Upon arrival at an application site, fly an initial inspection pass to verify that

- local weather conditions are suitable for the prescribed aerial application work
- agricultural workers, spectators, trespassers, and others, including their vehicles and equipment, are not within or immediately adjacent to the application area
- all members of the ground crew assigned to this operation are present and ready to begin their duties
- the communication link between pilot and ground crew is functioning correctly
- the DGPS system, if equipped, is properly functioning

Circle the field at a very low altitude, but high enough to clear all obstructions by at least 50 feet. Look for utility poles, guy wires, high tension power lines and other types of utility lines, and other obstructions such as trees, buildings, windmills, radio antennas, road signs, pipeline markers, and fences that are in or near the treatment area. Carefully check around trees that may conceal power lines or other obstacles. Look for breaks in the normal cultivation or planting pattern that may indicate the presence of power lines or other hazards (Figure 9.2). Poles, high fences, or other obstructions may prevent cultivation of weeds or other vegetative growth in these areas, so look for vegetative clues indicating the presence of obstructions that may otherwise blend into the background.



### Sidebar 32

## Pilot Checklist

Here are some things to consider before, during, and after any application:

- if operating the aircraft, never mix, load, or otherwise handle category one or two organophosphate or carbamate pesticides unless using a closed system for mixing and loading
- wear an approved safety helmet, long-sleeved shirt, long pants, shoes, socks, and, when out of the cockpit, the other required personal protective equipment specified on the pesticide label or in regulation
- check the field and surrounding area before applying pesticides to be sure there are no animals, humans, crops, waterways, streams, or ponds that might be injured or contaminated either by direct application or drift
- whenever possible, avoid flying through the suspended spray of a previous pass
- stop the application if winds rise or other adverse weather conditions develop and create a drift hazard; also stop the application if the wind is too calm, usually less than 2 mph
- never turn on dispersal equipment or check the flow rate except while over the area to be treated
- refuse to fly if the customer requires having pesticide applied in a manner and at a time that may create a hazard to crops, humans, animals, and the surrounding environment
- read the label and know the hazardous characteristics of the pesticides
- using a smoke generator or other device, identify how far and in what direction the chemical will drift
- never spray over a flagger, other handlers, or anyone else working in the area

After circling the field and noting obvious hazards, fly just above and to one side along power lines and telephone wires and check each pole. Look for branch wires, guy wires, and transformers. Transformers usually have branch wires leading to a house, shop, well, or other structure. A guy wire will normally be placed on the opposite side of a pole from a branch wire or at the pole where a main line makes a turn. If any structures are near the treatment area, look for wires that provide electrical power and telephone service to them.

Consider the possibility that conditions may have changed since previous inspections or aerial applications were made to this particular field. New buildings or wells may have



**FIGURE 9.2**

Before beginning an application, look for breaks in the normal cultivation pattern that may indicate the presence of hidden hazards.



## Sidebar 33

## Ground Crew Checklist

Members of the ground crew should take several precautions before, during, and after any application, including:

- using extreme care when handling pesticides or cleaning the aircraft or other equipment
- wearing label- or regulation-required work clothing and personal protective equipment
- tightly securing tanks and hoppers so the pesticides will not blow back over the pilot or the cockpit
- closing and securing the hopper and covering it as soon as loading is completed
- removing any pesticide spilled near the fill opening
- not standing in runoff water and avoiding splashes
- changing out of work clothing and washing thoroughly at the end of the work day after handling pesticides, washing the aircraft, or cleaning contaminated equipment.

The ground crew should also be familiar with the pilot's checklist.

necessitated new power poles, or the utility company may have relocated some power lines. Sometimes the height of the planted crop or trees may have changed since a previous application. For example, it may have been possible to fly under certain wires in the spring when a crop was first planted, but not possible later in the year when the crop is taller. In addition, heat causes wires to expand and therefore hang lower to the ground during hot summer days.

## WHAT TO WATCH FOR DURING AN APPLICATION

Conditions at an application site or surrounding areas may change during the course of an application. For this reason, be constantly alert and keep in contact with someone on the ground at the site. See Sidebar 34 for suggested responsibilities of the ground crew at an application site. Changes that may affect the safety or effectiveness of the operation include:

- **Weather.** Wind speed may increase or decrease or the wind direction may change, creating hazards of drift or contamination of sensitive areas. On the other hand, wind may stop altogether, increasing the chances of an inversion condition (see pages 169-170). The weather may worsen and turn to rain, requiring postponement or cancellation of the application. Some pesticides are restricted to applications at times when temperatures remain below a certain level—if the temperature at ground level rises above this point, plant damage (phytotoxicity) may occur.



### Sidebar 34

## Importance of a Ground Crew During an Application

Each on-site ground crew member needs to be able to communicate directly with the pilot, providing site-specific details of current weather conditions, topographical features, location and dimensions of ground-based hazards, buffer zone locations, and other information about hazards or sensitive areas.

Duties of on-site ground crew members typically include:

- acting as a liaison between the pilot and the property manager to ensure aerial applicator obligations are met
- preventing unauthorized individuals from entering the site, both immediately prior to and during the application operation
- immediately reporting the presence of unauthorized individuals in the treatment site to the pilot and the on-site field crew supervisor or leader
- assisting the pilot in pretreatment target area inspection
- acting as in-field reference points for the pilot to identify swath boundaries
- providing emergency response to crash incidents

- **Hazards.** Previously unidentified hazards may become apparent to either the pilot or ground crew, requiring that the pilot stop or modify the application at that site. This might include the discovery of livestock or wildlife in the area or a work crew arriving to work in an adjacent field or nearby. There may also be communication from the property manager or others with concerns about hazards.
- **Field workers.** Field workers may inadvertently walk or drive into an area being treated, requiring the operation to stop until they are safely out of the area. In addition, people working in adjacent fields may pass through or walk into the field under treatment if they are unaware of the application operation. This emphasizes the importance and usefulness of ground crew members in spotting people in the area and helping them to leave quickly.
- **Service People and Others.** Various people occasionally have reasons to enter fields or pass through them as part of their job responsibilities. This includes meter readers, people called to make repairs on equipment, irrigation district personnel, mosquito control district personnel, and others. In addition, some people enjoy walking or running through rural property, often without the permission of the landowner, and may be unaware of the hazards. The ground crew can assist in spotting and warning anyone attempting to enter the application site and remove them from the area for their own safety.

## APPLICATION METHODS

Practice safe flying procedures during all phases of the application operation. Never take risks at the expense of good judgment or safety. To ensure that the pesticide applica-

tion will be effective, follow label use directions and requirements in the label and regulations. Avoid offsite pesticide drift or other offsite movement of the pesticide material. Ways to avoid offsite pesticide drift is discussed later in this chapter. Visually check the spray or granule discharge to spot application problems.

Straight, parallel passes produce the most uniform spray pattern. Use a reliable method, as discussed in Chapter 6, to mark each swath to ensure uniform coverage and to avoid excessive overlap or gaps. Whenever possible, make passes perpendicular or at a 45 degree angle to the wind direction to assist in overlap and coverage uniformity. Begin treatments on the downwind side of the treatment site to minimize flying through spray suspended in the air from previous swaths. Also, try to make application passes parallel to the longest dimension of the treated area to reduce the number of turnarounds.

**Application Speed.** Maintain constant airspeed, consistent with the calibration of the aircraft, during each pass of an application. Variations in speed during an application may result in uneven coverage. Flying crosswind or 45 degrees to the crosswind during an application avoids the adverse effects of head- and tailwinds on the application rate.

**Altitude.** Notwithstanding legal requirements in the label, in law, or in regulation, the type of pesticide being applied usually determines application altitude. For example, liquid pesticides are most effective and offsite drift is less of a problem when applications are made 8 to 12 feet above the crop. Flying too low over bare ground or over short crops may produce a **ground effect** that forces air displaced by the aircraft to move upward from the ground. This upward moving air entraps and lifts some of the spray and can contribute to offsite pesticide drift. Trees and other plants with dense foliage may lower the risk of a ground effect (Figure 9.3).

The application height must be kept constant during each application pass to maintain the effective swath width that was determined during the calibration. Failure to do so will result in difficulty in obtaining uniform coverage.

**Obstructions.** If obstructions are located at the beginning or end of the swath run, turn the spray on or shut it off one or two swath-widths from the beginning or end of the field. Then, when all parallel swaths are completed, fly one or two swaths crosswise to the rest of the application direction to finish out the field. Never disperse materials while dropping in or pulling out of a field because this distorts the deposition pattern. Should this happen, the pesticide will be more likely to drift or concentrate in a small area. If there are obstructions along the sides of a field, fly parallel and as close to the obstruction as is safe. For safety, leave an untreated buffer strip adjacent to buildings, residences, livestock areas, bodies of water, and other sensitive areas.

Approach a tree, pole, or other obstructions in the middle of a field in the same manner as if they were at the end of the field—stop spraying one or two swath widths before reaching the obstruction. Pull up and fly over the obstruction. Then, make a 180-degree turn before dropping in to spray, approaching the obstacle from the other direction. This will allow better control of the aircraft speed and will avoid overshooting the other side. Complete the application by spraying one or two swath widths on each side of the obstacle, perpendicular to the previous swaths.

When a high enough wire crosses a swath that has trees at one end, it is safer to fly under the wire, if possible, and then pull up and fly over the trees than it is to enter the field over trees and then pass under the wire. Never fly beneath wires that have fences or other objects under them.

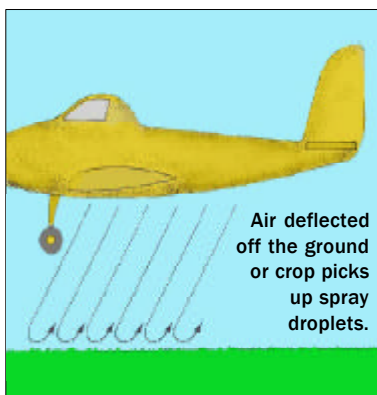


FIGURE 9.3

The ground effect caused by flying too low may force air upwards, entrapping some of the spray and contributing to offsite drift.



## FLIGHT PATTERNS

One flight pattern for aerial application is to fly bidirectional, or back and forth, swaths over the target in straight, parallel lines (Figure 9.4). In areas that are too rugged for uniform altitude and speed, application passes should follow the contours of the slopes. In hilly terrain, or where hills or mountains confine the application area and do not permit contour flying, make all passes in one direction, down slope. Upslope spraying can be dangerous.

The racetrack flight pattern shown in Figure 9.4 is usually the most energy-efficient application pattern. This pattern maximizes application time and lessens the time required for turns. It also allows time for the spray to settle, reducing the chance of flying through it.

### The Turnaround

When flying back and forth or racetrack swaths in a fixed wing aircraft, you must execute a careful turnaround because a pull up followed by a turn renders a low-speed, high-drag condition that could lead to a stall. Poorly executed turnarounds cause a considerable number of aerial application accidents. In addition, poorly executed turnarounds do not allow time for proper positioning for the next swath and may result in uneven applications.

When completing a swath run, pull up, clear any obstructions, and level off before starting a turnaround. After pull up, make a wide initial turn downwind that will provide

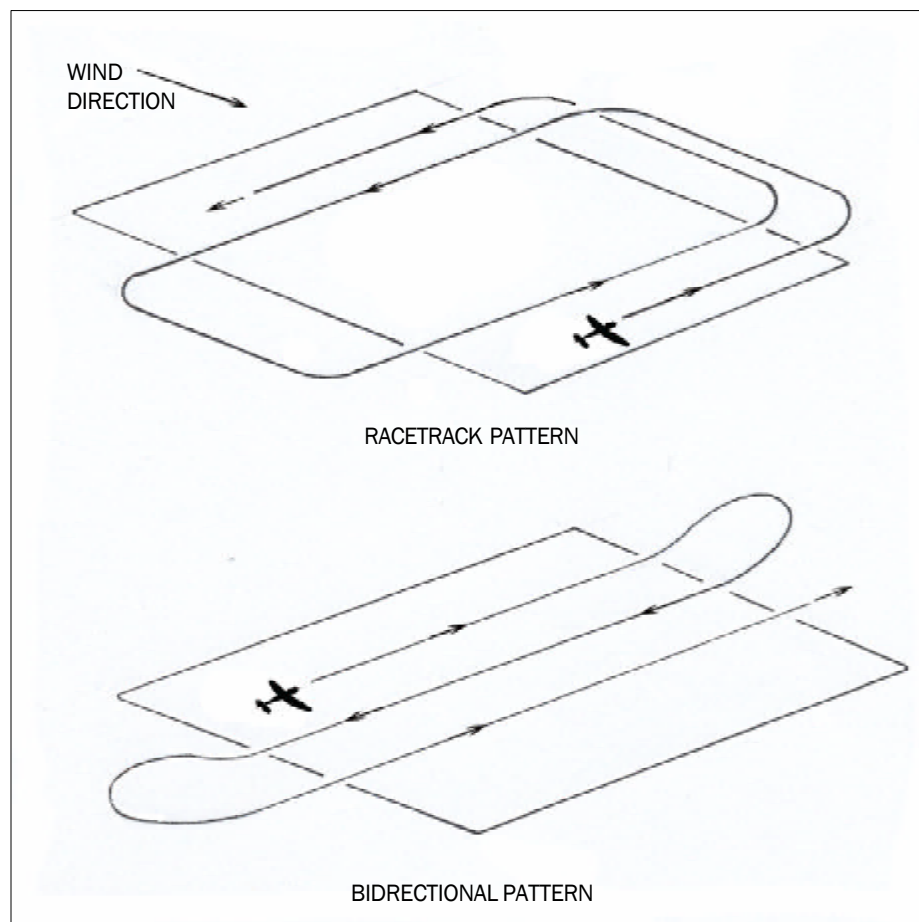


FIGURE 9.4

Racetrack and bidirectional application patterns

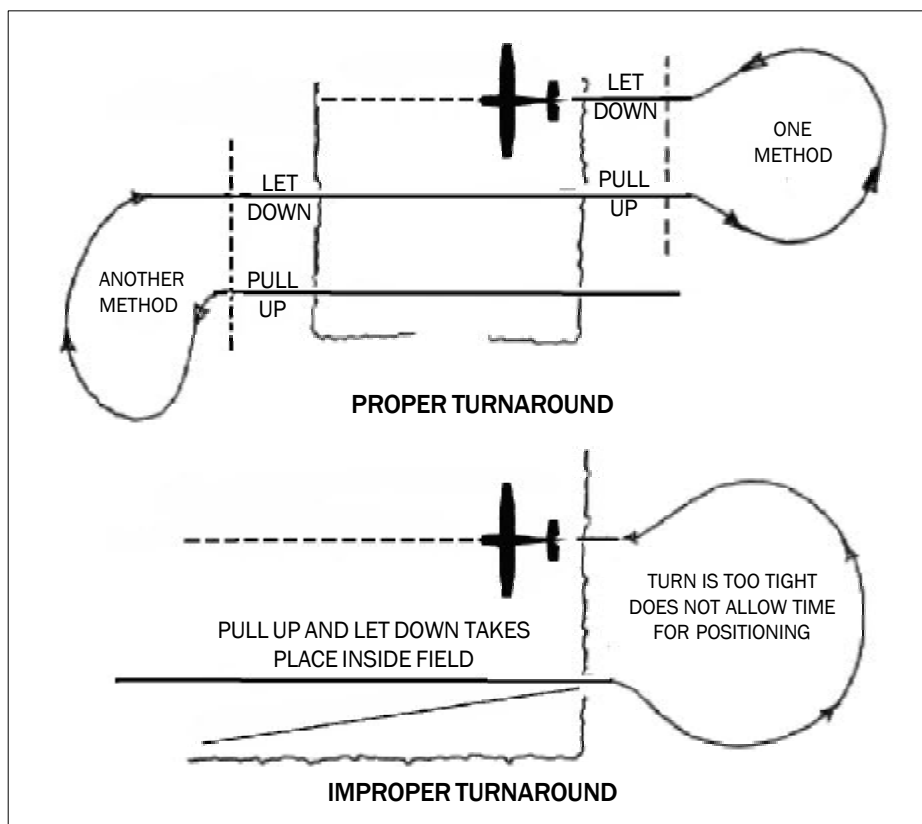


FIGURE 9.5

Proper method for making a turnaround (top) and improper turnaround (bottom). The bottom method does not allow time for proper positioning before the next swath.

enough room for a smooth turn around. Then level off for several seconds before completing the turn back into the treatment area (Figure 9.5). This provides ample time for the turn, prevents crowding the turn, and reduces the chance of a stall spin. Many factors affect the number of seconds needed in level flight before completing the turn, including swath spacing, speed and direction of the wind, air density, altitude, and the load weight, power, and maneuverability of the aircraft. Attentiveness to these factors and careful timing during this final stage of the turnaround are the keys to avoiding the hazards associated with fast or intricate maneuvering. Always complete the turnaround before dropping in over any obstructions on the next swath run approach.

Avoid snapping reversal or wingover turns. When making a turn by going upwind first, more space and time is required to complete the turn. Any turning while dispensing a spray or granules will distort the distribution pattern resulting in uneven distribution of the pesticide. Whenever possible, avoid making turnarounds over residences and other buildings, penned poultry or livestock, livestock watering places, ponds, reservoirs, or other bodies of water. This will mitigate or minimize nuisance from noise or sight of the aircraft, and possible contamination from leaking equipment that may go undetected until afterwards.

## Applying Granules

**Airspeed.** Airspeeds of 100 to 120 mph or faster (depending on the type of aircraft) for some fixed wing aircraft, but slower for rotary wing aircraft, are recommended when applying granules. These speeds maintain good airflow through the spreader and obtain proper distribution and maximum swath width.

**Application Height.** The maximum swath width at a certain height above the crop varies with the density, size, and grading of the granule particles. For most materials, this is in the range of 30 to 50 feet. Effective height is determined by the lateral distance the spreader throws the heavier particles. Flying below this height allows particles to hit the ground while still traveling in the lateral direction. Flying above this height achieves no increase in swath width because particles fall vertically after the lateral energy is dissipated (Figure 9.6). Do not fly any higher than necessary because this increases problems with swath displacement.

Maintain the flying height, airspeed, and correct ground track as constant as possible to obtain uniform results. Crosswinds have considerable effect on offsetting the dispersal pattern from the ground track centerline because of the higher-flying height required for granules. Head- or tailwinds affect ground speed; therefore, making adjustments in flow rate and/or airspeed can improve uniform distribution on alternating upwind-downwind passes. An onboard DGPS unit linked to a flow controller simplifies this process by providing automatic in-flight regulation of the dispersal system output as airspeed changes.

## Pesticide Dust Applications

The use of aircraft to apply pesticide dust formulations is declining because of two major problems inherent to dusts—offsite movement and flammability. Relative to liquid pesticide sprays or granular pesticides, it is difficult or impossible to control movement of the material after it leaves the dispersal system. For pesticide dusts, managing offsite movement cannot be achieved through engineering controls such as large droplet nozzles or system pressure regulation. Dusts are easily blown about by air movement, generating great anxiety over offsite movement and its potential to injure people in the area. There are also concerns about the impact to the environment and to air quality from offsite movement of pesticide dusts. In addition, when combined with air, dusts pose a flammability hazard. Suspended pesticide dusts, if ignited by a flame, spark, or other source of extreme heat, can affect the pilot, other handlers, and application equipment, especially the aircraft. These factors have led pesticide registrants to discontinue producing many dust formulations or to reformulate dusts as liquids, granulars, wettable powders, or other formulations.

In California, however, aircraft are still used to apply sulfur dust to various agricultural crops as an effective fungicide and miticide. It has a relatively low mammalian toxicity, is cost effective, and approved for organically grown crops. The aerial application of sulfur dust requires special care to prevent offsite movement and explosions or fires.

**Offsite Movement.** DPR and the California Sulfur Task Force collaborated to improve label directions and to develop written *best application practices* to address concerns sparked over the offsite movement of sulfur dust. Sulfur dust labels contain use directions that, if followed, help to prevent and mitigate offsite movement. In addition, labels direct users to review and understand the information in the pamphlet titled *Sulfur—Best Management Practices*. Because it is referenced on dusting sulfur labels, this document becomes part of the label and must be at the use site along with the sulfur label. The mitigation measures that apply to aerial applications requires operators or employers to

- adequately train handlers to recognize sensitive offsite areas or situations near the application site and to know how to prevent creating hazardous situations; handlers should understand the precautions to follow to prevent offsite movement
- establishing buffer zones between the application site and nontarget sites
- time applications to periods of minimal human activities in areas near the application site

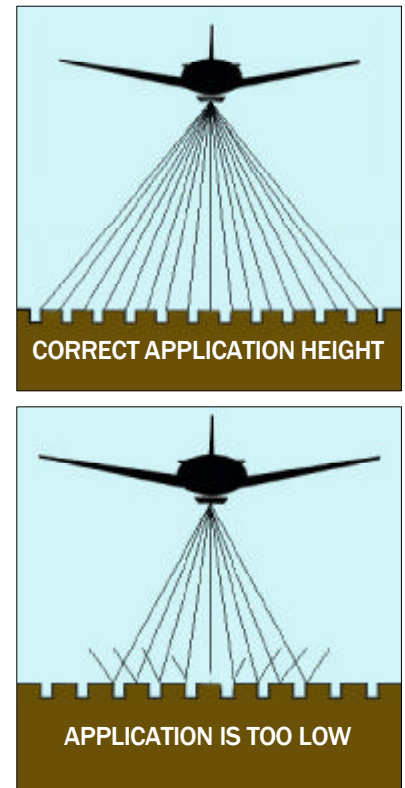


FIGURE 9.6

The top drawing shows the effect of granules being applied from the proper height. In this case, the granules fall vertically after their lateral energy is dissipated. The bottom drawing shows the problem when making an application too low. Granules are still moving horizontally, thus the application is uneven and the swath width is too narrow.

- make applications only during ideal weather conditions and optimum periods during the day to mitigate offsite movement
- maintain equipment so that it operates efficiently and safely
- use application equipment that has been specifically engineered to minimize or prevent the potential for sulfur dust to move offsite
- release the sulfur dust only when in or over the application site and avoid applications to any buffer zones

**Flammability.** Sulfur dust is flammable and, when mixed with air, may *flash* (suddenly burst into flame) and burn if exposed to an ignition source. The melting and burning temperature of sulfur dust is 246°F and sulfur dust will ignite at approximately 374°F.

**Ignition Sources.** Three sources of ignition can set off a sulfur dust fire or explosion. These include electrical sparks, heat, and certain chemical reactions. Electrical sparks from motors, poor wiring connections or short circuits, or static electricity discharges are all capable of setting off a sulfur dust flash or fire. Heat from flames or carbon particles in the aircraft's exhaust, vehicle or aircraft engines, aircraft brakes, and friction from moving parts can also start a sulfur dust fire. In addition, oxidizer chemicals, such as sodium chlorate, can react with sulfur dust and cause a spontaneous combustion.

**Sulfur Dioxide Gas.** Besides the hazards posed by explosions and fire, burning sulfur produces sulfur dioxide, which is an extremely toxic gas. This gas is very damaging to eyes as well as nasal and respiratory passages, and sufficient exposure could cause death. A full-face respirator rated for sulfur dioxide is required to prevent injury in a burning sulfur atmosphere.

### Reducing Sulfur Dust Application Hazards

You can reduce fire and explosion hazards when applying sulfur dust by following these steps recommended by the California Agricultural Aircraft Association:

- avoid high temperature and low humidity conditions during applications
  - ambient temperatures above 75 to 85°F significantly increase the potential for sulfur dust to flash
  - early mornings usually have the highest humidity, making it the safest time to apply sulfur dusts by air
- never make sulfur dust applications during temperature inversion conditions—air movement should be at least 2 mph up to 10 mph for good circulation
- avoid applications during times when the atmosphere is static-charged (usually after the passage of a dry cold front with extremely low humidity)
- avoid abrupt aircraft engine power changes that could produce hot carbon particles in the aircraft's exhaust
- avoid flying through clouds of sulfur dust—skip passes or fly a racetrack pattern to avoid flying through part of the previous pass
- avoid putting the aircraft through positive or negative gravitational pull to get caked dust flowing from the hopper
- close the hopper gate well before each pull-up to avoid dumping a large quantity of sulfur dust into the spreader

- never attempt to dump a sulfur dust load in an emergency—this will increase the chances of a fire or explosion
- never attempt to apply sulfur dust that cakes or does not flow freely—return this defective product to the supplier
- for protection in case of a fire in the aircraft, pilots applying sulfur dust should wear a Nomex® (or equivalent) flying suit with sleeves rolled down, Nomex® (or equivalent) gloves, and a sealed, full-coverage faceshield with a built-in respirator

### Preparing the Aircraft for Sulfur Dust Application

The following are recommendations from the California Agricultural Aircraft Association for outfitting an aircraft for sulfur dust application:

- the tail section of the aircraft (empennage) should be all metal rather than fabric covered
- the belly panels of the aircraft should be stainless steel rather than aluminum to provide the cockpit with greater protection from an external fire
- keep the hopper vent closed to reduce oxygen that could support a fire
- install static discharge wicks to the trailing edges of wings and control surfaces to dissipate the static energy field that forms around the aircraft during flight
- attach a nonferrous static ground cable to the aircraft to discharge static electricity while the aircraft is on the ground
- to protect against static electricity arcing, use short lengths of wire or bonding strap to connect all flight control surfaces and removable fuselage and wing panels to the main airframe
- attach the dust spreader tightly and securely to the aircraft and attach a bonding strap or wire between the spreader and aircraft fuselage to prevent static electricity arcing
- if an agitator is used in the hopper, be sure it operates smoothly and free of friction that would build up heat—check bearings and replace them if they are worn
- be sure electric motors and all external wire terminals are sealed in dustproof enclosures
- inspect and tighten engine exhaust fittings and gaskets, exhaust collector ring segments, and the exhaust shroud to reduce the likelihood of red-hot carbon flakes passing through the spreader vanes
- seal removable and stationary fuselage panels, wing roots, wings, and the cockpit to keep sulfur dust out of the interior chambers of the aircraft components
- seal the battery inside a dustproof container
- check and tighten all electrical connections to prevent arcing or shorting
- if possible, use an air conditioner in the cockpit to pressurize it and help keep sulfur dust out
- carry a bottled air supply in the cockpit with a hose that attaches to the pilot's faceshield or respirator

- keep a fire extinguisher in the cockpit and, if possible, equip the hopper with a CO<sub>2</sub> fire extinguisher or extinguisher system that also protects the spreader and lower fuselage

### Ground Operations Preparations

To reduce the chances of sparks that could lead to a flash explosion or fire, precautions also need to be taken during storage, handling of sulfur dust sacks, and loading the aircraft. Smoking and open flames must be prohibited in any area where sulfur dust is being handled or stored. Spills must be cleaned up immediately. Motorized equipment must be grounded and have spark arrestors installed. Handlers must wear tight fitting goggles and respiratory protection according to the requirements on the product label and state regulations. Leather-soled shoes are preferable to rubber-soled shoes or boots because leather is less likely to generate static electricity. To reduce the possibility of sparks, tools used around the equipment during handling activities should be made of nonferrous materials such as bronze or aluminum.

## FACTORS INFLUENCING THE STABILITY AND MANEUVERABILITY OF THE AIRCRAFT DURING APPLICATION OPERATIONS

Density altitude as well as local weather conditions and load weight can affect the stability and maneuverability of an aircraft during an application operation. See Sidebar 35 for a description of density altitude and Sidebar 36 for a method used to estimate density altitude. Weather conditions such as wind can affect the stability and handling of the aircraft and contribute to uneven swaths and offsite pesticide drift.

Humidity also affects available engine power because higher humidity increases the water content of air, displacing oxygen that is vital for optimum engine internal combustion. For example, at 96°F, the water vapor content of the air can be as much as eight times greater than it is at 42°F. High humidity can reduce the available engine power needed for takeoff and climbs as well as maneuvers needed for pull-ups and turnarounds during applications.



FIGURE 9.7

This photograph illustrates how air displaced by an aircraft affects spray droplets.

## CONTROLLING OFFSITE PESTICIDE DRIFT

Pesticides are essential tools in managing pests in a particular location. Confining the pesticide to the intended application site during application is a crucial responsibility of the aerial applicator. Pesticides and pesticide residues can move off the application site several ways. These include

- droplets or dust particles drifting offsite at the time of dispersal during a pesticide application (Figure 9.7)
- vapor or droplets becoming concentrated by an inversion layer during an application and moving offsite
- volatilization into the atmosphere after the application when the pesticide adheres to treated surfaces, the crop plants, the soil in-between the plants, or bare ground



## Sidebar 35

## Density Altitude

Density altitude is a condition where air molecules spread out or become less dense, changing aircraft flight characteristics such as lift and maneuverability. In addition, less dense air means that less oxygen is available for optimum engine performance and will reduce horsepower unless the engine is turbocharged. Factors that influence how closely air molecules are packed together include pressure (the effect of altitude) and temperature. The higher the altitude, the less dense the air will be because the air molecules are further apart and therefore there are fewer molecules to provide lift for the aircraft. Warmer air temperature also causes air molecules to move further apart, making the air less dense.

Density altitude, as well as high air temperatures, affect the stability and maneuverability of the aircraft for making applications, takeoffs, and landings. It also changes stall thresholds and the ability to perform maneuvers such as turns and rolls. The effects of density altitude can even appear in low altitude areas, such as near sea level, when the air temperature goes above standard (59°F). Takeoff distance, available engine horsepower, and climb rate are all adversely affected. For an aircraft loaded with spray material or granules, an **increase** in density altitude results in



- increased takeoff distance
- reduced rate of climb
- increased true airspeed on approach and landing
- increased landing roll distance
- limited service ceiling of the aircraft while en route

Density altitude is a factor that limits the performance capabilities of the aircraft, but is not a height reference and should not be confused with

- pressure altitude
- indicated altitude
- true altitude
- absolute altitude

In high elevation areas, usually between midmorning and mid-afternoon, high temperatures sometimes have such an effect on density altitude that safe aerial application operations can become extremely hazardous. Very high temperatures at lower elevations can also affect aircraft performance, making it necessary to reduce the weight of the pesticide load for safer flight. During periods of high temperatures, it may be safer to make applications during early mornings, when temperatures generally are lower.





## Sidebar 36

## Estimating Density Altitude

The following is a fairly accurate and easy-to-remember general rule for determining the density altitude at locations above sea level:

- For each 10°F above standard temperature at any particular elevation, add 600 feet to the field elevation. For each 10°F below standard temperature, subtract 600 feet.
- Standard temperature at sea level is 59°F. For elevations above sea level, subtract 3.5 degrees per thousand feet of elevation from the sea level temperature of 59°F.

**Example.** The elevation of Lancaster, California is 2,342 feet. 2,342 divided by 1,000 = 2.342.

1. Multiply 2.342 by 3.5:

$$2.342 \times 3.5 = 8.197$$

2. Subtract 8.197 from the sea level standard temperature of 59°F:

$$59 - 8.197 = 50.803$$

3. The standard temperature at Lancaster is 50.80°F. In this example, assume that the current temperature at Lancaster is 97°F. Subtract the standard temperature at Lancaster from this

$$97 - 50.8 = 46.2$$

4. Divide this difference by 10 degrees (for each 10°F above standard)

$$46.2 / 10 = 4.62$$

5. Multiply 4.62 by 600 (600 feet per 10 degrees)

$$4.62 \times 600 = 2,772$$

6. Add this correction factor of 2,772 feet to the field elevation of 2,342 feet at Lancaster.

$$2,772 + 2,342 = 5,114$$

The density altitude for Lancaster when the temperature is 97°F is 5,114 feet. This means that you should handle the aircraft in Lancaster as you would on a standard day at 5,114 feet elevation.



- leaching through the soil at the application site and moving into ground water after application
- rainfall or irrigation water washing residues off the application site into surface waters after the application has been made
- blowing off the site attached to soil particles or dead plant material after application
- leaving the application site as residues remaining on harvested crops
- being carried off the application site on vehicles, equipment, animals, and people

The National Coalition on Drift Minimization (NCODM) defines spray drift to be “the movement of pesticide through the air at the time of pesticide application or soon thereafter from the target site to any non- or off-target site, excluding pesticide movements by erosion, migration, volatility, or windblown soil particles after application.” **Offsite pesticide drift** includes pesticide droplets, vapors, or dust particles that move off the application site after leaving the dispersal system but before adhering to the intended treatment site during a pesticide application. When pesticides or pesticide residues leave the application site at any other time and in any other manner, it is considered **offsite movement** rather than drift. During any application, a certain percentage of the spray droplets being applied will drift. If this drift is confined to the treatment site so that it is part of the pesticide application, there is generally little hazard to the surrounding areas that are not part of the application. Offsite pesticide drift, however, increases the hazard to people and other living organisms outside of the treatment site. The information presented in this section pertains to offsite pesticide drift. Reducing offsite pesticide drift is a major focus when any type of pesticide application is made because, if not controlled, this offsite drift can contribute significantly to the pesticide load in the environment.

Because any pesticide can be hazardous, if some amount moves off the application site it can be harmful to living organisms in the environment. For example, sulfur will pose a deadly hazard to individuals who are allergic to it, even though to some people sulfur is considered a benign, naturally occurring substance. Sulfur is not a pesticide that is created through the normal chemical manufacturing process that is often associated with most synthetic pesticides, but it can still pose a significant health hazard to a certain segment of the population and to some ecosystems.

Some pesticides that leave the application area either through offsite drift or offsite movement become concentrated in the cells of animals that are part of a food chain, a process known as **bioaccumulation**. As the pesticides become concentrated, they may disturb the natural physiological functions of these animals and interfere with natural life cycles. Very small quantities of other types of pesticides that leave a target site may be acutely harmful to people, animals, or plants and cause injury, illness, or disease.

### Minimizing Offsite Drift

Research conducted by pesticide manufacturers, the pesticide application industry, universities, and state and federal regulatory agencies has proven that offsite pesticide drift can be minimized during any application operation. The primary factors affecting droplet size spectra from aerial spray nozzles are

- nozzle type
- orifice size

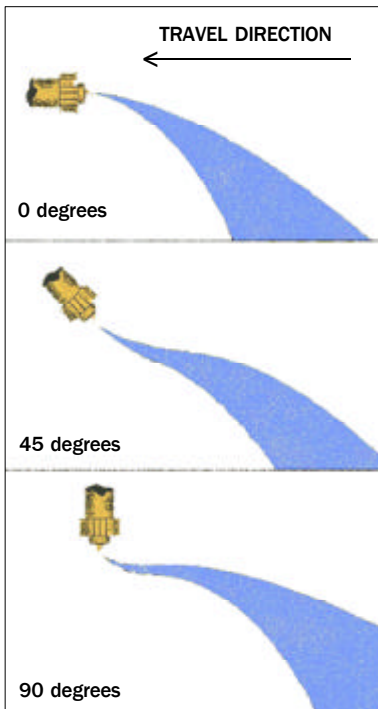


FIGURE 9.8

Wind shear across the face of a nozzle can contribute to small droplet sizes. The wind shear effect increases as the nozzle orientation changes as seen in these drawings. The least amount of wind shear occurs when the nozzle is oriented to be parallel to the direction of flight.

- nozzle orientation
- spray pressure
- physical properties of the spray mixture

Drift research has shown that nozzles and other spray components can be designed and manufactured to produce a desired spray droplet spectrum with a reduced propensity to drift. However, these advances in spray drift control can be negated and even worsened by wind shear effects on the nozzles of the pesticide dispersal system. Appropriate airspeed and correct nozzle orientation are the two wind shear factors to consider for maintaining the intended drift control aspects of nozzles (Figure 9.8). There should be a balance between the minimum airspeed needed for covering the desired acreage in a given period and the maximum airspeed necessary to minimize the adverse impact to spray droplets caused by wind shear. General recommendations for minimizing drift include

- selecting nozzle types with orifice sizes that produce large droplets, placement of nozzles on the boom, and orienting and positioning nozzles to reduce the effects of wind shear across the orifice face to reduce the quantity of very small droplets prone to drift (droplets that are 200 microns in diameter or smaller)
  - smaller orifices generally produce finer sprays
  - wider spray angles typically produce finer sprays
- accurately calibrating application equipment, including using a system pressure that is appropriate to the airspeed of the aircraft for maintaining a droplet size that results in optimal spray coverage
- avoiding applications during weather conditions that promote offsite drift, such as high winds or inversion conditions
- using spray drift control adjuvants when appropriate to increase spray droplet size

Spray drift control adjuvants are a specific class of chemical adjuvants and should not be confused with other adjuvants such as surfactants, wetting agents, spreaders, and stickers. Adjuvants such as these, and formulations containing alcohol or certain water miscible solvents, tend to reduce the dynamic surface tension of droplets, resulting in smaller droplet sizes. Spray drift control adjuvants, however, when added to the spray mixture can help reduce the number of driftable droplets under certain conditions. However, some types of drift control agents have been reported to lose their effectiveness when circulated through a sprayer pump.

Specific techniques for reducing offsite pesticide drift during an aerial application include

- leaving untreated buffer zones one, two, or more swath passes wide within the treated site or field, along the downwind edges so that any pesticide that drifts will stay on the treated site; these buffer zones could be treated later, when the wind direction reverses
- using nozzles or other dispersal systems that will produce a droplet spectrum with the maximum propensity to resist the forces that cause offsite pesticide drift and, as a result, will stay on target
- getting good field-end coverage on initial spray runs; end passes made to fields that are bordered by trees or other obstacles usually means flying higher, which increases the chance of drift

- flying at the optimum airspeed that will, when combined with pump output pressure, help to maintain larger droplets
- keeping application height between 8 and 12 feet above the crop
- making sure the positive shut-off and suck-back system is working properly and is being used
- confining boom length to no more than 75% of the wingspan of a fixed wing aircraft, or 90% of the rotor diameter on rotary wing aircraft, to reduce drift caused by wingtip and rotor vortices
- using a nozzle orientation straight back in relation to the aircraft's level flight line so that the discharged spray is least affected by wind shear across the nozzle face, therefore maintaining the rated desired droplet size (some research is showing that a slight angle of about 5 degrees allows the spray to be directed downward without affecting droplet size)

Spray droplets are normally finer at greater flight speeds, especially when using wide-angle fan nozzles or nozzle orientation that is not straight back in relation to the level flight of the aircraft. However, for applications using solid stream nozzles pointed backward, increasing the spray pressure can actually result in a coarser spray if the exit velocity from the nozzle becomes closer to the speed of the aircraft. Doing this reduces the air shear effect.

## Droplet Size

There are certain external factors that remain beyond the control of the person responsible for deciding to proceed with or to postpone or cancel an application. These external factors include physical properties of the spray mixture (see Sidebar 37), weather like rain, extremely high or low temperatures, wind, or conditions leading to an inversion layer. Aside from these external factors, the size of the spray droplets and the percentage of droplets within a certain size range are the key factors affecting offsite drift. Moreover, some of these factors can be controlled by the applicator.

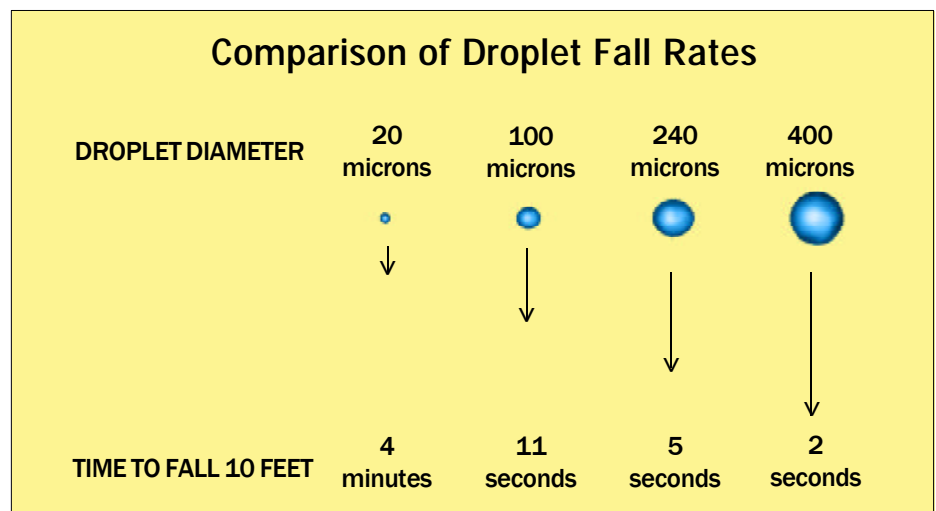
Spray droplet diameters are measured in microns (also referred to as micrometers). The mathematical symbol for a micron or micrometer is  $\mu$ . One micron is  $1/25,000$  or 0.00003937 of an inch. To illustrate the relative size of one micron, a sheet of paper is about 100 microns thick.

The longer a spray droplet remains airborne or suspended in the air, the greater the chance it will drift from the application site. A small spray droplet is more susceptible to drift than a larger droplet because the small droplet is lighter and therefore remains airborne much longer. For example, while it takes approximately 4 minutes for a 20-micron droplet to travel a vertical distance of 10 feet, it takes only 2 seconds for a 400-micron droplet to travel the same distance (Figure 9.9).

Research shows that there is a rapid decrease in the drift potential of

FIGURE 9.9

This drawing illustrates the time it takes for droplets of various sizes to fall 10 feet. The larger the droplet size, the faster it will fall.



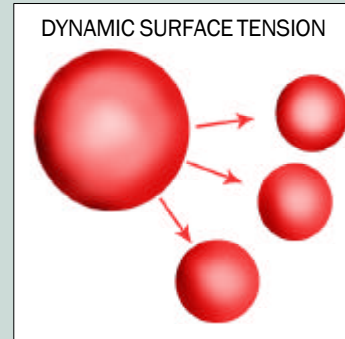


## Sidebar 37

## Key Physical Properties of a Spray Mixture that Affect Spray Droplet Size

Three key physical properties of a spray mixture that have a significant effect on droplet size in aerial applications are

- **dynamic surface tension** - Surface tension is the force that keeps a droplet together. When the fluid that makes up the droplet contains adjuvants or other substances, the normal surface tension changes, but it takes a certain amount of time for the molecules in the adjuvants to move to the surface of the droplets. Therefore, the surface tension of spray droplets can change after the droplets are formed, causing a larger droplet to split into smaller droplets.
- **extensional viscosity** - When a spray liquid is forced through a nozzle orifice, it stretches to a certain point before breaking off to form a droplet. The amount of stretching or “stringiness” is the extensional viscosity. Pressure in the system, which regulates the speed that the liquid is ejected, affects the extensional viscosity. Higher pressure lowers this viscosity, therefore producing smaller droplets.
- **shear viscosity** - Shear viscosity is a liquid’s resistance to flow. Some liquids are thicker and therefore resist flow or flow more slowly than less thick, or less viscous, liquids.



droplets that are larger than about 200 microns. Conversely, research also has proven those droplets smaller than 200 microns are very prone to drift. Those that are 100 microns or smaller are defined as **driftable fines**. In wind speeds in the range of 1 to 9 mph, droplets that are 200 microns or larger have an insignificant drift potential. For instance, the theoretical distance that spray droplets are carried laterally while falling from 10 feet above the ground in air moving at 3 mph would be only about 8 feet for 400-micron droplets. However, this distance increases to about 1,000 feet for 20-micron droplets (Figure 9.10). Higher velocity winds would increase the drift potential of droplets in these ranges.

The droplet size at which spray drift becomes a concern is 200 microns and below. Spray droplets smaller than 200 microns present a greater drift potential than larger droplets. Droplets smaller than 50 microns in diameter remain suspended in the air indefinitely or until they evaporate. Droplets of this size have no benefit to a pest control program because they are never likely to reach target surfaces. Avoid nozzles or nozzle orientations and configurations that produce droplets in this size range because there is no way to assure they remain on the application site.

In addition to finding the balance between proper airspeed to minimize atomization of large droplets, the other challenge to an aerial application operation is to find a balance between drift reduction provided by large droplets and good coverage associated with smaller droplets.

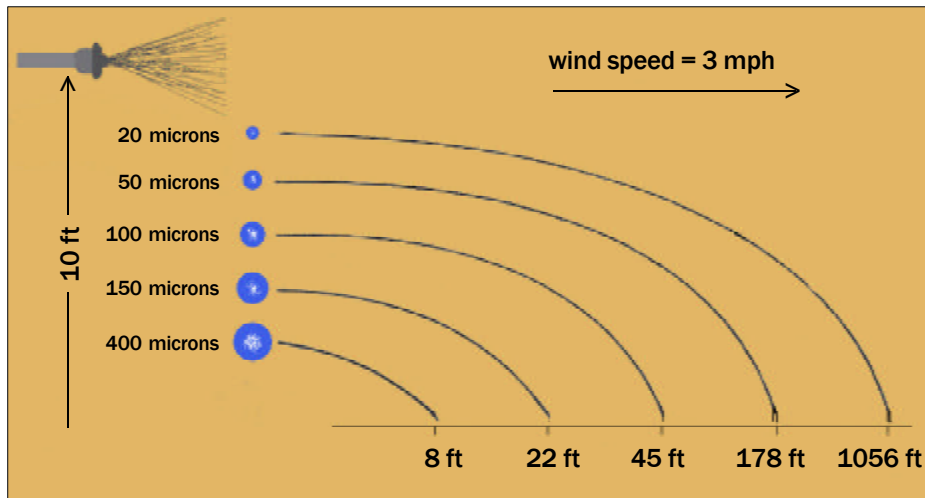


FIGURE 9.10

This drawing illustrates how far spray droplets of various sizes would move when released at 10 feet from the ground during a 3 mph wind.

### Classification of Droplet Size

All nozzles produce a range of droplet sizes, known as the *droplet-size spectrum*. This means that even when using a nozzle having a large orifice that mainly produces large droplets, some percentage of the droplets in the spray emitted by the nozzle are going to be small enough to be prone to drift.

A common classification method used to describe the droplet-size spectrum produced by a nozzle is the *volume median diameter* (VMD). This means that half of the total spray volume of that nozzle consists of spray droplets smaller than the VMD numerical value, while the other half is larger than the VMD numerical value. When referring to a numerical value for spray droplet size, it will be expressed as  $D_{v0.5}$ . For example, as shown in Figure 9.11, a nozzle with a  $D_{v0.5}$  of 800 microns sprays out half its total volume in droplets having a diameter greater than 800 microns and the other half in droplets having a diameter smaller than 800 microns. However, the VMD in this example does not reveal how much of the spray volume is made up of droplets that are smaller than 200 microns.

Another way of classifying the droplet sizes produced by a nozzle is to identify the percentage of the total spray volume that contains droplets smaller or larger than a specific diameter, usually 200 microns. This directly addresses those droplets at risk for drift. For instance, a nozzle may produce 2% of its total spray volume in droplets smaller than 200 microns in diameter. This means that only a small portion of the droplets produced by this nozzle are at risk for drift. This type of description, however, tells nothing about the size of the remaining droplets produced, which is the information that is needed to determine the type of coverage that can be expected.

The most useful means of describing the droplet sizes produced by a nozzle is to use droplet-size categories based on the entire droplet-size spectrum of a nozzle, rather than just the VMD or a specific size droplet by percentage of volume. The spray-classification system used is the American Society of Agricultural Engineers (ASAE) standard S-572: *Spray Nozzle Classification by Droplet Spectra*. This classification system has six categories: very fine, fine, medium, coarse, very coarse, and extra coarse (Table 9.1). Using these categories, an applicator can select a nozzle and operating pressure that produces a specific droplet-size spectrum.

The droplet-size spectrum required for an aerial application operation is based on the type of pesticide being applied. Eventually, all pesticide labels will contain specifications for

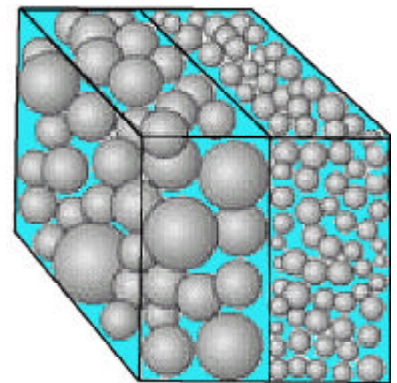


FIGURE 9.11

This is an illustration of Volume Mean Diameter (VMD). Half of the total volume of spray droplets are larger than a specific size and the remaining half of the volume of spray droplets are smaller than that size.

**Table 9.1**  
**Spray Droplet Spectrum Categories and Recommendations For Various Pesticide Types or Uses.**

ASAE Standard S-572 Droplet Spectrum Categories	VMD (microns)	Contact insecticide and fungicide	Systemic insecticide and fungicide	Contact foliar herbicide	Systemic foliar herbicide	Soil-applied herbicide	Incorporated soil-applied herbicide
Very Fine (VF)	<150	not recommended	not recommended	not recommended	not recommended	not recommended	not recommended
Fine (F)	150 - 250	recommended	not recommended	not recommended	not recommended	not recommended	not recommended
Medium (M)	250 - 350	recommended	recommended	recommended	recommended	not recommended	not recommended
Coarse (C)	350 - 450	not recommended	recommended	not recommended	recommended	recommended	recommended
Very Coarse (VC)	450 - 550	not recommended	not recommended	not recommended	not recommended	recommended	recommended
Extremely Coarse (XC)	>550	not recommended	not recommended	not recommended	not recommended	not recommended	recommended

nozzles and/or the required droplet-size spectrum. Table 9.1 shows the pesticide types and uses for which each nozzle category is recommended. Even though a VMD range is given for each category, the classification is based on the entire droplet spectrum produced by a nozzle, not just the VMD. The VMD is used in this table for reference.

The droplet-size spectrum categories are the best method for achieving a specific droplet size for an application. First, determine the droplet spectrum needed for a particular application operation. Then, using a nozzle catalog, select a nozzle type, size, and operating pressure that corresponds to that droplet size. By selecting the appropriate category based on the type and use of a pesticide, you get acceptable results while keeping the risk of drift to a minimum.

California regulations may prescribe even more specific droplet size restrictions to prevent drift of some pesticides registered for use in the state. For example, the California Code of Regulations pertaining to the application of *propanil* requires that "... each operating aircraft nozzle shall produce a droplet size, in accordance with the manufacturer's specifications, not less than 600 microns volume median diameter ( $D_{v0.5}$ ) with not more than ten percent of the diameter by volume ( $D_{v0.1}$ ) less than 200 microns..."



## Effects of Evaporation on Droplet Size

Once exposed to the atmosphere, individual spray droplets will generally begin to evaporate (Figure 9.12). Evaporation removes water or other carriers, making the spray droplet smaller than it was when it left the nozzle. As the droplet becomes smaller, it becomes more prone to drift. Conditions that contribute to evaporation include

- air temperature—evaporation is more rapid as temperature increases
- humidity—evaporation is more rapid as humidity decreases
- air movement—evaporation is more rapid as air movement increases
- distance from discharge to the target—the further the droplet has to fall the more time is available for evaporation
- spray carrier—water will evaporate faster than oil carriers

The optimum time to make an aerial application when evaporation of spray droplets is a concern is during the coolest part of the day. Early morning is ideal because it is also usually more humid at this time and the wind may be mild. However, inversion conditions (see below) may be greater during early mornings. Avoid making applications during hot, dry periods of the day. Keep the application height between 8 and 12 feet from the target to shorten the distance that spray droplets must fall. To minimize drift risk, small droplet sprays require lower application heights.

## Co-distillation

Pesticides can also move offsite through a process called *co-distillation*. This phenomenon has been shown to occur when the pesticide contacts very hot surfaces, usually soil free of vegetation. Pesticides, even those that are not highly volatile, appear to be carried from the soil surface with water molecules during rapid evaporation that occurs immediately after irrigation. Fog also is able to pick up pesticides from the application site and carry them offsite.

## Effect of Wind and Thermals on Drift and Offsite Movement

Air movement from wind or thermals is a major contributing factor to offsite pesticide drift. Wind carries lighter and smaller droplets away from the target site where they accumulate until a given volume of air becomes saturated with sprayed pesticide. As winds become stronger, more and more larger droplets are also entrapped in the air movement and may move offsite before they return to the ground.

Upward air movement caused by thermals also entraps and moves small droplets, increasing the probability that they will drift away from the application site.

## Temperature Inversions

Differing air temperatures in stratified layers of the atmosphere is responsible for the inversion phenomenon that can exacerbate the problem of offsite pesticide drift (Figure 9.13). Inversions

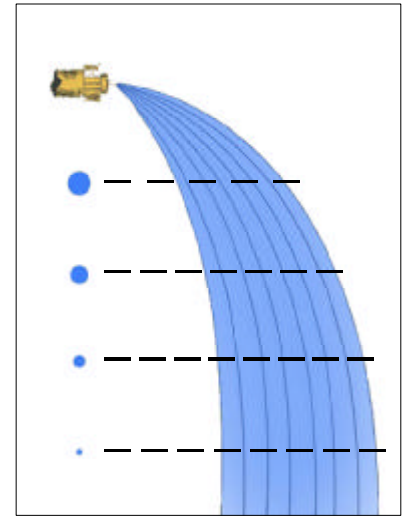


FIGURE 9.12

Evaporation begins to take place once spray droplets are released. Evaporation causes spray droplets to become smaller and more prone to drift

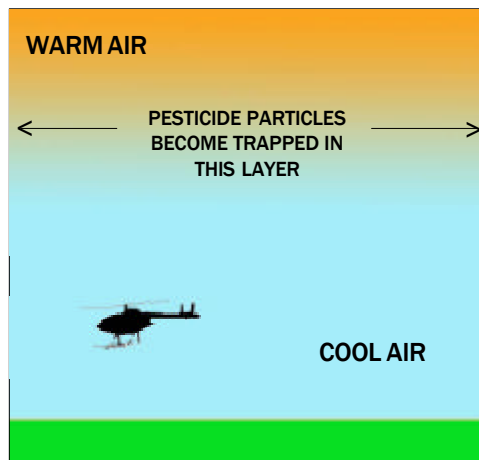


FIGURE 9.13

Temperature inversions block vertical air movement and can cause spray droplets to concentrate above the application site and eventually move off. This poses an environmental risk as the pesticide returns to the surface.

occur when an upper layer of air is warmer than the air below it. This warm air cap may start at 20 to 100 or more feet above the ground and block the cooler air below it, preventing vertical air movement.

Over a wide area, it may be possible to ascertain the presence of an inversion condition by checking with the National Weather Service. In some areas, during certain times of the year, temperature inversions occur regularly. One method for detecting a temperature inversion in a localized area is to observe a column of smoke rising into the air. Sometimes, dust from agricultural operations may serve the same purpose. If the rising smoke column or dust cloud flattens and begins moving sideways or collects in one area above the ground, an inversion condition probably exists.

Inversion conditions are dangerous during an aerial application because the inversion layer traps fine spray droplets and pesticide vapors. These become concentrated, similar to smoke particles in the smoke column. Rather than dispersing somewhat evenly throughout the atmosphere over a relatively large area, the pesticide often moves as a concentrated cloud away from the treatment site. Afterwards, the concentrated pesticide cloud will return to the ground and may cause problems for people, non-treated crops, and other living organisms.

An inversion condition can occur when the air is calm with very little air mixing. This condition makes it possible for the cloud of spray droplets or vapor to move slowly downwind. Temperature inversions generally occur in early morning or near bodies of water.



## Chapter 9

## Review Questions

SEE PAGE 178 FOR ANSWERS

1. Learning how to manage offsite pesticide drift during an aerial application is part of
  - a. the ground crew responsibilities
  - b. the property owner's responsibility
  - c. application technology
  - d. a requirement of the pilot's FAA licensing
2. The last application flight of the day
  - a. is more relaxed and requires less attention
  - b. is not as important as other flights of the day
  - c. requires the same attention as every other flight
  - d. should only carry one-half of a load
3. Ferrying flights must be made at an altitude of at least
  - a. 8 to 10 feet
  - b. 100 feet
  - c. 500 feet
  - d. 1500 feet
4. Ferrying flights that pass over areas where people live or work should
  - a. follow the same route in each direction for all trips
  - b. be varied by  $\frac{1}{8}$  to  $\frac{1}{4}$  mile for each trip
  - c. follow the same route each time to the field, but vary the route when returning to base
  - d. follow a different route each time to the field, but use the same route for each return to base
5. One purpose of a flight over the field to be treated just before the actual application is to
  - a. test the ground crew communication system
  - b. frighten birds away from the area
  - c. make people in surrounding areas aware of the application
  - d. comply with pesticide label requirements

6. Breaks seen in the normal cultivation patterns of a field may alert the pilot to
  - a. changes in soil type
  - b. problems with field cultivation equipment
  - c. hidden hazards
  - d. changes in the needed application rate
7. Relying solely on maps and observations of hazards made during a previous application to the same field is not a substitute for a pre-application inspection flight because
  - a. weather conditions may have changed
  - b. the pilot may be working with a different ground crew
  - c. the pesticide being applied may be different
  - d. there may be new hazards to consider at the site
8. It is necessary to suspend the application if
  - a. the air temperature drops
  - b. the wind speed decreases
  - c. people are seen walking on the upwind edge of the field being treated
  - d. a crew is working in a field located ¼-mile upwind
9. Too wide or too narrow overlapping of spray passes will result in
  - a. flight hazards
  - b. increased chances of offsite drift
  - c. uneven application patterns
  - d. disabling of the DGPS system
10. The recommended application height for most liquid sprays is
  - a. 8 feet
  - b. 15 feet
  - c. 22 feet
  - d. 25 feet
11. To avoid the adverse effect of headwinds or tailwinds on an application rate, you should fly
  - a. into the wind
  - b. against the wind at all times
  - c. back and forth, alternating between into the wind and against the wind
  - d. crosswind or 45 degrees to the crosswind

12. Varying the speed during an application will
  - a. provide a more even application rate
  - b. accommodate for wind direction changes
  - c. result in uneven coverage
  - d. increase offsite drift potential
13. The application pattern that helps to avoid flying through spray from a previous swath is the
  - a. race track pattern
  - b. bidirectional pattern
  - c. back and forth pattern
  - d. upslope pattern
14. The usual height for making granule applications is
  - a. 8 to 12 feet
  - b. 10 to 20 feet
  - c. 20 to 30 feet
  - d. 30 to 50 feet
15. The problem with flying too low when making a granule application is that
  - a. granules are still moving vertically at lower heights
  - b. granules are still moving horizontally at lower heights
  - c. even granule dispersal is affected by the ground effect at lower heights
  - d. propwash has a greater effect on granules at lower heights
16. Offsite pesticide drift is the offsite movement of the pesticide that occurs
  - a. any time after an application
  - b. at the time of pesticide application or soon thereafter
  - c. as residues on objects that move from the application site
  - d. several hours to several days after an application
17. When applying a contact insecticide, the recommended droplet spectrum category is
  - a. very fine
  - b. fine
  - c. coarse
  - d. very coarse

18. When applying contact or systemic foliar herbicides, the recommended droplet spectrum category is
- fine
  - medium
  - very coarse
  - extremely coarse
19. The optimum time for making an aerial application of a liquid when droplet evaporation is a concern is
- early morning
  - mid morning
  - early afternoon
  - late afternoon
20. Which of the following factors has NO effect on offsite pesticide drift?
- nozzle orientation
  - spray pressure
  - constant 3 mph wind
  - physical properties of the spray mixture
21. Wider-angle spray nozzles usually produce \_\_\_\_\_ droplets than narrower spray nozzles.
- coarser
  - more uniform
  - less uniform
  - finer
22. The most effective boom lengths for reducing the amount of drift are
- 90% of the wingspan or 75% of the rotor span
  - 75% of the wingspan or 90% of the rotor span
  - 65% of the wingspan or 80% of the rotor span
  - 65% of the rotor span or 80% of the wingspan
23. Aside from external factors, the most important factors affecting offsite drift are
- physical properties of the spray mixture
  - extremely high or low temperatures
  - the size of the spray droplets and the percentage of droplets within a certain size range
  - conditions leading to a temperature inversion layer

24. **Driftable fines** are droplets in the size range of
- 300 to 500 microns
  - 200 to 300 microns
  - 100 to 300 microns
  - 50 to 100 microns
25. The droplet size at which spray drift becomes a concern is
- 50 microns and below
  - 100 microns and below
  - 200 microns and below
  - 300 microns and below
26. Spray that has a numerical value for droplet size of  $D_{v0.8}$  less than 200 microns will result in a spray that has \_\_\_\_\_ percent of the droplets greater than 200 microns.
- 2
  - 8
  - 20
  - 80

## Review Question Answers

CHAPTER 1	CHAPTER 4	2. d	15. c
1. c	1. b	3. c	16. c
2. d	2. b	4. b	17. b
3. c	3. d	5. d	18. b
4. d	4. c	CHAPTER 7	19. c
5. a	5. b	1. b	20. b
6. b	6. b	2. d	CHAPTER 9
7. c	7. c	3. a	1. c
8. c	8. c	4. d	2. c
9. d	CHAPTER 5	5. c	3. c
10. a	1. d	6. c	4. b
CHAPTER 2	2. a	7. a	5. a
1. c	3. c	8. d	6. c
2. c	4. a	9. d	7. d
3. d	5. d	10. d	8. c
4. a	6. d	11. d	9. c
5. c	7. c	12. c	10. a
6. d	8. b	CHAPTER 8	11. d
7. b	9. b	1. c	12. c
8. c	10. a	2. c	13. a
CHAPTER 3	11. d	3. c	14. d
1. b	12. d	4. b	15. b
2. a	13. b	5. b	16. b
3. b	14. c	6. d	17. b
4. c	15. c	7. b	18. b
5. d	16. d	8. b	19. a
6. c	17. b	9. a	20. c
7. a	18. a	10. c	21. d
8. c	19. c	11. d	22. b
9. b	20. b	12. b	23. c
10. d	CHAPTER 6	13. c	24. d
11. c	1. a	14. b	25. c
			26. c

# Glossary

**accidental misapplication.** an unintentional, incorrect application of a pesticide.

**acetylcholine.** a short-acting neurotransmitter, widely distributed in the body, that transmits nerve signals between nerves and muscles, nerves and sensory organs, or nerves and other nerves.

**adjuvant.** a material added to a pesticide mixture to improve or alter the deposition, toxic effects, mixing ability, persistence, or other qualities of the active ingredient.

**adsorb.** to take up and hold on the surface.

**agitation device (agitator).** a mechanical or hydraulic device that stirs the liquid in a spray tank to prevent the mixture from separating or settling.

**agricultural aircraft operations.** the Federal Aviation Administration Regulation Part 137 of the Code of Federal Regulations Title 14 (14 CFR 137) prescribes rules governing agricultural aircraft operations within the United States and the requirements for commercial and private Agricultural Aircraft Operator certificates for those operations.

**agricultural aircraft operator certificate.** certificate issued by the Federal Aviation Administration under provision of 14 CFR 137 to pilots who meet specific requirements as provided in Part 137.

**agricultural commissioner.** the official in each county in California who has the responsibility for enforcing the state and federal pesticide regulations and issuing permits for restricted use pesticides. County agricultural commissioners and their staff frequently inspect pesticide applications and application sites. All agricultural uses of pesticides must be reported monthly to county agricultural commissioners.

**annual.** a type of plant that passes through its entire life cycle in one year or less.

**anti-drip device.** a spring-loaded mechanism built into an aircraft spray nozzle that closes off the nozzle when the fluid pressure drops below a certain level. This prevents nozzles from dripping when the spray is shut off.

**apiary.** a place where bees are kept, such as a beehive.

**application pattern.** the course the pilot follows above the area being treated with a pesticide. See also *bidirectional application pattern* and *racetrack application pattern*.

**application swath.** see *swath* and *swath width*.

**Apprentice Pest Control Aircraft Pilot Certificate.** a Department of Pesticide Regulation certificate given to a pilot who meets the qualifications prescribed in the California Code of Regulations and successfully passes the Laws, Regula-

tions, and General Principles examination and the Apprentice Pest Control Aircraft Pilot certification examination.

**apprentice pilot.** a pilot who holds a current Apprentice Pest Control Aircraft Pilot Certificate and works under the supervision of a Journeyman Pest Control Aircraft Pilot.

**area of a circle:**  $\text{area} = 3.14 \times \text{radius} \times \text{radius}$  ( $A = \pi \times r^2$ )

**area of a square or rectangle:**  $\text{area} = \text{length} \times \text{width}$

**area of a triangle:**  $\text{area} = \text{base} \times \text{height}$  divided by 2

**artificial respiration.** see *rescue breathing*.

**back siphoning.** the process that permits pesticide-contaminated water to be sucked from a spray tank back into a well or other water source. Back siphoning is prevented by providing an air gap or check valve in the pipe or hose used to fill a spray tank.

**backflow.** see *back siphoning*.

**baffle.** a structure built into an aircraft-mounted spray tank that suppresses the sloshing of liquid in the tank, reducing the effect of load shift on the aircraft.

**bidirectional flight pattern.** also known as a *back and forth* flight pattern. Making application swaths in a sequential manner by flying a swath in one direction and the adjacent swath in the opposite direction.

**biennial.** a plant that completes part of its life cycle in one year and the remainder of its life cycle in the following year.

**bioaccumulation.** the gradual buildup of certain pesticides within the tissues of living organisms after feeding on lower organisms containing smaller amounts of these pesticides. Animals higher up on the food chain accumulate greater amounts of these pesticides in their tissues.

**boom.** a structure attached to an aircraft to which spray nozzles are attached.

**broadcast application.** a method of applying granular pesticides by air by dispersing them over a wide area using a spinning disc or ram-air spreader.

**broadleaves.** one of the major plant groups, known as dicots, with net veined leaves usually broader than grasses. Seedlings have two seed leaves (cotyledons); broadleaves include many herbaceous plants, shrubs, and trees.

**buffer strip.** an area of a field left unsprayed for protecting nearby structures or sensitive areas from drift. The minimum buffer strip is usually one swath width.

**buffer zone.** a part of an area that is not treated with a pesticide to protect adjoining areas from pesticide hazards.

**California Code of Regulations.** regulations used to enforce the California laws. Title 3 of the California Code of Regulations (3 CCR) deals with pesticides and pest control operations.

**California Department of Pesticide Regulation (DPR).** the state agency responsible for regulating the use of pesticides in California.

**carbamate.** a class of pesticides commonly used to control insects, mites, fungi, and weeds. N-methyl carbamate insecticides, miticides, and nematicides are cholinesterase inhibitors.

**cardiopulmonary resuscitation (CPR).** a procedure designed to restore normal breathing after breathing and heartbeat have stopped.



**carrier.** the liquid or powdered inert substance that is combined with the active ingredient in a pesticide formulation. May also apply to the water, oil, or other substance that a pesticide is mixed with prior to application.

**caution.** the signal word used on labels of the least toxic pesticides.

**certified commercial applicator.** a person holding a valid Qualified Applicator License (QAL) or Qualified Applicator Certificate (QAC) issued by the Department of Pesticide Regulation; a pilot holding a valid Journeyman Pest Control Aircraft Pilot Certificate issued by the Department of Pesticide Regulation; a person holding a Certified Technician Certificate issued by the Vector Biology and Control Section of the Department of Health Services; a person holding a valid Structural Pest Control Operator or Field Representative license issued by the Structural Pest Control Board of the Department of Consumer Affairs.

**certified private applicator.** a private applicator holding a valid Private Applicator Certificate issued by a county agricultural commissioner.

**chemical resistant.** a material that allows no measurable movement of the pesticide through it during use.

**cholinesterase.** an essential enzyme found in many living organisms, including human beings, that deactivates the chemical *acetylcholine* that is responsible for transmitting nerve impulses between nerves and between nerves and muscles. Without proper cholinesterase activity, which allows the nerve signals to stop at the appropriate time, nerves and muscles do not function properly.

**cholinesterase determination.** a laboratory test, prescribed by a physician, used to measure the amount of cholinesterase in an individual's red blood cells or blood plasma. Physicians use the results of this test to help them determine, among other things, if exposure to organophosphate or N-methyl carbamate pesticides has occurred.

**Class 'E' Airspace.** airspace that is controlled by an air traffic control tower.

**closed mixing system.** a device used for measuring and transferring liquid pesticides from their original container to the spray tank. Closed mixing systems reduce chances of exposure to concentrated pesticides. Closed mixing systems are usually required when mixing liquid materials with the signal word "DANGER".

**closed system.** a procedure for removing a liquid pesticide from its original container, rinsing the emptied container, and transferring the pesticide product, mixtures and dilutions, and rinse solutions into a spray tank through connecting hoses, pipes, and couplings.

**Code of Federal Regulations (CFR).** regulations used to enforce federal laws. The CFR contain sections that address aerial application of pesticides as well as training and certification of pesticide handlers.

**co-distillation.** a phenomenon where pesticide molecules are picked up in water vapor and can move off site.

**Commercial Agricultural Aircraft Operator.** a category of the FAA certification process applying to pilots who make pesticide applications by air for hire.

**commercial applicator.** a person who, for hire, uses or supervises the use of a pesticide for any purpose or on any property.

**complete metamorphosis.** the complete transformation of certain orders of insects

from a larval stage to an adult form. This transformation occurs during a resting or pupal stage. The adult form of insects that undergo complete metamorphosis does not resemble its larval form.

**conflict with labeling.** any deviation from instructions, requirements, or prohibitions of pesticide product labeling concerning storage, handling, or use, except: a decrease in dosage rate per unit treated; a decrease in the concentration of the mixture applied; application at a frequency less than specified; use to control a target pest not listed, provided the application is to a commodity/site that is listed and the use of the product against an unnamed pest is not expressly prohibited; employing a method of application not expressly prohibited, provided other directions are followed; mixing with another pesticide or with a fertilizer, unless such mixing is expressly prohibited; an increase in the concentration of the mixture applied, provided it corresponds with the current published UC Pest Management Guidelines of the University of California, which are available from the Statewide Integrated Pest Management Program, One Shields Avenue, Davis, California 95616, or on-line at <http://www.ipm.ucdavis.edu>; the use of personal protective equipment consistent with the exceptions and substitutions in California regulations.

**congested area.** a populated area where personal injury or property damage might occur if an aircraft crashes or if the pesticide load must be dumped.

**contact herbicide.** an herbicide that controls plants by destroying or injuring the plant surfaces contacted by the herbicide.

**contact pesticide.** a pesticide that provides control when target pests come in physical contact with it.

**conventional application rate.** for aircraft, the conventional application rate ranges between 5 to 15 or more gallons of spray per acre.

**corrosive materials.** certain chemicals that react with metals or other materials. Some pesticides are corrosive, and special handling requirements are needed when using these.

**county agricultural commissioner.** see *agricultural commissioner*.

**coverage.** the degree to which a pesticide is distributed over a target surface.

**coverall.** a one- or two-piece garment of closely woven fabric that covers the entire body except the head, hands, and feet, and must be provided by the employer as personal protective equipment. Coverall differs from, and should not be confused with, work clothing that can be required to be provided by the employee.

**CPR.** see *cardiopulmonary resuscitation*.

**crop stage.** the stage of development of agricultural crops, such as seedling, flowering, and fruit set, etc. Different pests attack crops at different stages of development.

**danger.** the signal word used on labels of highly hazardous pesticides.

**danger/poison.** the signal words found on labels of highly toxic pesticides, those that can seriously injure or kill humans at low doses.

**decontaminate.** the most important step in reducing potential injury when someone has been exposed to a pesticide. Decontamination involves thoroughly washing

the exposed skin with soap and water or flushing the exposed eye with a gentle stream of running water.

**dehydration.** the process of a plant or animal losing water or drying up. Dehydration is a major contributor to heat related illnesses in people.

**density altitude.** a condition where air molecules spread out or become less dense as altitude increases and/or as temperatures rise. Density altitude has an effect on the operational performance of an aircraft.

**Department of Pesticide Regulation.** see *California Department of Pesticide Regulation*.

**dermal.** pertaining to the skin. One of the major ways pesticides can enter the body to cause poisoning.

**dicot.** see *broadleaves*.

**differential GPS (DGPS).** a global positioning navigation system that relies on a mobile receiver mounted in an aircraft and a fixed ground-based receiver, providing a higher degree of positional accuracy than a mobile receiver used alone.

**directions for use.** the instructions found on pesticide labels indicating the proper procedures for mixing and application.

**disease triangle.** the factors that must be present to cause an infection in a plant. These include the pathogen, the host, and the conditions (environment) suitable for infection.

**drift (spray).** (From National Coalition on Drift Minimization) “the movement of pesticide through the air at the time of pesticide application or soon thereafter from the target site to any non- or off-target site, excluding pesticide movements by erosion, migration, volatility, or windblown soil particles after application.”

**driftable fine.** spray droplets that are 100 microns in diameter or smaller.

**droplet spectrum categories.** a classification of spray droplets into six categories based on the volume median diameter of the spray droplets. The six categories are very fine, fine, medium, coarse, very coarse, and extremely coarse.

**dynamic surface tension.** variation or changes in the surface tension of a liquid based on the position of molecules of substances within droplets that alter surface tension.

**economic poison.** (1) any substance or mixture of substances intended for preventing, destroying, repelling, or mitigating any insects, rodents, nematodes, fungi, weeds, and other forms of plant or animal life or viruses, except viruses on or in people or other animals, which the Secretary of Agriculture shall declare to be a pest, and (2) any substance or mixture of substances intended for use as a plant regulator, defoliant or desiccant.

**effective swath width.** a swath that includes overlaps made with each pass to achieve a more even application.

**emergence.** the appearance of a plant thorough the surface of the soil.

**environmental contamination.** spread of pesticides away from the application site into the environment, usually with the potential for causing harm to organisms.

**eradicator.** a pesticide material that destroys or eradicates a pest or all life forms where it is applied.

- evaporate.** the process of a liquid turning into a gas or vapor.
- exposure.** the unwanted contact with pesticides or pesticide residues by people, other organisms, or the environment.
- extensional viscosity** the amount of stretching or stringiness required for a droplet to break off from a stream or flow of liquid.
- farm advisors.** University of California specialists in most counties of California who serve as resources for residents of the state on pest management, water management, soil management, nutrition, and many other issues.
- Federal Aviation Administration.** the federal agency responsible for enforcing rules affecting aircraft operations.
- ferrying.** the process of flying an aircraft from its home base to a pesticide application site and returning to its home base or location where the material loading takes place.
- field worker.** any person who, for any kind of compensation, performs cultural activities in a field. Field worker does not include individuals performing tasks as a crop advisor, including field checking or scouting, making observations of the well being of the plants, or taking samples, nor does it include local, state, or federal officials performing inspection, sampling, or other similar official duties.
- field worker training.** specific training mandated by the U.S. Environmental Protection Agency and the state of California to assist field workers in protecting themselves from pesticide residues when they work in areas that have received pesticide applications. Training is required if field workers enter areas during a 30-day period after the expiration of a restricted entry interval.
- filter screen.** fine screens placed in key locations in a spraying system to catch foreign materials that would otherwise clog the spray nozzles.
- fine.** a spray droplet that is 100 microns in diameter or smaller.
- first aid.** the immediate assistance provided to someone who has received an exposure to a pesticide. First aid for pesticide exposure usually involves removal of contaminated clothing and washing the affected area of the body to remove as much of the pesticide material as possible. First aid is not a substitute for competent medical treatment.
- flash.** to suddenly burst into flame, similar to an explosion.
- flow rate.** the amount of pesticide being expelled by a pesticide spray or granule applicator per unit of time.
- general use pesticide.** pesticides that have been designed for use by the public as well as by licensed or certified applicators. General use pesticides usually have minimal hazards and do not require a permit for purchase or use.
- geostationary communication satellite.** a satellite whose orbit speed exactly matches the rotation of the earth, and thus remains stationary in relation to the earth; used for communication and global positioning.
- global positioning system (GPS).** a navigational device that uses signals from satellites to determine the receiver's position.
- granule.** a dry formulation of a pesticide active ingredient and inert materials compressed into small, pebble-like shapes.

**ground effect.** when an aircraft flies low to the ground, air displaced by the aircraft hits the ground and is deflected upward, contributing to possible offside pesticide drift.

**growth regulator.** a type of insecticide that controls certain insects by disrupting the normal process of development from immature to reproductive life stages.

**handle.** mixing, loading, transferring, applying (including chemigation), or assisting with the application (including flagging) of pesticides; maintaining, servicing, repairing, cleaning, or handling equipment used in these activities that may contain residues; working with opened (including emptied but not rinsed) containers of pesticides; adjusting, repairing, or removing treatment site coverings; incorporating (mechanical or watered-in) pesticides into the soil; entering a treated area during any application or before the inhalation exposure level listed on pesticide product labeling has been reached or greenhouse ventilation criteria have been met; performing the duties of a crop advisor, including field checking or scouting, making observations of the well being of the plants, or taking samples during an application or any restricted entry interval listed on pesticide product labeling. Handle does not include local, state, or federal officials performing inspection, sampling, or other similar official duties.

**handler.** a person who mixes, loads, transfers, applies (including pilots), or assists with the application (including flagging) of pesticides; who maintains, services, repairs, cleans, or handles equipment used in these activities; who works with unsealed pesticide containers; who adjusts, repairs, or removes treatment site coverings; who incorporates pesticides into the soil; who enters a treated area during any application or before the restricted entry interval has expired; or who performs crop advisory duties.

**heat-related illness.** potentially life-threatening overheating of the body under working conditions that lack proper preventive measures, such as drinking plenty of water, taking frequent breaks in the shade to cool down, and removing or loosening personal protective equipment during breaks. California regulations require that pesticide handlers receive training on recognizing, avoiding, and treating heat illness.

**human flagger.** an individual who assists in an aerial application by positioning and waving marking flags to indicate to the pilot the location of swaths. Flaggers must receive pesticide handler training.

**incomplete metamorphosis.** the process found in several orders of insects where development from young (nymphs) to adults is gradual and without a resting pupal stage. Young usually resemble adults but do not have functioning wings.

**inhalation.** the method of entry of pesticides through the nose or mouth into the lungs.

**integrated pest management.** a pest management program that uses life history information and extensive monitoring to understand a pest and its potential for causing economic damage. Control is achieved through multiple approaches including prevention, cultural practices, pesticide applications, exclusion, natural enemies, and host resistance. The goal is to achieve long-term suppression of target pests with minimal impact on nontarget organisms and the environment.

- intentional misapplication.** the deliberate improper use of a pesticide, such as exceeding the label rate or applying the material to a site not listed on the label.
- inversion.** a weather phenomenon in which cool air near the ground is trapped by a layer of warmer air above. Vapors of pesticides applied during an inversion can become trapped and concentrated and move away from the treatment area with the potential to cause damage or injury at some other location.
- irreversible injury.** a health condition caused by certain exposures to some pesticides where there is no medical treatment or recovery.
- Journeyman Pest Control Aircraft Pilot Certificate.** a Department of Pesticide Regulation certificate given to a pilot who meets the qualifications prescribed in the California Code of Regulations and successfully passes the Laws, Regulations, and General Principles examination and the Journeyman Pest Control Aircraft Pilot certification examination.
- journeyman pilot.** a pilot who holds a current Journeyman Pest Control Aircraft Pilot Certificate.
- labeling.** the pesticide label and all associated materials, including supplemental labels, special local needs registration information, and manufacturer's information. The pesticide labeling are legal documents.
- light bar.** an accessory to the aircraft mounted global positioning system that enables the pilot to locate the center of each spray swath through the use of an array of lights.
- low volume (LV) application rate.** application of liquid pesticides at the rate of 0.5 to 5 gallons of liquid per acre.
- Material Safety Data Sheet (MSDS).** an information sheet provided by a pesticide manufacturer describing chemical qualities, hazards, safety precautions, and emergency procedures to be followed in case of a spill, fire, or other emergency.
- medical monitoring.** a requirement of California employers to arrange with a medical care provider to monitor the cholinesterase levels of employees who handle category 1 (DANGER) and category 2 (WARNING) organophosphate or N-methyl carbamate pesticides for more than 6 days in any 30-day period.
- medical supervision.** occupational health guidance and necessary associated health evaluation by a physician licensed to practice medicine.
- mesh.** the number of wires per inch in a screen, such as a screen used to filter foreign particles out of spray solutions to keep nozzles from becoming clogged. Mesh is also used to describe the size of pesticide granules, pellets, and dusts.
- metamorphosis.** the changes that take place in certain types of living organisms, such as insects, as they develop from eggs through adults. In some families of insects, the young do not resemble adults.
- microbial insecticide.** pertaining to pesticides that consist of bacteria, fungi, or viruses used for control of weeds, invertebrates, or (rarely) vertebrates.
- micron.** a very small unit of measure:  $\frac{1}{1,000,000}$  of a meter.
- miosis.** excessive contraction of the pupil of the eye.
- monocot.** a member of a group of plants whose seedlings have a single cotyledon; some monocots are known as grasses.

**MSDS.** see *material safety data sheet*.

**negligent application.** a pesticide application in which the applicator fails to exercise proper care or follow label instructions, potentially resulting in injury to people or surrounding areas.

**nonspecific herbicide.** an herbicide that will destroy any type of plant.

**nontarget organism.** animals or plants within a pesticide-treated area that are not intended to be controlled by the pesticide application.

**Notice of Intent.** oral or written notification to the agricultural commissioner, as specified by the commissioner, prior to the use of certain types of pesticides.

**offsite pesticide drift.** pesticide drift that moves outside of the application area during or immediately following a pesticide application.

**offsite pesticide movement.** any movement of a pesticide from the location where it was applied. Offsite movement occurs through drift, volatilization, percolation, water runoff, crop harvest, blowing dust, and by being carried away on organisms or equipment.

**oral.** through the mouth—this is one of the routes of entry of pesticides into the body.

**organophosphate.** a commonly used class of pesticides. Organophosphates are organic molecules containing phosphorus. Some organophosphates are highly toxic to people. Most break down in the environment very rapidly.

**output rate.** the amount of a pesticide mixture discharged by an aircraft over a measured period. The usual output rate for aircraft liquid sprayers is measured in gallons per minute or gallons per mile.

**pattern testing.** the process used to determine the spray swath or granule swath pattern by flying test passes and visualizing the droplet array or granule distribution across the swath.

**perennial.** a plant that lives longer than two years—some may live indefinitely. Some perennial plants lose their leaves and become dormant during winter; others may die back and resprout from underground root or stem structures each year. The evergreens are perennial plants that do not die back or become dormant.

**performance objectives (also *knowledge expectations*).** the breadth of knowledge about an occupation or procedure, such as pesticide handling, that a person performing this job is expected to have. Regulations establish minimal expectations for pesticide applicators, and certification examinations test a person's knowledge of these expectations.

**personal protective equipment (PPE).** apparel and devices worn to minimize human body contact with pesticides or pesticide residues. PPE must be provided by an employer and is separate from, or in addition to, work clothing. PPE may include chemical resistant suits, chemical resistant gloves, chemical resistant footwear, respiratory protection devices, chemical resistant aprons, chemical resistant headgear, protective eyewear, or a coverall (one- or two-piece garment).

**pesticide drift.** any movement of pesticide material from its intended swath during application. Movement of pesticide material becomes problematic when it moves from the application site.

**pesticide handler.** see *handler*.

- pH.** a measure of the concentration of hydrogen ions in a solution—as the number of hydrogen ions increase, the pH reading gets lower and the solution becomes more acidic.
- phytotoxic.** injurious to plants.
- pilot in command.** the Journeyman Pest Control Aircraft Pilot supervising or conducting a pesticide application.
- postemergence herbicide.** an herbicide applied after emergence of a specified weed or crop.
- precautionary statement.** the section on pesticide labels where human and environmental hazards are listed; personal protective equipment requirements are listed here as well as first aid instructions and information for physicians.
- preemergence herbicide.** an herbicide that controls specified weeds as they sprout from seeds before they push through the soil surface.
- preplant herbicide.** an herbicide that has been incorporated into the soil to control weeds prior to planting crop seeds.
- private agricultural aircraft operator.** a category of the FAA certification process applying to pilots who make pesticide applications by air on their own property or property they control.
- private applicator.** an individual who uses or supervises the use of a pesticide for producing an agricultural commodity on property owned, leased, or rented by him or her or his or her employer. In addition, a householder who uses or supervises the use of a pesticide, outside the confines of a residential dwelling for the purpose of controlling ornamental, plant, or turf pests on residential property owned, leased, or rented by that householder.
- prop wash.** the displacement of air and spray droplets caused by the propeller of the aircraft. The spray pattern is displaced to the left of the centerline of the aircraft.
- protectant.** a pesticide that provides a chemical barrier against pest attack.
- Qualified Applicator Certificate (QAC) holder.** a person who has qualified by examination in one or more pest control categories to supervise pesticide applications.
- Qualified Applicator Licensee (QAL).** a person who has qualified by examination in one or more pest control categories to supervise the pesticide applications made by a pest control business licensed in accordance with the California Food and Agricultural Code, and who is responsible for safe and legal operations under such license.
- qualified trainer.** an individual who possesses a valid California Qualified Applicator Certificate (QAC), Qualified Applicator License (QAL), or Pest Control Adviser License (PCA); an individual possessing a valid California Certified Private Applicator Certificate; an individual holding a valid County Biologist License in Pesticide Regulation or Investigation and Environmental Monitoring issued by the Department of Food and Agriculture; an individual holding employment as a farm advisor employed by the University of California Cooperative Extension Service; an individual holding a certificate of completion from a Department of Pesticide Regulation-approved instructor training program; an individual holding a valid California Registered Professional Forester license.



- racetrack flight pattern.** the application pattern that involves making successive overlapping loops across a field rather than a back and forth pattern.
- regulations.** the guidelines or working rules that a regulatory agency uses to carry out and enforce laws.
- rescue breathing** also known as artificial respiration. Given mouth-to-mouth to assist or restore breathing to a person overcome by pesticides. Rescue breathing is given if the victim has a pulse.
- residual effectiveness.** the pesticidal action of material after it has been applied. Most pesticide compounds will remain active several hours to several weeks or even months after being applied.
- restricted entry interval (REI).** the period after a field is treated with a pesticide during which restrictions on entry are in effect to protect people from potential exposure to hazardous levels of residues
- restricted use pesticide.** highly hazardous pesticides that can only be possessed or used by certified commercial or private applicators.
- reversible injury.** a pesticide-related injury (or illness) that can be reversed through medical intervention and/or the body's healing process.
- rotor distortion.** similar to prop wash of a fixed wing aircraft, but involving the displacement of air and entrapped spray droplets as a result of the rotation of the rotary wing aircraft rotor.
- selective herbicide.** an herbicide that controls only certain types of weeds and has little or no effect on other types of weeds.
- service container.** any container designed to hold concentrate or diluted pesticide mixtures, including the sprayer tank, but not the original pesticide container.
- shear viscosity.** the resistance of a liquid to flow.
- smoke generator.** a device mounted on an aircraft that produces smoke by injecting oil into the exhaust system. This smoke trail is used by the pilot to visualize air movement.
- statement of practical treatment.** a section of the pesticide label that provides information on treating people who have been exposed to the pesticide. This includes emergency first aid information.
- stomach poison.** a pesticide that kills target animals that ingest it.
- suffocating pesticide.** a pesticide, such as mineral or vegetable oil, that blocks the respiratory passages of target insect or mite pests.
- supplemental label.** additional instructions and information not found on the pesticide label because the label is too small but legally considered to be part of the pesticide labeling.
- supplied air respirator.** a tightly fitting facemask that is connected by hose to an air supply such as a tank worn on the back of the person using the respirator or to an external air supply. Supplied air respirators permit people to enter oxygen-deficient areas or areas where there are toxic pesticide vapors.
- swath.** the area covered by one pass of the pesticide application equipment.
- systemic herbicide.** an herbicide that is taken up through the plant leaves or stems and is translocated to another part of the plant, such as the roots, where it causes damage or injury.

**systemic pesticide.** a pesticide that is taken up into the tissues of the organism and transported to other locations where it will affect pests.

**temperature inversion.** see *inversion*.

**ultra low volume (ULV) application rate.** applications of less than 0.5 gallons of spray per acre.

**volume median diameter (VMD).** half of the total spray volume of a nozzle consists of spray droplets that are smaller than the VMD numerical value, while the other half is made up of droplets that are larger than the VMD numerical value.

**warning.** the signal word used on labels of pesticides considered moderately toxic or hazardous.

**waterproof.** a material that allows no measurable movement of the pesticide through it during use.

**work clothing.** garments such as long-sleeved shirts, short-sleeved shirts, long pants, short pants, shoes, and socks. Work clothing is not considered personal protective equipment although pesticide product labeling or regulations may require specific work clothing during some activities. Work clothing differs from and should not be confused with a coverall. While the employer shall provide coveralls, work clothing can be required to be provided by the employee. Short sleeved shirts and short pants are considered acceptable work clothing only under conditions expressly permitted by pesticide product labeling.

**wide area augmentation system (WAAS).** a highly accurate GPS navigational system used for precision flight positional determination.

**wingtip vortex.** the circular or spiral swirling of air caused by the wingtips of an aircraft, and resulting in entrapment of spray droplets affecting the dispersal pattern. Keeping the fixed wing aircraft boom length at approximately 75% of the wingspan eliminates spray droplets becoming entrapped.

**Worker Protection Standard.** the 1992 amendment to the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) that makes significant changes to pesticide labeling and mandates specific training of pesticide handlers and workers in production agriculture, commercial greenhouses and nurseries, and forests.

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