Aerial Applicator's MANUAL

A NATIONAL PESTICIDE APPLICATOR CERTIFICATION STUDY GUIDE

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INTRODUCTION

Applying pesticides by air is an important part of many agricultural pest management activities. If you are a pilot and plan to engage in this type of work, you must become proficient in making safe, legal, accurate, and effective pesticide applications from an aircraft. However, before you begin applying federal *restricted-use* pesticides for hire, you have to demonstrate your skills and knowledge through a certification process administered by a pesticide regulatory agency.

Pesticide regulatory agencies within states, tribes, and territories, as well as federal departments or agencies, are responsible for certifying pilots who intend to apply restricted-use pesticides to agricultural crops from aircraft. This federally-mandated certification process applies to pilots who make applications of restricted-use pesticides for hire and those who work for commercial pest control operators. State, tribal, and territorial pesticide regulatory agencies may require certification of pilots who apply other pesticides as well. Many state pesticide regulatory agencies in the U.S. have adopted the National Aerial Pesticide Applicator Pilot Certification Examination as their tool for pilot certification.

In addition to the National Aerial Pesticide Applicator Pilot Certification Examination, state pesticide regulatory agencies may require pilots to pass a core examination and possibly one or more category-specific examinations (agriculture, forest, right-of-way, aquatic, etc.) as part of their certification process. Check with the pesticide regulatory agency in whose jurisdiction you will be working for complete certification requirements. (See Appendix 1 for pesticide regulatory agency contact information). Requirements may differ from one jurisdiction to another, and you may need to participate in separate certification processes for each jurisdiction. In addition to the aerial applicator pilot certification requirements, Chapter 1 of this book covers the general standards set by Federal regulations for certifying all commercial pesticide applicator pilots and aerial pest control operators who apply federal restricted-use pesticides for hire.

Robert Wolf—Kansas State University

THE NATIONAL EXAMINATION

A team of experienced pilots and business owners who are actively engaged in aerial application of pesticides participated with an examination specialist to develop the National Aerial Pesticide Applicator Pilot Certification Examination. This committee identified the essential knowledge and skills each entry-level pilot applicator needs to competently, safely, and legally perform all aspects of aerial pesticide application.

The committee developed a Detailed Content Outline, included on pages 3 through 7, which serves as the blueprint for all examination questions and for this study manual. Before taking the examination, review this document so you understand the scope of knowledge and skills expected of you as you apply pesticides from an aircraft. The examination tests you on this knowledge and required skills.

SCOPE OF THIS MANUAL

This manual focuses on how to apply pesticides properly and safely from an aircraft. It includes all the content found on the National Aerial Pesticide Applicator Pilot Certification Examination and consists of the following six chapters:

1 — *Laws and Regulations for the Aerial Applicator Pilot*

2 — *Operation and Application Safety*

3 — *Preventing Pesticide Drift*

4 — *Aerial Pesticide Dispersal Systems*

5 — *Calibrating Aerial Application Equipment*

6 — *Making an Aerial Pesticide Application*

Also included in this manual is a glossary of terms, an index, and several appendices that provide additional information that may prove useful as you prepare for the examination.

How to Use this Manual

Since this is a study manual, the end of each chapter has a number of review questions to help test your understanding of the information you just read. These review questions are similar to the types of questions on the actual examination so they will help you become familiar with the examination style and process. Each chapter begins with a set of objectives corresponding to certain skills and knowledge expected of you as an aerial pesticide applicator pilot.

John Mateski—Newberg, OR

Read a chapter and then test your understanding of the material presented by answering the review questions. Check your answers to these questions by turning to page 97. If you miss some questions, go back and review sections of the chapter that covers that information. Repeat this process for each of the chapters. Information of special interest is organized into sidebars throughout the manual. You may find this information helpful in your work as an aerial application pilot.

DETAILED CONTENT OUTLINE

FOR

LICENSED/CERTIFIED AERIAL APPLICATOR PILOTS

I. OPERATIONS

A. Federal and State Regulation Compliance

1. Maintain requirements for a commercial pilot's certification for aerial application (e.g., biennial flight review, medical)
2. Comply with all FAA regulations
3. Recognize an area that may be construed as congested by the FAA
4. Plan flight patterns to avoid passes over residences, schools, communities, field workers, or animals
5. Comply with state regulations regarding aerial pesticide applications
6. Operate according to government regulations while applying good judgment during each application
7. Maintain aircraft according to generally-accepted maintenance practices
8. Tailor application plans to the job situation and locale while addressing requirements of regulatory agencies
9. Obtain the required FAA Part 137 knowledge and skills endorsement from the business owner/operator
10. For agricultural operations, communicate with the business owner/operator and grower:
    a. regarding job scheduling, rescheduling, and special considerations to meet Worker Protection Standard regulations
    b. ensuring they have proper documentation (label) regarding the application as required by the Worker Protection Standard regulations
11. Ensure proper notification is given, including required field posting, before starting an application

B. Field Operations

1. Secure aircraft so it cannot be accessed or flown by unauthorized personnel
2. Ensure:
    a. ground-support crew members can implement their job responsibilities

b. the area to be treated is clear
c. unplanned conditions have not arisen at the time of an application

3. Resist pressure to apply a product that presents unacceptable risk for the pilot, aircraft, public, surrounding crops, or wildlife
4. Refuse jobs that are unsafe or illegal
5. Participate in pre-application planning sessions and in post-application debriefings
6. Document special precautions required to protect sensitive areas or situations

II. COMMUNICATIONS

A. Mixer/Loader Supervision

1. Review responsibilities of the mixing-loading crew at the base and satellite locations
2. Ensure the proper product is loaded into the aircraft for each application
3. Perform minor in-field repairs on ground-support equipment
4. React in a positive and helpful way in an emergency situation (e.g., broken loading hose)

B. Pilot and Ground Crew

1. Use radio transceivers to communicate with the ground crew
2. Communicate information on work order changes in the field directly between the customer/field men and the business owner/operator or crew leader
3. Contact appropriate personnel when uncertain about any aspect of an application
4. Practice procedures and contingency plans to ensure necessary communications are detailed, quick, and accurate
5. Develop a strategy to notify a pilot when an aircraft should not be flown because of maintenance problems

III. APPLICATION SAFETY

A. Emergency Planning

1. Anticipate types of accidents or incidents that can happen during the course of an aerial application or loading operation
2. Devise a contingency plan for evacuating the aircraft in case of emergency
3. Review pilot and ground crew procedures for an aircraft crash

B. Pre- and Post-Flight Preparations

1. Check aircraft fuel and oil levels
2. Seek local advice regarding topography and sensitive areas when an application will occur in an unfamiliar location
3. Review an application job order to determine whether the job can be accomplished safely and adequately with reasonable precautions and work procedures
4. Inspect flight suits, safety harnesses, and flight helmets for proper operating condition
5. Wear a proper aviation flight helmet

6. Check the operation of seat restraints
7. Inspect:
   a. the fire extinguisher
   b. dispersal equipment (e.g., nozzles, hoses, connections) for signs of leakage and mechanical damage
8. Develop a procedure to ensure contaminates are not carried on clothes into the cockpit
9. Maintain maps and aerial photos if available and mark any obstacles, hazards, and sensitive areas
10. Survey a field before treatment noting sensitive situations including
    - field crews
    - traffic or individuals
    - crops in the vicinity
    - domestic animals and wildlife
    - aquatic areas
    - private residences
11. Check each field for in-flight hazards (e.g., towers, power lines, guy wires, irrigation pipes, and vent pipes) before each application begins
12. Report equipment deficiencies to the business owner/operator
13. Ensure known equipment deficiencies have been addressed
14. Protect employees from chemical exposure while changing nozzles and spray equipment configurations

C. Scheduling

1. Implement work schedules that provide adequate rest periods
2. Perform the most difficult and sensitive jobs when rested
3. Help the business owner/operator plan equipment overhaul activities prior to periods of high demand

D. Pesticide Label

1. Comply with label requirements and restrictions for aerial application of pesticides including:
   a. spray volumes (Gallons per Acre—GPA)
   b. buffers and no-spray zones
   c. weather conditions specific to wind and inversions
2. Interpret labels that do not include a reference to aerial use

IV. DISPERSAL EQUIPMENT

A. Selection

1. Inspect dispersal system components for proper operating condition including hopper/tank, pump, filters, pipes, and fittings
2. Select proper nozzles for desirable coverage and drift minimization
3. Describe:
   a. major components of an aerial application liquid dispersal system
   b. desirable features of pesticide hoppers and tanks
   c. primary ways pumps are powered, and requirements for location and output capacity

d. features, advantages, and disadvantages of a fan-driven pump
e. desirable features of pipes and fittings in an aerial dispersal system

4. List primary types of spray patterns produced by hydraulic nozzles
5. Describe:
   a. features of filters and screens
   b. hollow cone and flat fan patterns
6. Determine the number of nozzles for required sprayer output using manufacturer's specified nozzle flow volume chart, aircraft speed, and swath width

B. Position

1. Describe where:
   a. filters/screens should be located in the system
   b. pressure gauges should be positioned
2. Ensure
   a. booms and nozzles are positioned to release spray into a laminar airflow
   b. nozzles are placed to compensate for uneven dispersal from uneven airflow from:
      - wing tip vortices
      - aircraft propeller turbulence
      - high or low helicopter rotor speeds
3. Drop nozzles to either side of, or below, airflow obstructions (e.g., landing gear, oil coolers, boom hangers, pumps and swath markers) to minimize distortion of the spray pattern
4. Place nozzles:
   a. in the air stream to produce the appropriate droplet size consistent with boom pressure to give acceptable performance for each job while adhering to label restrictions
   b. along the boom to produce a uniform deposition on the target when the aircraft is flown at the normal spraying airspeed and altitude
5. Check swath pattern uniformity for each nozzle configuration used for various flows

C. Maintenance

1. Check dispersal system pressure gauge accuracy
2. Maintain appropriate dispersal system filter cleaning schedule
3. Check nozzles for excessive wear
4. Correct leaking nozzles, fittings, and diaphragms on the ground during loading by cleaning or replacing parts as often as needed
5. Keep:
   a. spray system connections and fittings tight and in good repair to minimize leaks
   b. the boom suck-back valve adjusted and in working order to ensure a positive shut-off and safeguard against leaking nozzles

D. Performance Measurement and Adjustment

1. Change nozzle tips and orifices as required for various flows
2. Calculate required and actual flow volumes, and actual output
3. Verify flow volume using fixed timing, open timing, known distance, or a flow meter
4. Adjust and calibrate:
   a. the aircraft dispersal system prior to use on a job
   b. after any modification is made to the aircraft or dispersal system

V. APPLICATION CONSIDERATIONS

A. Site-Specific Meteorological Criteria

1. Recognize application limits imposed by weather
2. Determine wind velocity, direction, and air density at the job site
3. Identify climatic conditions that:
   a. can affect aircraft engine power, take-off distance, and climb rate
   b. promote spray droplet evaporation
4. Anticipate air temperature and humidity effects on spray droplet size
5. Describe conditions associated with:
   a. thermals
   b. a temperature inversion

B. Minimizing Off-Target Product Movement

1. Assess risks of off-target movement
2. Refer to USDA Agricultural Research Service spreadsheet information and nozzle manufacturer fact sheets to facilitate nozzle selection and spray droplet size
3. Select proper nozzles, operating pressure, orientation, and placement to minimize spray drift
4. Relate:
   a. volume-median-diameter (VMD) and relative span to desired deposition
   b. physical properties of a product to on-target deposition
5. Using a smoke generator, determine if the spray has a potential to drift
6. Evaluate vertical and horizontal smoke plumes to assess wind direction, speed, and concentration
7. Identify positive air movement away from critical areas
8. Relate dispersal equipment configurations to airflow around the aircraft
9. Select techniques (e.g., boom shut-offs, cross-wind applications, buffer zones) that minimize product movement out of the treatment area
10. Apply product to headlands and edges of fields when drift potential is minimal
11. Document special equipment configurations or flight patterns used to reduce off-target movement

C. Making the Application

1. Select a flight altitude that minimizes streaking and off-target movement
2. Choose a flight pattern that provides the best performance and safety level for job conditions and operation mode
3. Engage and disengage spray precisely when entering and exiting a predetermined swath pattern
4. Utilize swath marking tools (e.g., GPS, flags)
5. Continuously evaluate an application to ensure uniform dispersal
6. Document the product(s) applied and application conditions

Glenn Martin—Gettysburg, PA

CHAPTER 1

Laws and Regulations for the Aerial Applicator Pilot

LEARNING OBJECTIVES

Studying this chapter will help you to:

- Understand why you must comply with federal, state, and local regulations regarding aerial pesticide applications while using good judgment, best management, and safety practices during each application.
- Understand the requirements for applying for a private or commercial pilot certification for aerial application of pesticides and how to maintain a valid certificate.
- Know the requirements and processes for maintaining an aircraft according to applicable regulations, safety practices, and aircraft manufacturer guidelines and recommendations.
- Tailor aerial pesticide applications to the job situation and locale while following the requirements of regulatory agencies.
- Recognize congested areas and the importance of planning flight patterns that avoid passes over residences, schools, communities, field workers, and animals.
- Comply with label requirements and restrictions for aerial application of pesticides and interpreting labels that do not include specific use directions for aerial use.

As an aerial pesticide applicator pilot, you must abide by all regulatory requirements and restrictions that pertain to pesticide handling and aerial pesticide application. Only under an extreme emergency, where the public or environment may be in danger, can you vary from any legal flight and aircraft handling requirements. Federal, state, tribal, territorial, and sometimes local laws and regulations address the handling and application of pesticides in the United States. These laws and regulations help:

- Provide for the proper, safe, and efficient uses of pesticides essential for the production of food and fiber and protecting public health and safety.

- Protect the environment by prohibiting, regulating, or controlling certain pesticide uses.
  - Assure agricultural and pest control workers of safe working conditions where pesticides are present.
  - Assure that aerial agricultural pest control is performed by qualified, competent, and responsible individuals.
  - Assure users that pesticides are appropriate for the use designated by the label.
  - Require that pesticide and service containers are properly labeled.
  - Encourage the development and implementation of pest management systems that stress the incorporation of biological and cultural pest control techniques with selective pesticide uses when necessary to achieve acceptable levels of control with the least possible harm to nontarget organisms and the environment.

Federal regulations applicable to the certification of people who apply pesticides and to pesticide handling and application are part of the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA). The U.S. Environmental Protection Agency (EPA) and state, tribal, and territorial pesticide regulatory agencies enforce the provisions of FIFRA. EPA regulations focus on applicator (pilot) job knowledge including pesticide handling and protecting people and the environment. State licensing, use, storage, handling, and disposal regulations, as well as tribal, territorial, and local regulations, often further regulate application procedures and pesticide uses in order to protect people and vulnerable sensitive areas or organisms.

The U.S. Federal Aviation Administration (FAA) certifies agricultural aircraft operations and enforces Federal Aviation Regulations (FARS) pertaining to aircraft operation. FARS Section 14, part 137 of the Code of Federal Regulations specifically addresses agricultural aircraft operations. An agricultural aircraft operation is a business that operates aircraft for the purpose of:

- Dispensing any economic poison.
- Dispensing any other substance intended for plant nourishment, soil treatment, propagation of plant life, or pest control.
- Engaging in dispensing activities directly affecting agriculture, horticulture, or forest preservation.

FAA regulations concern such areas as aircraft operation, aircraft inspection and maintenance, ferrying routes, operation altitude, pilot licensing, and medical exams. Appendix 2 provides a summary of the FAA agricultural aircraft operator certification requirements and process.

REQUIREMENTS FOR PILOT CERTIFICATION

Applicants for aerial applicator pilot certification must hold and maintain a commercial pilot's license and have a current Class II Medical Certificate. If you work as a pilot-in-command for an agricultural aircraft operator, you also need an endorsement letter from that operator or a person designated by that operator. The aircraft you fly must be equipped with approved and properly labeled seat belts and shoulder harnesses for each pilot station.

EPA Requirements

State-administered EPA pesticide applicator certification determines the competency of individual pilots who will be applying pesticides. You must demonstrate your knowledge of general aspects of pesticide handling and application as well as your knowledge of the specialized area or areas of application where you intend to work, e.g., agricultural crops, forests, rights-of-way, public health pest control.

Determination of Competency

State pesticide regulatory agencies use written examinations to determine your competency in using and handling pesticides. State competency standards must, at a minimum, conform to federal regulations. To prepare for examinations testing your knowledge of general aspects of pesticide handling and application, obtain a copy of the National Pesticide Applicator Certification Core Manual published by the National Association of State Departments of Agriculture Research Foundation, Washington, DC. You can download PDF versions of manual chapters at http://www.nasda.org/StaticContent/workersafety/. The manual covers the general standards listed below. States may also have additional study materials available to assist in preparing for the exam.

General Standards for All Certified Commercial Applicators

To become a certified commercial applicator, you must demonstrate practical knowledge of the principles and practices of pest control and safe pesticide use and handling. General standards of competency include the following categories.

Label and Labeling Comprehension. You must know the format and terminology of pesticide labels and labeling, including:

- Understanding instructions, warnings, terms, symbols, and other information commonly appearing on pesticide labels.
- Recognizing product classification: "general-use" or "restricted-use."
- Adhering to the requirement to use pesticides consistent with their label instructions.

Safety Factors. Regulations require you to understand:

- Pesticide toxicity and hazards to people.
- Symptoms of pesticide poisoning.
- The usual pesticide exposure routes.
- Types and causes of common pesticide accidents.
- The precautions necessary to guard against injury to applicators and other individuals in or near treated areas.
- The need for and proper use of protective clothing and equipment.
- First aid and other procedures to follow in case of a pesticide accident.
- Proper identification, storage, transport, handling, mixing procedures, and disposal methods for pesticides and used pesticide containers, including precautions to prevent children from having access to pesticides and pesticide containers.

Environment. You must recognize how the following factors possibly influence the environmental fate of pesticides:

- Weather and other climatic conditions.
- Types of terrain, soil, or other substrate.
- Drainage patterns.
- Presence of fish, wildlife, and other non-target organisms.

Pests. For effective pest control, you need to be able to identify relevant pests and recognize the common characteristics of pest organisms and their damage symptoms and signs. You must also understand pest development and biology relevant to identification and control.

Pesticides. Your knowledge of pesticides must include:

- Knowing the general types of pesticides.
- Being familiar with various types of formulations.
- Understanding compatibility, synergism, persistence, and animal and plant toxicity of the formulations.

- Recognizing hazards and residues associated with use.
- Being aware of factors that influence effectiveness or lead to such problems as pesticide resistance.
- Knowing the proper procedures for diluting pesticide concentrates.

Equipment. You must demonstrate your familiarity with types of application and mixing equipment and know the advantages and limitations of each. You must be proficient in calibrating and maintaining pesticide application equipment.

Application Techniques. Regulations require you to demonstrate proper application methods for various formulations of pesticides, their solutions, and choose the correct application technique to use in a given situation. You must demonstrate how to prevent drift and pesticide loss into the environment.

Laws and Regulations. You must also demonstrate your knowledge of applicable state and federal laws and regulations. States may require certification (examinations) in additional categories over and above the general standards. These additional categories align with various pesticide uses, such as agricultural pest control, rights-of-way vegetation control, vector control, or forest pest control.

THE PESTICIDE LABEL

The pesticide container label and associated labeling are important legal documents that contain directions and restrictions you must follow when making an aerial application. Some labels refer to other documents, such as endangered species area protection maps or the Worker Protection Standard provisions of the Code of Federal Regulations applicable to agricultural operations (40 CFR part 170). These and other documents referred to on pesticide labels become part of the pesticide labeling.

Some labels and associated labeling contain information specifically applicable to aerial application. Other labels and associated labeling contain information pertaining to any type of application method and do not provide specific instructions or precautions for aerial application. Certain pesticide labels prohibit the aerial application of the labeled material, so you must never apply these materials by air, even when mixed with other pesticides approved for aerial application.

Labels having specific aerial application information are usually easier to interpret than those that only provide general information. Examples of

The use of 80-degree or 110-degree flat-fan nozzles is highly recommended for optimum spray coverage and canopy penetration. To achieve uniform spray coverage, use nozzles and pressure that deliver MEDIUM spray droplets as indicated in nozzle manufacturer's catalogs and in accordance with ASAE standard S-572. Use screens that are 50 mesh or larger.

AERIAL APPLICATION

Herbicide should be applied in a minimum of 5 gallons of water per broadcast acre. Weed infestations should be treated before they become competitive with the crop.

To achieve uniform spray coverage, use nozzles and pressure that deliver MEDIUM spray droplets as indicated in nozzle manufacturer's catalogs and in accordance with ASAE standard S-572. DO NOT use raindrop nozzles.

Aerial applications with this product should be made at a maximum height of 10 feet above the crop with low drift nozzles at a maximum pressure of 40 psi. Avoid application under conditions where uniform coverage cannot be obtained or where excessive spray drift may occur.

Flagmen and loaders should avoid inhalation of spray mist and prolonged contact with skin.

See the ***SPRAY DRIFT MANAGEMENT*** section of this label for additional information on proper application of herbicide.

MIXING INSTRUCTIONS

Herbicide must be applied with clean and properly calibrated equipment. Prior to adding herbicide to the spray tank, ensure that the spray tank, filters, and nozzles have been thoroughly cleaned. In-line strainers and nozzle screens should be 50 mesh or coarser.

aerial-specific information covered in labels may include:

- Statements that refer to or allow aerial application.
- Specific use directions, such as for rate and dilution that apply directly to aerial applications without interpretation or calculations.
- Allowable weather conditions for applications.
- Restrictions pertaining to spray volume and dilution.
- Droplet size information based on ASABE S-572.1 (see Page 37) Spray Nozzle Classification by Droplet Spectra.
- Drift management requirements.
- Off-target and especially sensitive area precautions.
- Buffer zone requirements.

Manufacturers must register pesticide products with the EPA before anyone can buy or use them. The EPA registers specific products, not generic pesticide materials. This registration procedure protects people and the environment from ineffective or harmful chemicals. The registration procedure includes an evaluation of each chemical and establishes how the EPA classifies the material at the federal level. This evaluation determines whether the EPA classifies a pesticide as restricted-use or general-use. Only certified pesticide applicators can buy, use, or supervise the use of a federal restricted-use pesticide (RUP). States may also have specific registration and labeling requirements and may restrict the use of other products not classified as restricted-use by the EPA.

Regulations set the format for pesticide labels and prescribe what information they contain. Some pesticide containers are too small, however, to have all this information printed on them. In these cases, the EPA requires registrants or manufacturers to attach additional labeling. On metal and plastic containers, registrants or manufactures put such packets into plastic sleeves glued to the sides of the containers. Paper packages usually have label directions inserted under the bottom flaps of the package.

States or local regulatory agencies may impose additional restrictions or prohibitions on aerial applications that may or may not be included on the pesticide label. For example, local regulations may be more restrictive on requirements such as buffer areas, no-spray zones, and dilution rates. Always follow the requirements that are most restrictive in the location where you are making an application. For example, local agencies might prohibit aerial applications regardless of label use directions, or they might prohibit fixed-wing applications under certain circumstances and require that only rotary-winged aircraft make aerial applications in these situations.

Professional Aerial Applicator's Support System (PAASS)

A pesticide drift mitigation and education project initiated in 1996 by the National Agricultural Aviation Association (NAAA). PAASS is an industry-based collaborative educational effort that focuses on outreach to pilots and operators of aerial applicator businesses. The program's primary goals are to reduce the number of pesticide agricultural aviation accidents, improve pilot safety, and reduce pesticide drift incidents by fostering professionally-sound decision-making.

The PAASS interactive program improves critical decision-making skills sensitive to environmental factors. The agricultural aviation industry regards the PAASS program as the single relevant recurring training source for modern agricultural aviation pilots. Many companies providing insurance to agricultural aviators require pilots to participate in this training as a condition of insurability.

Statistics show that aerial application accidents and drift incidents have notably declined since the PAASS program first began.

Review Questions

CHAPTER 1: Laws and Regulations for the Aerial Applicator Pilot

1. **Pesticide laws and regulations help to:**
   - **A.** Encourage pesticide use.
   - **B.** Protect the environment.
   - **C.** Avoid dependence on alternative pest control methods.
   - **D.** Prevent pests from developing control resistance.

2. **Knowing the proper procedures for diluting pesticide concentrates is:**
   - **A.** An FAA requirement.
   - **B.** The requirement of local pesticide regulatory agencies.
   - **C.** Part of the federal Worker Protection Standard provisions.
   - **D.** An EPA general standard for certified applicators.

3. **The format of pesticide labels is established by:**
   - **A.** Pesticide manufacturer guidelines.
   - **B.** Federal regulations.
   - **C.** State laws.
   - **D.** ASABE professional standards.

4. **Knowing how to properly handle, mix, store, and dispose of pesticides is a requirement of the:**
   - **A.** Environmental Protection Agency (EPA).
   - **B.** Occupational Safety and Health Administration (OSHA).
   - **C.** United States Department of Agriculture (USDA).
   - **D.** Federal Aviation Administration (FAA).

5. **One purpose of federal pesticide regulations is to:**
   - **A.** Require public notification about pesticide applications.
   - **B.** Provide health benefits to agricultural workers.
   - **C.** Establish safety standards for pesticide application equipment.
   - **D.** Prevent agricultural workers from handling pesticides or working in pesticide-treated areas.

6. **State pesticide regulatory agencies generally have the responsibility for:**
   - **A.** Certifying commercial pesticide applicators.
   - **B.** Determining the personal protective equipment required on pesticide labels.
   - **C.** Developing material safety data sheets (MSDS).
   - **D.** Identifying endangered species.

7. **In addition to the actual pesticide label, which of the following is part of the pesticide labeling?**
   - **A.** Any product sales brochures.
   - **B.** The job work order.
   - **C.** Worker Protection Standard provisions.
   - **D.** The Material Safety Data Sheet.

8. **Which of the following is one of the requirements for pesticide applicator certification?**
   - **A.** Knowing how to use appropriate application methods for various pesticide formulations.
   - **B.** Demonstrating safe aircraft operation.
   - **C.** Following recommended aircraft inspection and maintenance schedules.
   - **D.** Making applications at altitudes specified in regulations.

9. From the choices below, what pesticide use information found on a product label would be specific to an aerial application?

- **A.** PPE requirements.
- **B.** ASABE droplet size requirements.
- **C.** Field posting requirements.
- **D.** Restricted-entry interval requirements.

10. Having a current Class II Medical Certificate is a requirement of the _____ for all pilots making aerial pesticide applications.

- **A.** U.S. Environmental Protection Agency (EPA).
- **B.** State Lead Agency (SLA).
- **C.** Federal Aviation Agency (FAA).
- **D.** National Transportation Safety Board (NTSB).

REVIEW QUESTION ANSWERS ON PAGE 97

CHAPTER 2

Operation and Application Safety

LEARNING OBJECTIVES

This chapter will assist you to:

- Understand the importance of preventing security threats to the operations and reducing hazards to the public from unauthorized or illegal access to the aircraft, pesticide materials, and equipment.
- Understand the importance of protecting people and the environment from hazards associated with aerial application of pesticides.
- Know steps to make pesticide applications that are safe for you and the ground operations crew.
- Understand what precautions to take to protect sensitive areas while making pesticide applications from an aircraft.
- Recognize the importance of good communications with the ground operations crew and others before, during, and after making pesticide applications.
- Prepare for emergencies, including knowing proper first-aid procedures for pesticide exposure and related illnesses or injuries, and heat-related illnesses.

Safety awareness and practices in all as-pects of an aerial pesticide application operation protects employees, the public, and the environment. Your operation needs procedures to secure the aircraft, ground equipment, and pesticide materials when not in use to prevent unauthorized access. Unauthorized access can range from individuals wanting to damage or burglarize property to crimes of opportunity, such as unplanned acts of vandalism. There is also the possibility that people are unaware of the hazards associated with a pesticide application operation while inadvertently gaining access to the facility. An example would be children who might be curious about and attracted to aircraft or other pesticide use equipment, thereby trespassing to inspect the equipment when company personnel are not at the facility. In addition to securing the facility, you can protect people and

the environment by carefully planning each function of the application operation to avoid accidents and hazards. Provide safety training to ground crew members so they know how to handle pesticides properly and work carefully around aircraft and other associated equipment.

Make sure each person involved in the application operation is well rested, alert, and not under the influence of alcohol or drugs. Develop reliable methods of communication between you, the customers, and ground operations. In case an accident or mishap should occur, take immediate steps to reduce damage and injury, including performing proper first aid and decontamination procedures for pesticide exposure.

AIRCRAFT AND PESTICIDE SECURITY

Progressive and conscientious operations that handle pesticides work to actively manage risks to ensure the safety of their employees, their customers, and their communities. They focus on safely operating aircraft and mixing-loading equipment. To achieve these goals, they use preventative maintenance, up-to-date operating procedures, and well-trained staff. Because of heightened concerns about terrorism and sabotage, the operation must also pay more attention to the security of aerial application equipment, facility sites, and pesticide storage areas. All aerial application operations need some measure of site security in place to minimize crime, prevent unauthorized access, and protect company assets.

While many of the steps you take to ensure an effective security program seem routine, they are important to the health and safety of the aerial application operation staff and the surrounding community. Without effective security procedures, the business risks being vulnerable to both internal and external threats, which can pose hazards to you and the employees, sensitive business information, the facilities and equipment, and stored pesticides.

Evaluating Aerial Application Operation Security

There are several important security needs and critical control points for an aerial application operation.

Securing Facilities, Storage Areas, and Surrounding Property

One of the most fundamental security needs is keeping intruders out of areas used for pesticide storage. Elements of an effective security plan can range from basic fencing, lighting, and locks, to intrusion detection systems and cameras. Inventory management policies help limit the amount of pesticides stored on site, reducing the risks of accidental or intentional release or theft.

Securing Pesticide Application Aircraft, Vehicles, and Equipment

The operation you work for needs appropriate security protections to prevent intruder access to equipment used for mixing, loading, and applying pesticides. Accepted methods to prevent unauthorized flying of aircraft include installing hidden electrical system shut-off switches, parking disabled trucks or other equipment in front and back of aircraft, removing batteries from aircraft, using devices that lock propellers or rotors, and disabling engines in unused aircraft. Use similar methods to prevent intruders from operating ground vehicles, such as trucks, tractors, forklifts, and other motorized equipment. Always park the aircraft in a secure place when it is not in use. In addition, establish methods to know at all times the location and status of all equipment used in the operation. Routinely update equipment records.

Security awareness is particularly important for large-scale pesticide application equipment, like aircraft. The Federal Bureau of Investigations (FBI) requests that aerial operators 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. If you observe any suspicious behavior, irregular circumstances, or unusual requests for information, immediately report this to a local law enforcement agency and the FBI.

Employees

Effective hiring and labor relations policies are important to obtain and retain good employees who will support and follow the operation's safety precautions. The hiring process should ensure that pesticide handlers have all requisite training necessary to handle pesticides safely. Background checks of employees who will have access to secure areas, particularly those areas where pesticides are stored, can be an important employee selection tool.

Emergency Response

Effective emergency response procedures help to 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 need to consider vandalism, burglary, arson and bomb threats that target the operation, and potential widespread terrorist activity that involves the equipment or pesticides.

Minnesota Department of Agriculture

Timely Coordination with Authorities

If a breach of security or suspicious activity does occur, immediately contact the local police or sheriff's department. The U.S. Department of Homeland Security requests that operations also report security breaches, threats, or suspicious behavior to the local FBI field office. Information on the location of the nearest FBI office is available at http://www.fbi.gov.

PROTECTING PEOPLE AND THE ENVIRONMENT

The aerial application operation you work for depends on your piloting skills as well as competent ground crew members who safely and responsibly carry out their duties. Proper training and enforcing safety practices within the operation help reduce hazards to ground crew members working around equipment and aircraft. In addition, a well-developed safety program provides the structure to protect the public and nontarget areas from pesticide exposure. Providing training, assuring good employee habits, checking areas before an application, and resisting pressure to make unsafe or illegal applications are important components of the operation that protect people, areas surrounding treatment sites, and the environment.

Employee Training

States have Occupational Safety and Health Administration (OSHA) regulations that require employers to train employees on how to safely operate equipment and avoid hazards associated with their work. The EPA Worker Protection Standard (WPS) mandates specific training requirements for employees who handle pesticides in agricultural operations. According to this regulation, a pesticide handler in an aerial application operation is any employee who:

- Mixes, loads, transfers, or applies pesticides.
- 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.

California Agricultural Aircraft Association

California Agricultural Aircraft Association

- Flags during aerial applications.

The Worker Protection Standard requires that employers in agricultural operations provide training to pesticide handlers working in their operations. Employers must either provide the training themselves or arrange for someone else to provide it.

The Training Program

The WPS requires that a pesticide handler training program address the following topics as they apply to the specific pesticide materials employees handle:

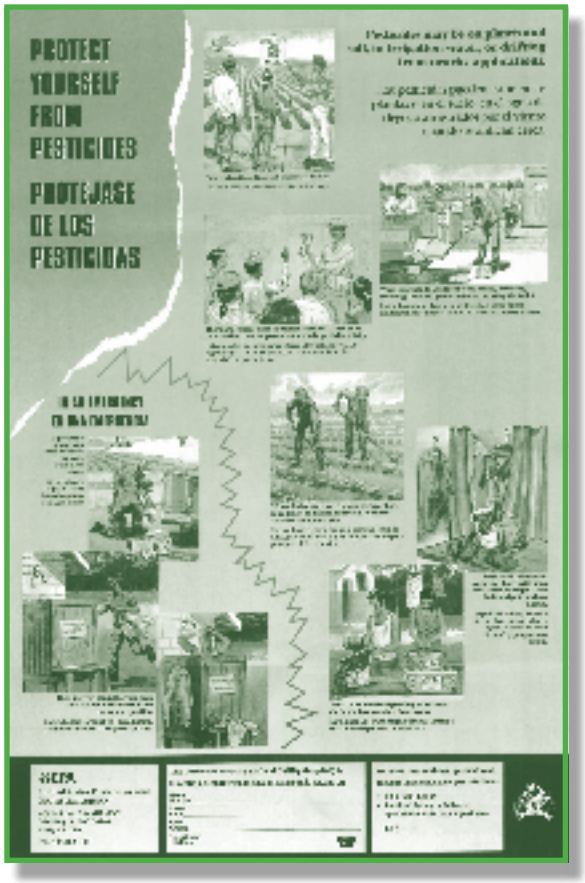
- Understanding the format and meaning of information, such as precautionary statements about human health hazards, contained in the labeling of the pesticide products.
- Understanding the health hazards associated with pesticides handled by employees, including acute and chronic effects, delayed effects, and sensitization, as identified in pesticide product labeling.
- Knowing the routes by which pesticides can enter the body.
- Recognizing how exposure occurs and being familiar with signs and symptoms of exposure-related injury or illness.
- Knowing specific emergency first-aid procedures for overexposure to the pesticides that employees handle.
- Knowing how to obtain emergency medical care when a pesticide injury or illness occurs.
- Knowing routine and emergency decontamination procedures, including spill clean up and the need to thoroughly shower with soap and warm water after the pesticide handling exposure period.
- Understanding the pesticide label requirements for using personal protective equipment (PPE), recognizing its limitations, knowing how to use and clean it properly, and knowing how and when to repair or replace it.
- Knowing how to prevent, recognize, and provide first aid for heat-related illness.
- Understanding safety requirements and procedures for pesticide handling, including the use of engineering controls (such as closed mixing systems and enclosed cabs), and proper ways to transport, store, and dispose of pesticides and properly rinsed containers.
- Recognizing how drift and runoff cause environmental damage and hazards to wildlife.
- Understanding why it is unsafe to take pesticides or pesticide containers home.
- Knowing what is required to handle pesticides safely.

- 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 Important Topics

Training must include the following general pesticide handling procedures that apply to all pesticide products:

- Understanding the importance of wearing clean work clothing daily.
- Knowing how to properly and safely handle, open, and lift containers.
- 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 legally recycle or dispose of empty containers.
- Knowing how to confine spray to the target area.
- Knowing how to avoid contaminating people, animals, waterways, and other non-target objects and areas.
- Knowing how and where to properly and safely store containers that hold pesticides or have been emptied but not rinsed.
- Understanding and following procedures to prevent unauthorized access when containers cannot be locked up or otherwise secured.
- Understanding the importance of washing hands thoroughly before eating, smoking, drinking, or using the restroom.



Consult with your state pesticide regulatory agency to see if there are any additional training requirements for pesticide handlers.

Federal WPS regulations require pesticide handlers receive training every five years at a minimum. States may require more frequent training. Training must take place before any pesticide handling activities. Employees who are certified as pesticide applicators are exempt from this training requirement.

Employee Habits

Every aerial pesticide application requires alertness and attention to detail. Before and during work periods, you and the ground crew members should never use alcohol or any drugs or medications that impair judgment or decrease mental alertness. Employees who wear personal protective equipment 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 the ability to handle or apply pesticides safely. These substances may also alter the toxicity of pesticides in case of exposure. Make your physician aware of your occupation handling pesticides so that is considered when prescribing medications. Do not use alcohol or drugs before, during, or immediately after handling pesticides, or before or during flight operations.

Staying Alert

Physical and mental alertness requires that you and the ground crew get sufficient sleep before an application operation and avoid other activities prior to the operation that cause fatigue. In addition, stress from work or personal activities distracts and interferes with alertness. Therefore, individuals experiencing high levels of stress should not participate in aerial application operations.

Preventing Dehydration and Heat-Related Illness

Drinking insufficient water coupled with wearing personal protective equipment during hot weather may lead to heat-related illness that 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. Along with training on recognizing pesticide illness, WPS regulations require that pesticide handlers receive training on recognizing, avoiding, and treating heat stress. Appendix 3 describes useful methods to avoid and treat heat stress.

APPLICATION SAFETY

Aerial application safety processes and procedures involve the highly important components of the aircraft, the pesticide dispersal system installed on the aircraft, and ground equipment used to mix pesticides and load them into the aircraft.

Each pesticide application you make is possibly unique for you because of differences between application site locations, obstacles, non-target areas, weather, pesticide materials, crops or target areas, and other variables. Therefore, you and the ground crew must begin by clearly understanding the work order and the pesticide label. Arrange to scout the target site and surrounding areas so you can plan the application before scheduling it. Review the pesticide label to understand application restrictions and precautions and to prepare for emergencies or other problems. Some pesticide materials may have local application restrictions such as time of use, height of application, prohibitions due to nearby sensitive crops, and requirements for buffer zones. Check with state or local pesticide regulatory agencies if you need information about additional restrictions.

Glenn Martin—Gettysburg, PA

The Equipment

As a pilot, you must understand the importance of, and legal requirements for, scheduled inspections, servicing, and maintenance of the aircraft you fly. Take responsibility to assure the aircraft meets these requirements. This includes a preflight fuel and oil check, taking responsibility for proper fueling of the aircraft, and inspecting the aircraft for maintenance items each time you stop the operation for the day or for a

rest break. In addition, any 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 been inspected under a progressive inspection system. Congested areas include populated areas where chances of personal injury or property damage are greater if the aircraft should crash or if you must dump the pesticide load.

Have the aircraft's application equipment inspected and maintained regularly to assure that it functions properly and accurately and does not have leaks or other problems. When something malfunctions, repair it immediately. Make a daily inspection of the aircraft's application equipment, the same as you do for the aircraft. After winter storage of the aircraft's dispersal system, carefully inspect it for wear and leaks. Make sure all hoses are in good condition and tighten all fittings. Look for seepage around the pump housing that indicates a leaking gasket or loose connections.

Also, establish an inspection and maintenance program for ground equipment used for mixing and loading pesticide materials into the aircraft, as well as ground vehicles used to transport people, pesticides, and equipment. Keep all associated equipment in good repair. Any breakdown in this equipment will delay the pesticide application, wreak havoc with scheduling, and could be costly to the business and customers.

Keep on hand spare parts and supplies, such as nozzles, hoses, fittings, drive belts, fuel, lubricants, and other components that are critical to the operation. Replace spare parts and supplies used during a breakdown so you always are ready for future operations.

Understanding the Work Order

Review the work order carefully to be certain you can make the application safely, correctly, and legally, according to the label and state and federal regulations. You should be able to perform the requested work with reasonable precaution and within the expectations of normal work procedures for both yourself and the ground crew. Take into account the following factors when evaluating a work order.

Features and Limitations of the Aircraft

The aircraft must be operationally ready to perform the aerial pesticide application. Be sure that the operator you work for has a procedure in place to prevent use of an unsafe aircraft or faulty dispersal equipment and to notify you in situations when you or others should not fly the aircraft due to maintenance issues or mechanical malfunctions. This includes involving the company's job scheduler in all company procedures for grounding an aircraft. Take responsibility for notifying the operator of problems that may affect the safety or efficient operation of the aircraft or involve your safety equipment. This includes:

- Developing a way to communicate details of the problem to the person in charge.
- Establishing a timeline in which the problem needs to be corrected.
- Verifying that the problem is corrected before putting the aircraft or equipment back into service.

The aircraft must be capable of safely delivering the appropriate amount of pesticide to the target site. It must:

- Have the power and performance capabilities for the routine maneuvers needed to carry out the application, as well as being able to perform emergency maneuvers.
- 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 (acre) of target site area.
- Be able to produce and deliver spray droplets that provide an effective application and have low spray drift potential at the intended location.

Pilot Qualifications and Limitations

Your competence, alertness, and capacity for timely and accurate judgment largely determine the safety of the operation and the quality of the application. In addition, your attitude about making safe and legal applications goes a long way in positively influencing others to accept and follow the safety procedures. You must be:

- Aware of your personal limitations in operating the aircraft and be fully aware of the features and limitations of the aircraft.

California Agricultural Aircraft Association

Robert Wolf—Kansas State University

- Capable of executing emergency maneuvers appropriate to common emergency situations that you might experience.
- Capable of safely maneuvering the aircraft under normal flight conditions when it is loaded to its maximum legal weight.
- Able to determine the best direction in which to apply the pesticide to reduce its off-target movement.
- Capable of immediate and clear communication exchanges with on-site ground crew members and others.
- Sufficiently rested to accomplish the job safely.
- 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 work order and observe any state regulations regarding aircraft setup or product restrictions.
- Familiar with each pesticide product label to know first-aid measures in the event of accidental overexposure, special precautions required for aerial application, and registered crops or sites.
- Able to recognize different types of crops from the air in order to ensure the correct site is treated.
- Able to delineate boundaries of adjacent nontarget areas.

Take the following measures to reduce the potential for spray droplets to drift off the application site:

- Use a nozzle type, size, pressure, and orientation that maintains the desired droplet spectrum.
- Ensure 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 the appropriate height for the aircraft type and speed.
- Use a boom length that does not exceed 75% of the wingspan of

fixed-wing aircraft or the rotor diameter of rotary-wing aircraft in order to reduce drift caused by wing tip and rotor vortices.

- Consult the pesticide label for recommendations on boom type and setup requirements.

Scouting the Target Site

Each application site may contain unique obstacles and hazards. Before committing to make an application, someone from the operation should visit the target site to identify obstacles, hazards, and sensitive areas. Do this by ground, by air, or both. Afterwards, coordinate visual observations with maps and photographs of the area. Should the application site and surroundings be unfamiliar, seek more information regarding weather patterns, topography, and sensitive areas from the property operator and other people familiar with the area. During scouting, collect information about the:

- Location of the site and the size and shape of the area to be treated.
- Types of crops adjacent to the application site.
- Proximity of the site to adjacent fields and other areas where field workers may be present.
- 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, feedlots, swine operations, dog kennels, and horse stables.

USDA—ARS Image Library

- 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.

Charting all sensitive areas and obstacles will prove useful during the operation and for future reference. Established aerial pest control operators often have a collection of maps and aerial photographs that identify hazards and sensitive areas. Be sure to keep these up-to-date. Prior to the actual application, make a final check to confirm there are no recent changes that would put you, other people, the property, or the surrounding areas at risk.

Understanding Pesticide Label Restrictions

Review the pesticide label to understand the legal requirements and use restrictions for that material and designations of which type of aircraft is or is not acceptable. If the recommendation or work order calls for a tank mix of two

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PREVENTING ENVIRONMENTAL HAZARDS

or more pesticide products, review the labels of all the products to ensure you can combine them legally and that there are no compatibility issues. Follow the directions of each label having the most restrictive requirements for application, mixing, personal protective equipment, and other factors. You must understand the pesticide label.

Application Instructions

Confirm that there are no prohibitions to applying any of the prescribed materials by air. Check to see if there are restrictions such as buffer areas, spray material dilution parameters, air temperature requirements during application, and time of day spraying.

Personal Protective Equipment Requirements

Understand the PPE requirements on the label or labels and have available the most restrictive PPE required for handlers and you when you are outside of the aircraft cockpit. Make sure your flight suit, safety harness, and flight helmet are in good condition. Remove pesticide PPE before entering the aircraft cockpit.

First Aid and Decontamination Requirements

Read the label or labels for instructions on what type of first aid and decontamination procedures to follow in case of pesticide exposure.

Sensitive Crop Restrictions

Review all label precautions regarding applying the material onto or near sensitive crops or other plants.

Notification and Posting Requirements

Understand the responsibilities for informing people about hazards prior to making an application and any requirements for preventing entry by workers or people from the surrounding areas. Pesticide labels may require oral notification, field posting, or both. According to the Worker Protection Standard, agricultural employers are responsible for this notification and, when required, posting. However, aerial operations often post fields as a service to their clients. Never begin an application until the grower, property manager, or you meet the notification and posting requirements.

Honey Bee and Other Pollinating Insect Restrictions

Check the labels to see if the materials you are applying are harmful to foraging honey bees and other pollinating insects. If the label has such warnings or restrictions, adjust the application time to coincide with times these insects are most predictably not in the field you are treating.

Environmental Hazards

Check for precautions relating to environmentally sensitive areas, protecting natural enemies and beneficial insects, and other environmental hazards.

Cleaning Application Equipment

After each use, clean and decontaminate application equipment. Even some very small quantities of residues remaining in a tank can contaminate subsequent pesticide mixtures resulting in crop damage. Other times residues may affect tank mix compatibility or the toxicity of a subsequent product. Be particularly careful and clean between herbicides. Some herbicide labels bear explicit instructions on tank cleaning; make sure you follow their instructions and use their prescribed cleaning materials.

Rinse the inside of the tank with water. If necessary, decontaminate it by using an appropriate tank cleaning material; common cleaners are ammonia or commercial tank cleaning product (e.g., 1 quart of household ammonia to each 25 gallons of water). Buy commercial pesticide tank cleaning and neutralizing compounds from chemical suppliers and farm equipment dealers. Be sure to check the pesticide label for any precautions regarding the use and disposal of cleaning and decontaminating chemicals. Follow the directions for the amount of cleaner to use for your spray tank. Be sure to run pumps and agitators, and flush all hoses and booms. Wear appropriate PPE and eye protection.

Pesticide residue on the outside of application equipment can be hazardous to people who must operate or repair this equipment. Wash the outside of spray equipment with water, using a small amount of detergent if necessary. Clean equipment in an area where you can contain runoff. Otherwise, clean the equipment at the application site.

Resolving Conflicts

If the work order appears to be in conflict with any of the previously-listed factors, or if you or others have any safety concerns, delay the application until you and the property manager agree on modifications that resolve the conflicts and concerns. Resist pressure to perform an aerial application that presents high levels of risk. Also, refuse any job that is clearly illegal or not in compliance with any of the pesticide labels. Never apply a material for pest control that the EPA has not registered as a pesticide. This includes household and other products whose labels do not have EPA Registration numbers, such as soaps, spices, and vinegars.

Reviewing and Documenting the Application

After completing an application, especially a challenging one, spend time with the ground crew to identify parts of the operation that went especially well and things you could improve when working in another similar situation. Examine possibilities of better planning, better communication, making different adjustments to the equipment, using different equipment, becoming more familiar with the target site, or changing other aspects of the application process. A debriefing such as this will take a little time, but will improve efficiency and fine-tune future operations.

Record Keeping

Keep records of every application. Federal regulations require keeping records of certain information when you make applications of federally restricted-use pesticides, and some states require keeping records of all agricultural pesticide applications—restricted- and general-use (www.pesticidestewardship.org). To comply with federal record keeping when you make an application of federally restricted-use pesticides, you must have a record of the:

- Date (month, day, and year) of the application.
- Brand or product name of the pesticide material applied.
- EPA registration number.
- Total quantity of pesticide product used.
- Location where you made the application.
- Size of the treated area.
- Name and certification number of the applicator.

Regulations require the operator to provide this information to the grower or property manager for whom you made the application within 30 days of the application. Federal regulations require the operator to keep copies of these records for a minimum of two years; state requirements may differ.

In addition to meeting federal and state requirements, application records are useful and important information for future reference and should questions or problems show up after an application. Consider including in the application records some or all of the following additional or more detailed information about the application. This documentation will serve in your defense in case of possible legal action due to crop damage or off-target movement of the pesticide:

- Description of the application site, including type of site or crop treated.
- Proximity of the treated area to roads, structures, other crops, field workers, hazards, and sensitive sites.
- Recent or ongoing cultural practices (such as irrigation) at the application site.
- The date and time the application started and the time the application finished.

- Weather conditions at the time of application—air stability, temperature, humidity, wind speed, and wind direction recorded in degrees using a compass.
- Any changes in weather conditions occurring during the application.
- Names and amounts of all pesticides and adjuvants applied, and the dilution rate.
- Application equipment configuration, including nozzle type, size, spacing, pressure, and orientation.
- Application pattern and directions in which you flew the swaths.
- Application speed and height.
- Precautions taken to protect sensitive areas.
- Location of the mixing-loading site.
- Routes taken for ferrying between the loading site and target area.
- Names of ground crew members and people present at the site during the application.
- Observations made by you, the ground crew, or others that may have had any influence on the operation.

Save all electronic files from an application, including flight data and the **as-applied** map files from the GPS system. These files serve as documentation for much of the information included in your records.

PLANNING FOR EMERGENCIES

A very important 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, helps everyone know how to respond and reduces the possibility of injury or death. Emergency planning must include providing ground crew members at the loading zone and satellite strips with emergency telephone numbers. Equip the aircraft and loading areas with first-aid kits and ensure the aircraft has a working and properly-labeled fire extinguisher. Have a complete spill cleanup kit at the loading area. Develop a plan of action for ground crew members to follow in case your aircraft is overdue at the loading site or home base.

Train everyone in emergency response by actually play acting on how to deal with different emergency situations. Practicing also helps to point out deficiencies in the emergency response plan so you and the ground crew can correct them.

Emergency Information

Locate the nearest medical facility to the application site and provide each crewmember with instructions on how to get there. A good strategy is to discuss the type of operation and its hazards with staff of nearby medical facilities to prepare them in advance for possible pesticide emergencies. Train all members of the ground crew how to direct emergency responders to the application or mixing-loading site. Equip members of the application operation with cell phones or radios to call for emergency help or to arrange transport of an injured person to a medical facility. Provide them with telephone numbers of the local hospital, fire department, police or sheriff's department, and local Flight Standards District Office (FSDO). These numbers may change when using different landing areas, so prepare lists for each specific location.

Flight Hazards

Whenever possible, have a ground crew member present at the application site who is able to communicate with you during the entire operation. This person can warn you of hazards and notify you of problems on the ground that require stopping or delaying the application. The ground crew member should communicate with anyone on the ground

who might be at risk during the application, and take action to warn them or escort them from the area. Provide this ground crew member with a map that shows the hazards and sensitive areas within the application site and in surrounding areas.

Plans in Case of Aircraft Crash

Make emergency plans for catastrophic events such as aircraft engine or landing gear failure leading to a forced landing or crash. This requires training every member of the ground crew to respond immediately, act promptly, stay calm, and focus on helping you. Should a crash occur, switch off the aircraft's batteries and shut off its fuel line. If you are uninjured yet unable to open the cockpit door, break open a window and exit the aircraft as quickly as possible. Instruct ground crew to get to the crash site immediately with a fire extinguisher and to communicate the exact location of the site to emergency responders and others by cell phone or radio.

Application Equipment Malfunction

Application equipment malfunction could include ruptured hoses or lines, a tank leak, pump failure, nozzle and check valve leaks, or electronic controller failure. Any of these problems risk contaminating areas outside of the target area and may require a load jettison before the aircraft can return to an airport for repairs. Prepare for this type of emergency by locating possible places to jettison the load or to set down the aircraft. Any route you take with an aircraft having a pesticide leak should be over areas not occupied by people or animals. To protect the public when experiencing any emergency of this type, FAA regulations permit you to deviate from required flight patterns and other restrictions.

Ground Crew Emergencies

Ground crew emergencies include leaks and spills of concentrated pesticides or diluted spray materials as well as splashes or spills that contaminate one or more of the ground crew members. It could also be a fire involving pesticide materials. These serious problems require immediate action to protect people and the environment. Regulations require that pesticide labels be at the use site, which includes the area you are spraying, in addition to the mixing-loading site. There is an exemption to this requirement for aerial applications as long as you maintain radio contact with the ground crew and any flaggers. Labels serve as references for emergency personnel responding to accidents involving spills and they provide first-aid information in case of pesticide exposure.

The ground crew must first take steps to prevent any human exposure and then immediately control, contain, and clean up spills or leaks to prevent further contamination of the mixing-loading area. Preparations for a leak or spill emergency includes training and practicing cleanup procedures and having an adequately equipped spill cleanup kit at the mixing-loading site at all times. Train handlers performing the mixing-loading jobs on proper ways to clean up a spill (see Appendix 4). Provide them with a cell phone or radio to summon help for major spills or in case of a pesticide fire or other emergency. Keep instruction sheets at the mixing-loading site for cleaning up spills, dealing with pesticide fires, and situations requiring assistance from fire fighters or emergency medical technicians.

Train handlers how to follow the first-aid information on the pesticide label if someone involved in mixing-loading activities gets exposed to a pesticide. Be sure there is sufficient clean water for emergency eye washing and decontamination of the entire body. Have soap and single use towels available at the mixing-loading site along with changes of clothing for each crew member.

Overspray, Drift, and Other Misapplication

As the applicator, you assume responsibility for any pesticide misapplication. Overspray, off-target movement, and other types of misapplication may damage surrounding

crops, residential plantings, landscapes, and other property, as well as cause environmental contamination. These are all violations of pesticide labels as well as many state pesticide control laws. Train ground crews to be alert during an application and quickly communicate with you if they spot any potential for such problems. Considerable financial liability and legal consequences may result from any damage caused by misapplication.

Spray or Dust Contacting Bystanders or Vehicles

It is illegal to apply any pesticide in a manner that exposes people, livestock, vehicles, and other objects 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, especially wind direction, can also change rapidly, causing pesticide from the application to move off site and possibly onto workers or other people nearby. For example, you might plan and begin an application based on the wind blowing away from nearby areas where people are present. However, during the application the wind direction could change and blow towards these areas. Therefore, develop a plan that includes communication between you and the ground crew to delay or stop the application if anyone spots people nearby, and only make applications if no one is in adjacent areas where they might be subject to exposure. Inspect the application site and adjoining areas before beginning an application to confirm no one is around the site.

In the emergency plan, include instructions to follow if spray contacts bystanders. This should involve decontamination methods and procedures for obtaining medical care for exposure victims.

COMMUNICATIONS

Operational problems can result from poor communications or sketchy information about jobs the ground crew performs. It is risky to assume that ground crew employees already possess all the vital information they need to carry out their jobs safely. Job delays, having to return for forgotten materials, treating the wrong fields, or spraying improper pesticide types, formulations, or concentrations are examples of mistakes that may occur when ground crew employees are operating with incomplete information.

Involve the supervisor and ground crew in:

- Developing maps of all areas to be treated and charting all hazards, adjacent crops, and environmental sensitive areas.
- Scouting all new areas and keeping maps up to date so you can identify new obstacles or changes in conditions promptly.
- Developing a system for accepting or transmitting information between you and the ground crew on work order changes in the field.
- Filling out mix sheets and determining the order of mixing spray batches.
- Ensuring that mixer/loaders are trained in calculating tank batches, pesticide handling procedures, and the use and care of personal protective equipment.

Provide the ground crew with essential site-specific job information and make sure they have a checklist outlining the steps to take to comply with applicable regulations and company policies. Develop and complete an up-to-date Standard Operating Procedures (SOP) for ground crew members to use and make sure it is available at the loading site. This is especially useful when communication with you is impaired and ground crew members disagree or are uncertain about procedures such as mixing batches of pesticide spray.

Review Questions

CHAPTER 2: Operation and Application Safety

1. **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.

2. **If a person shows signs of pesticide poisoning, he or she 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.

3. **If a person spills liquid pesticide onto his or her arm, the amount of exposure and injury can often be reduced by:**
   - **A.** Wiping arm with antibacterial wipes.
   - **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.

4. **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.** Only when mixing and loading.

5. **First-aid instructions to use for pesticide exposure is found on:**
   - **A.** Pesticide labels.
   - **B.** OSHA's Emergency Response website.
   - **C.** Supplemental labeling.
   - **D.** Manufacturer literature.

6. **An up-to-date Standard Operating Procedures (SOP) document is useful to ground crew members especially when:**
   - **A.** The communication channel with the pilot is lost.
   - **B.** The pilot begins applying the pesticide in a manner inconsistent with the work order.
   - **C.** Trying to determine the best time for applying the pesticide.
   - **D.** The pilot applies the pesticide to a site not listed on the label.

7. **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.** Protect employees from pesticide exposure.
   - **C.** Prevent intruder access to the equipment.
   - **D.** Comply with regulatory agency mandates.

8. **At a minimum, 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.

9. **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.

10. **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.

REVIEW QUESTION ANSWERS ON PAGE 97

CHAPTER 3

Preventing Pesticide Drift

LEARNING OBJECTIVES

This chapter will assist you to:

- Understand what off-target pesticide movement is and knowing the difference between drift and off-target pesticide movement.
- Recognize the way droplet size contributes to drift or reduces drift potential.
- Recognize the factors and conditions that contribute to drift and off-target pesticide movement.
- Learn how to minimize drift and off-target pesticide movement.

Pesticides are essential tools in managing pests in a particular location, but confining the pesticide to the intended target during application is an important responsibility. Reducing drift and off-target pesticide movement is necessary when you make any type of pesticide application because, if not controlled, this off-target movement can contribute significantly to the pesticide load in the environment. However, you must take steps to control drift of the pesticide material away from the target area during an application.

Off-target movement of pesticides is the condition where pesticides or pesticide residues leave the application site at any time and in any manner other than during a pesticide application. Often the physical and chemical characteristics of the pesticide contribute to or reduce the chances that the material may move offsite after an application. For example, pesticides that break down quickly after you have applied them will be less likely to move off the application site than pesticides that are highly persistent in the environment.

Pesticides and pesticide residues can move off the application site in several ways after they are applied. These include:

- Post-application volatilization into the atmosphere of the pesticide that adhered to treated surfaces, the crop plants, the soil in between the plants, or bare ground—pesticides with high volatility are more likely move off the application site than pesticides with low volatility.
- Leaching through the soil at the application site and moving into surface or ground water after application—pesticides with low solubility in water will not leach as much as those that are very soluble in water.

- Rainfall or irrigation water washing residues off the application site into surface waters after application—pesticides that have a high absorption potential are less likely to wash off plant surfaces.
- Blowing off the site attached to soil particles or dead plant material after application.
- Leaving the application site as residues on harvested crops.
- Being carried off the application site on vehicles, equipment, animals, and people.
- Being carried off the application site as fine droplets in an inversion cloud.

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." 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. This includes vapor or droplets that concentrate in an inversion layer during an application.

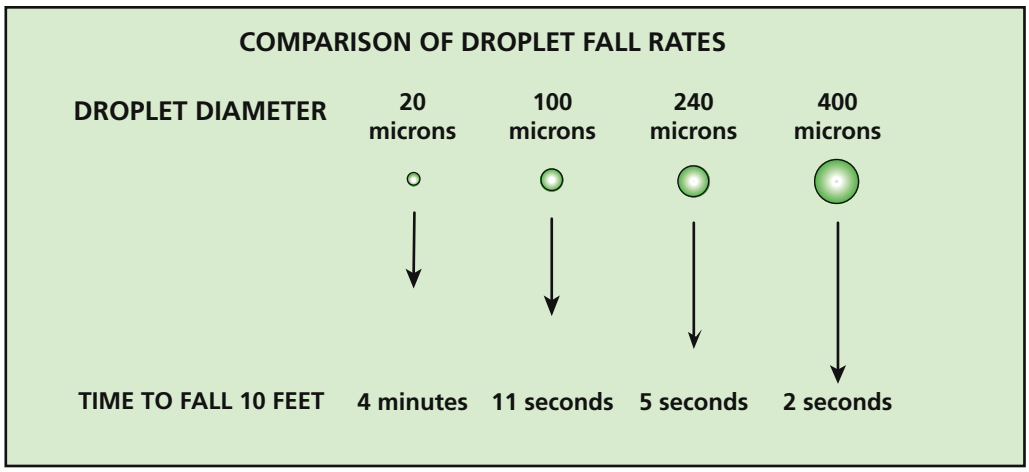
During any application, a certain percentage of the spray droplets will drift. If this drift is confined to the treatment site so that it is part of the pesticide application, there is generally little hazard to the surrounding areas that are not part of the application. Pesticide drift, however, increases the hazard to people and other living organisms outside of the treatment site. The following information pertains to recognizing the causes of pesticide drift and ways to reduce this problem.

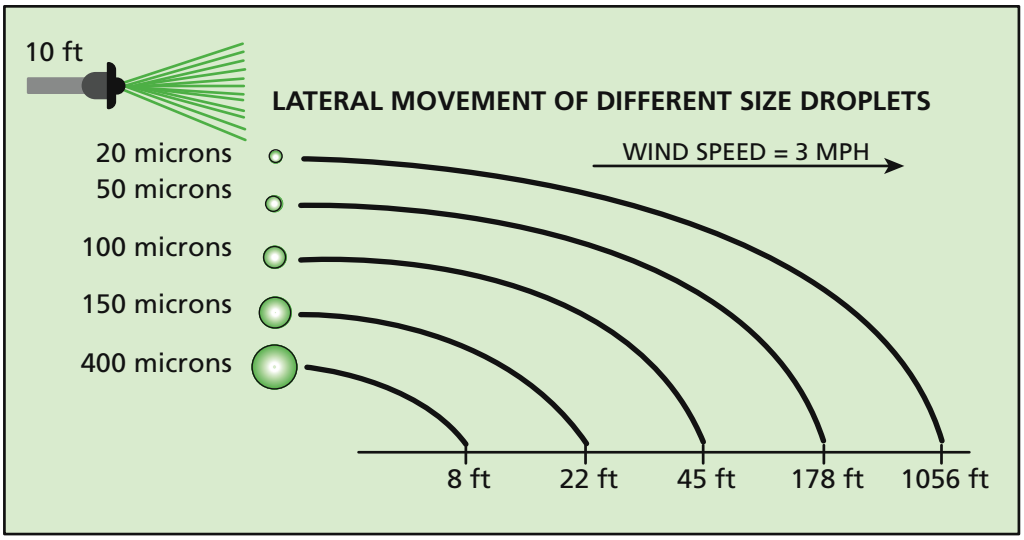
FACTORS THAT CONTRIBUTE TO DRIFT

The spray droplets and the percentage of droplets within a certain size range are the key factors affecting off-target drift. You can control some of these factors when making aerial applications.

The unit of measure for the diameter of a spray droplet is a **micron** (also referred to as a micrometer). The mathematical symbol for a micron or micrometer is µ. One micron is 1/25,000 or 0.00003937 of an inch. To illustrate the relative size of one micron, a single sheet of paper is about 100 microns thick.

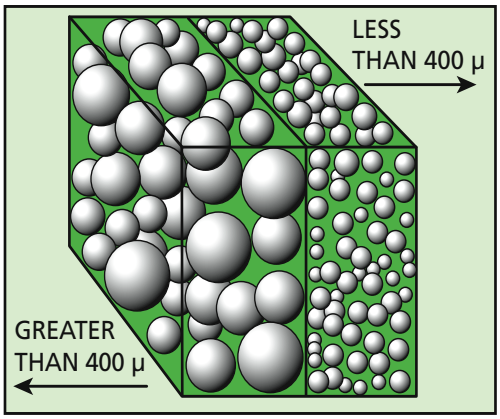
The longer a spray droplet remains airborne or suspended in the air, the greater the chance it will drift from the application site. A small spray droplet is more susceptible to drift than a larger droplet because the small droplet is lighter and therefore remains airborne much longer. For example, while it takes approximately 4 minutes for a





20-micron droplet to fall a vertical distance of 10 feet, it takes only 2 seconds for a 400-micron droplet to travel the same distance.

There is a rapid decrease in the drift potential of droplets larger than about 200 microns. Conversely, research has proven that droplets smaller than 200 microns are very prone to drift. People who study drift classify droplets that are 150 to 200 microns or smaller as **driftable fines**. In wind speeds ranging from 1 to 9 mph, droplets that are 200 microns or larger have an insignificant drift potential. For example, the theoretical distance that spray droplets move 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. Higher velocity winds increase the drift potential of all droplets.



Volume Median Diameter = 400 Microns

Droplets below 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, other than certain vector control operations, because they are never likely to reach target surfaces. Avoid using nozzles or nozzle orientations and configurations that produce droplets in this size range because there is no way to assure that these droplets will remain on or near the application site.

Classification of Droplet Size

All nozzles produce a range of droplet sizes, known as the **droplet-size spectrum**. This means that even when you use a nozzle having a large orifice that mainly produces large droplets, some percentage of the droplets in the spray 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. For instance, a nozzle with a VMD of 400 microns sprays out half its total volume in droplets having a diameter greater than 400 microns and the other half in droplets having a diameter smaller than 400 microns. However, this does not

tell you 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 percent 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 you need to determine the type of coverage you can expect.

The most useful way to describe 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. This spray-classification system is the American Society of Agricultural and Biological Engineers (ASABE) standard *S-572.1: Spray Nozzle Classification by Droplet Spectra*. This classification system has eight categories: extra fine, very fine, fine, medium, coarse, very coarse, extra coarse, and ultra coarse (see chart on next page). Using these categories, you can select a nozzle, orifice size, and operating pressure that produces the label-recommended droplet-size spectrum.

All pesticide labels will eventually contain nozzle specifications and/or the required droplet-size spectrum. The chart on page 37 shows the standard droplet size categories and color coding.

Consult the pesticide label for specific instructions when selecting nozzles. Using the droplet-size spectrum categories, determine which nozzle to use to reduce drift and provide adequate coverage in a particular application operation. 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.

Spray Mixture Physical Properties

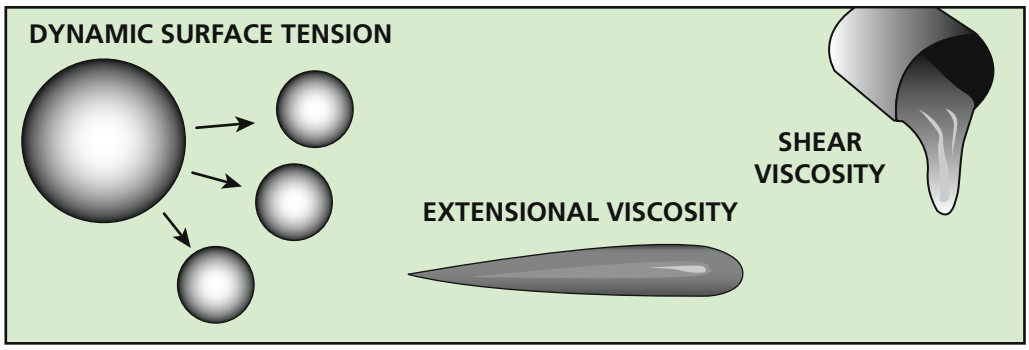
Three key physical properties of a spray mixture have a significant effect on droplet size in aerial applications.

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 the pump forces spray liquid 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 ejection speed of the liquid, affects the extensional viscosity. Higher pressure lowers this viscosity, therefore producing smaller droplets.



Droplet Spectrum Category	Symbol	Color Code
Extra Fine	XF	**PURPLE**
Very fine	VF	**RED**
Fine	F	**ORANGE**
Medium	M	**YELLOW**
Coarse	C	**BLUE**
Very Coarse	VC	**GREEN**
Extra Coarse	XC	**WHITE**
Ultra Coarse	UC	**BLACK**

ASABE STANDARD S-572.1 Spray Droplet Spectrum Categories

This standard defines droplet spectrum categories for the classification of spray nozzles relative to the specified reference fan nozzle. The purpose of this classification is to provide the nozzle user with droplet size information primarily to indicate off-site spray drift potential and secondarily for application efficacy.

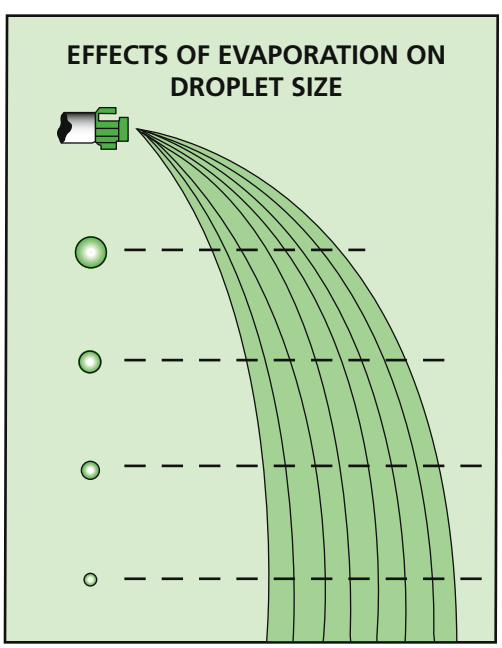
Refer to product labels for specific guidelines on a droplet spectra category required for a given application situation.

Nozzle manufacturers provide information necessary to place nozzle types into a droplet spectrum category based at least on orifice size and pressure. The color code is an industry standard.

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.

Spray drift control adjuvants, when added to the spray mixture, may help reduce the number of driftable droplets under certain conditions. However, reports indicate that some types of drift control agents lose their effectiveness when circulated through a sprayer pump. Studies show that some materials sold as drift control adjuvants actually do not perform as such. Spray drift control adjuvants are a specific class of chemical adjuvants, so do not confuse these with other adjuvants such as surfactants, wetting agents, spreaders, and stickers. These other adjuvants, and formulations containing alcohol or certain water miscible solvents, tend to reduce the dynamic surface tension of spray droplets, resulting in smaller droplet sizes.



External Factors Affecting Droplet Size and Drift

Certain factors remain beyond your control. These external factors include weather such as humidity, rain, extremely high or low temperatures, wind, or conditions leading to an inversion layer.

Effects of Evaporation on Droplet Size

Once exposed to the atmosphere, individual spray droplets will generally begin to evaporate. 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 usually ideal because it is generally more humid at this time and wind speeds are often low. However, **temperature inversion conditions** 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 the risk of drift caused by evaporation, small droplet sprays require lower application heights.

Co-Distillation

Pesticides can also move offsite through a process called **co-distillation**. This phenomenon occurs when the pesticide contacts very hot surfaces, usually soil with no vegetation. Pesticides, even those that are not highly volatile, leave 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 Off-Target Movement

Air movement from wind or thermals is a major contributing factor to off-target pesticide drift. Wind carries lighter and smaller droplets away from the target site where they accumulate until they saturate a given volume of air with the pesticide. As winds become stronger, the air traps more and more larger droplets and may move them away from the target before they return to the ground.

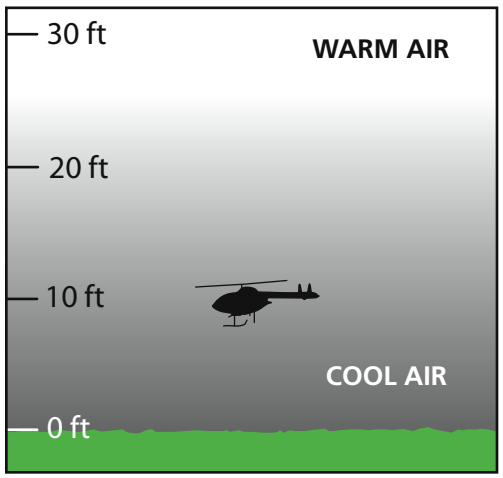
Upward air movement caused by thermals also entraps and moves small droplets, increasing the probability that they will drift away from the application site. Thermals occur as the ground heats up, usually in the afternoon, and especially after cool night temperatures. This causes air near the ground to rise, since warm air is lighter (molecules are further apart) than cool air.

Temperature Inversions

Differing air temperatures in stratified layers of the atmosphere are responsible for the inversion phenomenon that can exacerbate the problem of off-target pesticide drift. Inversions 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 identify 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.

Do not make applications during an inversion condition because the inversion layer traps fine spray



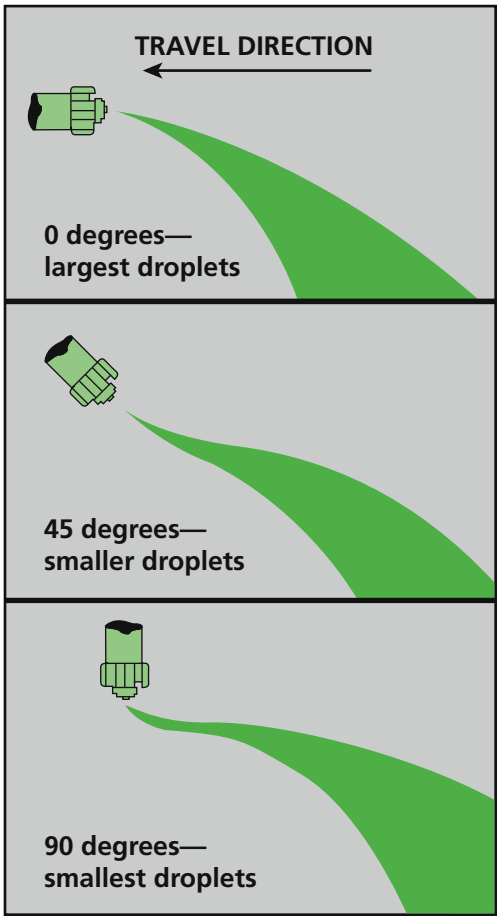
TEMPERATURE INVERSION

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 begin before sunset and remain into early morning or near bodies of water.

MINIMIZING OFF-TARGET DRIFT

Drift research shows that nozzles and other spray components can produce large spray droplets that have less of a tendency to drift. However, when improperly used, wind shear effects on nozzles result in drift-prone smaller droplets. Appropriate airspeed and proper nozzle orientation are the two factors that reduce wind shear effects. You need to find a balance between the aircraft's minimum airspeed needed for covering the desired acreage in a given period and the maximum airspeed before wind shear impacts the size of spray droplets.



In addition to selecting proper nozzles and finding the balance between proper airspeed to minimize atomization of large droplets, the other challenge you face is to find a balance between drift reduction provided by large droplets and good coverage associated with smaller droplets.

Research conducted by pesticide manufacturers, the pesticide application industry, universities, and state and federal regulatory agencies demonstrate that you can minimize off-target pesticide drift during any application operation by:

- Selecting nozzle types with orifice sizes that produce large droplets—wider spray angles typically produce finer sprays.
- 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).
- Confining boom length to no more than 75 percent of the wingspan of a fixed-wing aircraft or the rotor diameter on rotary-wing aircraft, to reduce drift caused by wing tip and rotor vortices.
- Increasing system pressure when flying at faster speeds to reduce the amount of smaller droplets.

- Making sure the positive shut-off and suck-back systems are working properly.
- 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.
- Using spray drift control adjuvants when appropriate to increase spray droplet size.

Spray droplets are normally finer at greater flight speeds, especially when using wide-angle fan nozzles or a nozzle orientation that is not straight back in relation to the level flight of the aircraft. However, for applications using straight stream or narrow angle (20 to 40°) flat fan 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.

Application Techniques

Some application techniques for reducing off-target 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; treat these buffer zones later, when the wind direction reverses into the field.
- 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 target crop.
- Avoiding applications during weather conditions that promote off-target drift, such as high winds or inversion conditions.

Smoke Generators

You use smoke generators on the aircraft to visualize air movement at the application site. You can also use it to identify inversion conditions below the application height. The smoke generator injects oil into the aircraft's exhaust system, which burns to produce smoke. You control the oil injector with a switch inside the cockpit.

When you activate the smoke generator, you can watch the smoke movement to estimate the off-site movement potential for spray you are applying. Although of limited effectiveness, you can also use the smoke to locate the position of the previous pass to estimate where to begin the next pass. However, due to possible movement of the smoke in air currents, this method is less reliable for swath marking.

Smoke generators are a common part of the onboard 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 typically also provided you with information about wind speed and direction. Since off-target pesticide drift is a major concern during aerial applications, a smoke generator provides a better visual picture of wind direction and relative wind speed at the time of spray release. Using a smoke generator before beginning the first pass of an application allows you to make immediate local wind condition evaluations without depending on someone on the ground.

Review Questions

CHAPTER 3: Preventing Pesticide Drift

1. **Managing off-target pesticide drift during an aerial application is:**
   - **A.** The ground crew's responsibility.
   - **B.** The property owner's responsibility.
   - **C.** The pilot's responsibility.
   - **D.** A requirement of a pilot's FAA licensing.

2. **Off-target 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 moving from the application site.
   - **D.** Several hours to several days after an application.

3. **The color code for a nozzle that produces spray droplets in the extra fine category is:**
   - **A.** Black.
   - **B.** Red.
   - **C.** Purple.
   - **D.** Orange.

4. **Generally, the optimum time for making an aerial application of a liquid when droplet evaporation is a concern is:**
   - **A.** Early morning.
   - **B.** Mid morning.
   - **C.** Early afternoon.
   - **D.** Late afternoon.

5. **Which of the following factors has NO effect on off-target pesticide drift?**
   - **A.** Nozzle orientation.
   - **B.** Spray pressure.
   - **C.** Constant 3 mph wind.
   - **D.** Physical properties of the spray mixture.

6. **Wider-angle spray nozzles usually produce _____ droplets than narrower spray nozzles.**
   - **A.** Coarser.
   - **B.** More uniform.
   - **C.** Less uniform.
   - **D.** Finer.

7. **The most effective boom lengths for reducing the amount of drift are:**
   - **A.** 90% of the wingspan or the rotor span.
   - **B.** 75% of the wingspan or the rotor span.
   - **C.** 65% of the wingspan or the rotor span.
   - **D.** 50% of the wingspan or the rotor span.

8. **Aside from external factors, the most important factors affecting off-target drift are:**
   - **A.** Physical properties of the spray mixture.
   - **B.** Extremely high or low temperatures.
   - **C.** The size of the spray droplets and the percentage of droplets within a certain size range.
   - **D.** Conditions leading to a temperature inversion layer.

9. Driftable fines are droplets in the size range of:

- **A.** Larger than 500 microns.
- **B.** 300 to 500 microns.
- **C.** 200 to 300 microns.
- **D.** 50 to 200 microns.

10. The droplet size at which spray drift becomes a concern is:

- **A.** 50 microns and below.
- **B.** 100 microns and below.
- **C.** 200 microns and below.
- **D.** 300 microns and below.

REVIEW QUESTION ANSWERS ON PAGE 97

CHAPTER 4

Aerial Pesticide Dispersal Systems

LEARNING OBJECTIVES

This chapter will assist you to:

- Understand the desirable requirements of an aircraft pesticide dispersal system for liquid and dry pesticide formulations.
- Become familiar with the components of an aircraft pesticide dispersal system for liquid and dry pesticide formulations.
- Understand the importance of inspecting, servicing, and maintaining dispersal systems.
- Become familiar with spray nozzles and how to correctly position them on spray booms.
- Know how to test dispersal systems for appropriate spray patterns.
- Understand the features of, and how to change the settings on, dry material spreaders.

Accurate metering and application of pesticides are the key purpose of all aircraft dispersal systems. Dispersal equipment has to deliver the labeled rate of a liquid or dry pesticide formulation uniformly and accurately.

Pesticide materials and the dispersal system add considerable weight, requiring aircraft that can safely lift, transport, and make applications when fully loaded. Fixed-wing aircraft used for pesticide application are fast, maneuverable, and carry heavier loads than rotary-wing craft. A limitation of a fixed-wing aircraft is the need for a designated landing area, which may not always be close to the application site. Rotary-wing aircraft used for pesticide application are more maneuverable but slower than fixed-wing aircraft, and can operate over a range of speeds and in almost any area since they do not require a runway for takeoff or landing. This allows ground crews to perform loading operations at or near the application site.

DISPERSAL SYSTEM REQUIREMENTS

The main function of a dispersal system is to allow you to apply an accurate and uniform amount of pesticide material over the application site as efficiently as possible. Liquid dispersal systems include a pump, a tank or hopper, hoses and/or metal lines, control valves with suck-back features, a pressure

gauge, filters, one or more booms, and nozzles. Pumps in these systems may be electric or hydraulic motor powered, wind-driven, or directly powered from the aircraft engine.

Equipment and Component Factors

Consider several factors for dispersal equipment and components used for aerial application of pesticides. They must be durable.

Corrosion Resistant

Many pesticide materials are corrosive, so only use corrosion resistant components in the dispersal system. Stainless steel, fiberglass, polyethylene, and polypropylene are non-corrosive, while steel, iron, and aluminum will corrode. In addition, acidic liquids may react with steel or iron to produce highly explosive hydrogen gas. Even though application components are corrosion resistant, the rest of the aircraft may not be, so regularly clean, inspect, maintain, and protect these parts.

Leak Proof

Make sure all components of the aircraft's pesticide dispersal system can resist leaks during the rigors of takeoffs, landings, and flight. This includes tanks, pumps, agitators, bearings and seals, hoses, and hose fittings. The presence of pesticide residues on the belly of the aircraft could be an indicator of a leaking hose or connection somewhere in the system. Leaks endanger you and can damage parts of the aircraft. In addition, leaks can expose workers to pesticide materials, contaminate places and objects used by people, and render runways, hangars, and other areas unusable until decontaminated. Leaks may also cause damage to crops and other plantings outside of the treatment area.

Allow You to Make Accurate Volume Measurements

The dispersal equipment has to include a way to measure accurate volumes of pesticide materials in order for you to apply the correct amount to the treated area.

Able to Produce Uniform Flow Volumes

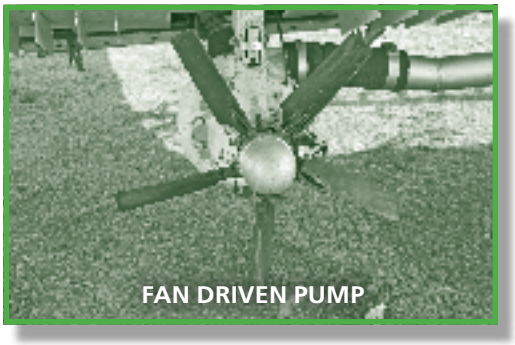
The dispersal system should provide a uniform flow of the pesticide through the nozzles for even distribution of liquid sprays over treatment areas. Systems that adjust the flow volume according to the application air speed (referred to as flow control) provide the greatest application volume uniformity, but can affect droplet size.

LIQUID DISPERSAL SYSTEM COMPONENTS

Important qualities of liquid dispersal systems include being dependable and durable, as well as being uncomplicated to service and repair. Descriptions of major dispersal system components follow.

Spray Pumps

The spray pump maintains the pressure in the system to ensure a uniform flow volume and proper atomization by the nozzles. The pump also may power the tank agitation system



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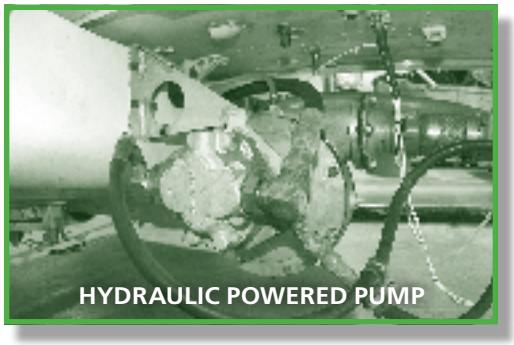

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that keeps the pesticide mixture in suspension. On fixed-wing aircraft, the most common power source for the pump is a fan mounted under the aircraft, below the tank. The aircraft's propeller slipstream drives this fan. Some fan-driven pumps have variable pitch blades so you can change the pump speed, and thus output, for different application requirements. Ultra low volume (ULV) applications may require modifications to the pumping system to make it suitable for such low output.

Other types of power sources for aircraft spray pumps include the aircraft's hydraulic system or an electric motor that drives the pump.

Pumps need enough power and capacity to meet the system's nozzle pressure, flow volume, and tank agitation requirements. The pump needs some extra capacity to make up for pressure loss due to friction in the lines and to operate nozzle anti-drip check valves. If you use a pump with too little capacity, you need to reduce the swath width to get adequate uniform coverage. However, this wastes time and fuel.

The centrifugal pumps commonly used on aircraft 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 10 and 70 pounds per square inch (psi). Centrifugal pumps made from aluminum with bronze or steel internal parts are most common. Centrifugal pumps have a high range of applications, including spraying abrasive wettable powders and flowable formulations, because there is no close contact between moving parts. These pumps usually require operating speeds between 1,000 and 5,000 revolutions per minute (rpm).

Pesticide Tanks and Hoppers

Tanks and hoppers have to be corrosion resistant, and most tanks used in aircraft are fiberglass. Other materials used for tanks and hoppers include stainless steel, high-density polypropylene, or polyethylene. Stainless steel tanks or hoppers generally are more durable than plastic or fiberglass, but they are heavier, therefore adding additional weight to the aircraft. Overall, tanks and hoppers made of stainless steel require less maintenance and can withstand rougher handling than those made of plastic or fiberglass. Although most popular because of less weight, a disadvantage of fiberglass is that it absorbs pesticide liquids if its surface is scratched or abraded, possibly contaminating future tank loads. However, scratches, small cracks, or punctures in fiberglass are easy to repair, while cracks or punctures in polypropylene and polyethylene tanks are difficult to fix.

EXTERNAL SPRAY TANK WITH QUICK COUPLING DISCONNECT

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Most tanks serve a dual use: they hold liquids for spraying and are hoppers for dry materials such as granular pesticides, fertilizers, and seeds. Tanks have top openings for filling, but it is easier to pump liquids through a pipe that has a quick coupling disconnect protruding through the side of the aircraft fuselage.

A gauge or visual level that shows the amount of material in the tank or hopper is necessary. This gauge has to be conveniently located so it is visible from the cockpit.

Interior baffles in tanks limit the sloshing of liquid during flight and dampen the effect of load shift on the aircraft's stability. In case of an emergency when a load must be dumped in a matter of seconds, the tank needs a large valve or port at the bottom that you can open quickly. Tank vents are necessary and these should accommodate a large enough passage of air to prevent a vacuum that would slow or stop the normal flow of liquid through the nozzles or bottom port. Adequate ventilation of the tank also prevents the buildup of hazardous fumes, explosive gases, or dusts that could damage the aircraft and even endanger your life.

On fixed-wing aircraft, mounting the tank or hopper in front of the cockpit and as close as possible to the

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aircraft's center of gravity reduces the effect on the aircraft's trim as the tank empties. Small rotary-wing aircraft have either a pair of tanks, with one mounted on each side of the fuselage, or a single belly tank. With two tanks, a pipe or hose connects them and allows the pump to draw the spray mixture equally from both, keeping the aircraft balanced. Larger rotary-wing aircraft have a tank mounted on the inside. Tank or hopper size depends on the load capacity of the aircraft.

Tank Agitation

Many pesticide formulations, such as emulsifiable concentrates, wettable 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 tank agitation is the recirculation of all or part of the pump output back into the tank (hydraulic agitation). A valve that diverts the flow from the spray boom back into the tank or hopper usually does this. Commonly, this boom valve provides a low negative pressure, or suck-back, to the boom when in the closed position. In another type of agitator, some external source powers a propeller mounted inside the tank (mechanical agitation). Mechanical agitation is not common on aircraft because the power required robs engine performance and adds extra weight.

Keep agitators running during ferrying to the worksite and during turnarounds. When the pump has sufficient capacity, some of the pump output recirculates back into the tank during spraying as well. Recirculated material enters near the bottom of the tank to prevent settling of the spray mixture.

If you apply dusts or powders, be aware that fine dry materials (60-mesh and above) in the aircraft hopper may also require mechanical agitation to prevent packing or caking on the top surface of the material during flight. This occurrence, known as bridging, creates voids under this top layer and leads to uneven flow of the dry material from the hopper.

Filters and Screens

Filters and screens protect the dispersal system from damage and keep nozzles from clogging. Clogged filters result in uneven applications. Screens require daily cleaning during spray operations and additional cleaning any time flow volume or change in system 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

Generally, agricultural aircraft do not use nozzle screens because aerial applications call for larger nozzle orifice sizes than ground applications do. However, certain types of nozzles and nozzles with smaller orifice sizes require screens or slotted strainers. The nozzle orifice size and the type of liquid you are spraying also determine the size of the nozzle screen.

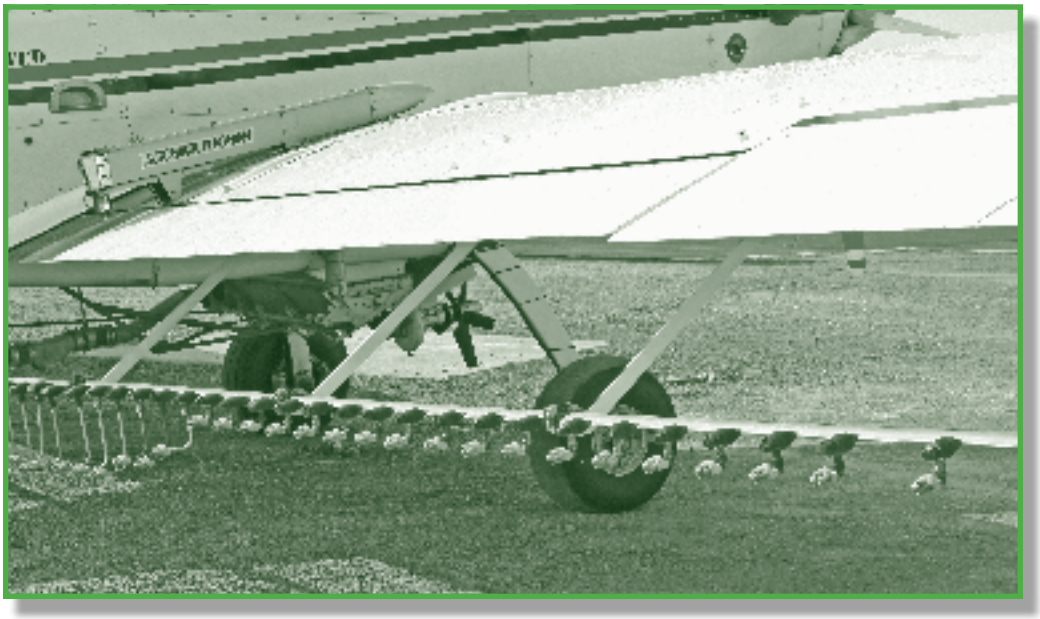
Line Screens

When using a centrifugal pump, place a line screen on the output side of the pump, in the line between the pump and the spray boom. For other types of pumps, locate the line screen on the suction side of the pump to help prevent damage from sand or other foreign particles, which can also cause nozzle check valves to leak.

Never store the dispersal system at the end of a season without thoroughly flushing out the booms. This reduces the likelihood of material accumulating on the inside surfaces of booms downstream from the line screen. This material can flake off later and clog nozzles or nozzle screens.

Pipes, Hoses, and Fittings

Main piping and fittings should be of a large diameter (up to 3 inches) to



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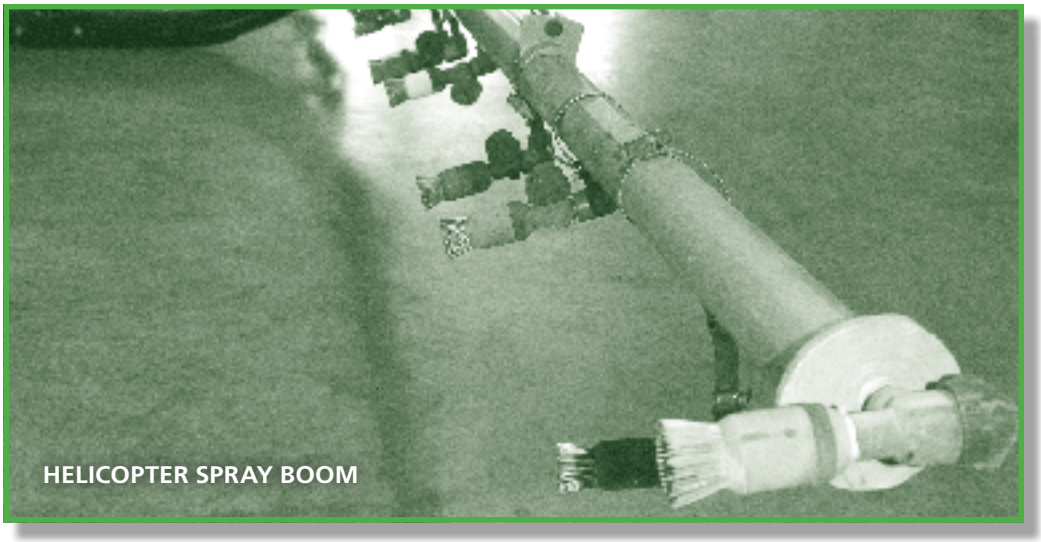
be able to apply high volumes of liquids. Smaller diameter pipes and fittings (approximately 1 to 1-½ inch) work for low-volume applications. Smaller piping is compatible with rotary-wing aircraft because their slower speed makes it possible to use lower flow volumes. Whatever the size, piping must be able to handle the maximum pump volume.

Hoses used in the dispersal system need to be large enough to carry the desired flow and must resist corrosion. Hoses are less likely to blow off if ends of the connecting tubes are beaded or flared. Using double clamps on hose connections also helps to keep them secure. Position hoses in such a way as to avoid sharp bends. Replace hoses if they swell, develop surface cracks, or otherwise show wear. Sometimes, hoses may not show external signs of wear or fatigue but they become brittle and hard after extended exposure to sunlight, high temperatures, vibration, and the various pesticides and other chemicals used in the system. Even when they look serviceable, hoses used beyond their life expectancy may fail without warning. Therefore, regularly replace hoses even if they look intact and free of defects or wear.

A positive shut-off valve, installed in the hose or line that delivers spray material to the nozzles, eliminates dripping when you shut off the spray. The most effective positive shut-off valve is one that incorporates a suck-back feature so that the pump applies a slight negative pressure to the liquid in the boom. The negative pressure aids the nozzle check valves in preventing any dripping. The system pressure gauge will register this slight negative pressure. If nozzles are not equipped with check valves, you may need to increase the negative pressure. Keep the negative pressure low enough so that it does not remove all the liquid from the spray boom, otherwise there will be too long of a delay as the boom refills when starting a new spray pass.

Spray Booms

The spray boom is the structure that supports nozzles along the wingspan or rotor span of the aircraft and usually carries liquid spray to the nozzles. It may be round, airfoil shaped, or streamlined. Streamlined booms create the least amount of turbulence, followed by airfoil booms and then round booms. To place nozzles in cleaner airflow on fixed wing aircraft, position the booms behind and below the trailing edge of the wings. For some configurations, use drop pipes from the boom to keep nozzles in clean air. Research shows that this lower position is likely to give a better deposition pattern. Securely attach spray booms to the aircraft to prevent bouncing. Make sure booms are durable enough to



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handle the output pressure of the pump. Some booms have separate right and left sections. Using a control valve, you can direct spray to either or both of these sections, making it easier to regulate spray placement in sensitive areas.

Operators of rotary-wing aircraft sometimes use special boom and nozzle combinations because of their ability to produce large, uniformly sized droplets at slower speeds. Operators use this type of boom most often for applying herbicides to rights-of-ways. Droplets form as the spray exits multiple needlelike nozzle tubes on the boom. The airstream pulls droplets into the air behind the boom.

Effective spray booms are approximately 75 percent as long as the wingspan for fixed-wing aircraft or the diameter of the main rotor blade of rotary-wing aircraft. If booms are longer than this, wing tip or main rotor vortices capture a large amount of the output from nozzles at the boom tips, causing distortions in the spray pattern and contributing to drift.

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 structural parts of the aircraft, it will likely:

- Collect and fall off in large drops.
- Distort the spray pattern.
- Waste material.
- Corrode aircraft surfaces.

Having removable caps on the ends of a boom is useful for periodic flushing of sediment buildup inside the boom. However, a boom with end caps prevents positioning nozzles at or near the boom ends. Trapped pressurized air in this space between the boom ends and the outermost nozzles causes the spray to continue flowing for a short while even after you close the spray valve. To eliminate this problem, install air bleed lines to each end of the boom. Attach the other ends of these bleed lines to one of the nozzles near the ends of the boom, making sure these nozzles only receive spray fluid from the bleed lines.

Flow Meters, Valves, and Pressure Gauges

The spraying system should include the following components to improve application ability.

Flow Meters

An accurate flow meter monitors the discharge volume of liquid from the pump through the nozzles. The flow meter alerts you to changes in the spraying system such as clogged nozzles, leaks, and pump malfunction.

Valves

Valves in the system start, stop, prevent dripping, and direct and regulate the flow of the liquid. Some valves have control levers that you manually move to turn on or shut off the spray.

Check valves are spring loaded and have a diaphragm, a ball, or needle and seat that starts or stops the liquid flow depending on whether the pressure in the system exceeds a preset minimum pressure. Electronic flow volume controllers employ motorized ball valves to regulate the amount of flow.

Inspect valves in the dispersal system frequently to confirm they are working correctly and are not leaking. Sediments or debris in the plumbing of the system may prevent some valves from shutting off completely or may restrict the flow of liquid passing through them. Make sure all nozzle check valves have the same size outlet diameter to provide uniform flow volumes along the length of the boom.

Pressure Gauges

Use a pressure gauge as another tool to monitor the spraying system. A pressure gauge helps you determine the correct pump speed or spray valve opening in order to achieve the proper nozzle output, droplet size, and spray pattern. You can use the pressure gauge to monitor and maintain system pressure during application should the electronic flow control system in the aircraft stop working. A pressure change in the system during spraying indicates potential problems. For instance, clogged nozzles or filter screens could increase pressure. 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 to determine the cause and make necessary repairs. To assure precise readings of pressure at the nozzles, connect the pressure gauge sensor line to the spray boom.

The pressure gauge in the aircraft needs periodic checking. When connected to the same pressure source, compare readings from the aircraft's gauge to another gauge known to be accurate.

Nozzles

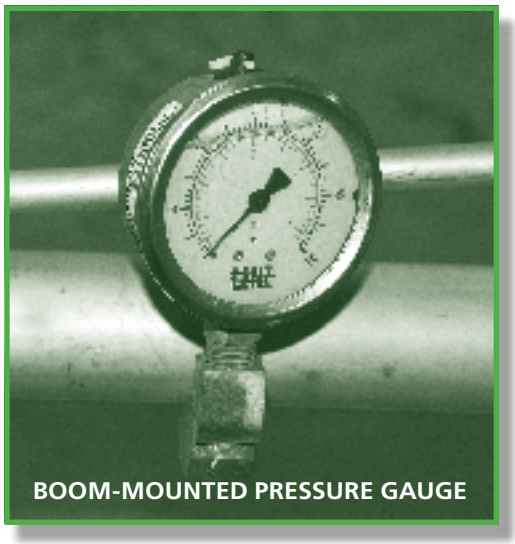
Nozzles provide the primary means of controlling three factors that affect any application and possible off-target movement of the pesticide: the application volume, droplet size, and spray pattern. It is important for nozzles to operate within the range of pressures and flow volumes prescribed by their manufacturers. Therefore, be sure that the spraying system is compatible with the specified pressure and flow volume ranges for the nozzles you use and the aircraft's speed. Manufacturers produce many types of nozzles for various liquid pesticide application situations.

The application volume influences the type of nozzle used in an aerial application. Aerial application volumes 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 were the norm for conventional volume aerial applications. Pilots made these types of applications with cone pattern nozzles. However, aerial spray drift studies indicate that spray output from cone pattern nozzles are likely to emit drift-prone droplets unless configured to produce coarser droplets. Many pilots now make conventional applications using straight stream nozzles, variable orifice flood nozzles, or flat fan nozzles.

Application volumes in the low volume (LV) range are often suitable



BOOM-MOUNTED PRESSURE GAUGE

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for certain situations, such as applying particular fungicides. You may use flat fan or variable orifice flood nozzles set to a suitable deflection angle, based on orifice size, pressure, and aircraft speed, for LV applications. Drift studies show that properly installed straight-stream or variable orifice flood nozzles reduce the amount of small droplets that are prone to drift.

When using vegetable oil carriers, or when you apply concentrates in forest or public health pest control, such as mosquito abatement spraying, ULV application volumes may be around one to a few ounces per acre. Rotary atomizers work well for ULV applications as well as LV applications.

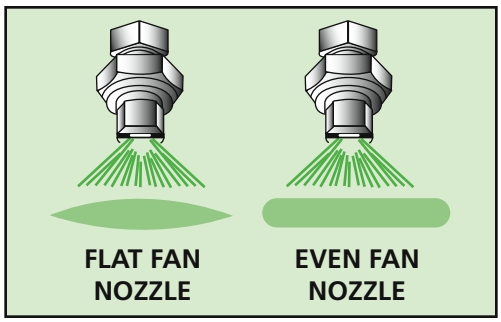
Straight Stream Nozzles

Straight stream nozzles oriented straight back often produce the largest droplets and the lowest drift compared to other nozzle types. These nozzles provide a way to produce large droplets at higher airspeeds when you match the flow volume of the stream from the nozzle with the airspeed. However, at very high speeds the large droplets produced by straight stream nozzles can shatter and create driftable fines.

Fan-Pattern Nozzles

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.

Flat fan and even flat fan nozzle tips produce flat, fan-shaped spray patterns. Flat fan patterns have the highest deposition in the center of the pattern and deposition tapers off towards the edges. Even flat fan nozzle patterns are uniform across the whole width of the nozzle pattern. 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 25, 40, 65, 80, or 110 degrees. In general, fan nozzle tips that produce wide angles 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. Typically, 40-degree flat fans are recommended for the higher speeds associated with fixed winged aircraft and 80 degree flat fans are recommended for slower speeds associated with rotary wing aircraft. Compared to standard flat fan nozzles, even flat fan nozzles have little effect on the spray distribution applied by an aircraft. The more critical consideration when using flat fan nozzles on an aerial boom is that the nozzle tip produces a narrow spray angle.



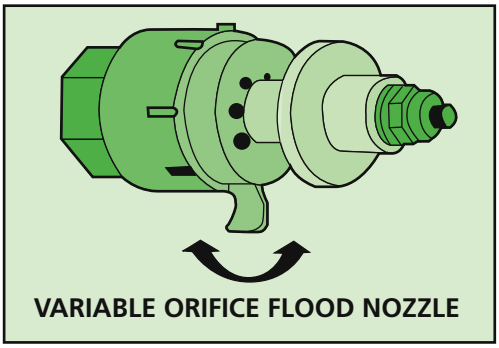
Variable Flow Rate Flat Fan Nozzles

Typically, nozzle orifice sizes are fixed and the only way to increase or decrease nozzle flow volume and maintain a desired spray droplet size range at a certain spray pressure is to change the size of the nozzle orifice. With standard nozzles, slightly increasing or decreasing the spray pressure allows minor adjustments in nozzle flow volume, but this adversely affects the optimum spray pattern. Variable flow rate nozzles overcome this problem because the nozzle orifice size is flexible and enlarges or gets smaller as the system pressure increases or decreases. This maintains greater integrity of the droplet size spectrum and spray pattern as system pressure changes. The advantages of variable flow rate nozzles include:

- The ability to change application volume on the fly by increasing or decreasing system pressure instead of replacing nozzle orifices.
- Better spray droplet uniformity that is less affected by system pressure changes.
- A more uniform application volume and spray pattern even when application airspeed varies.

Variable Orifice Flood Nozzles

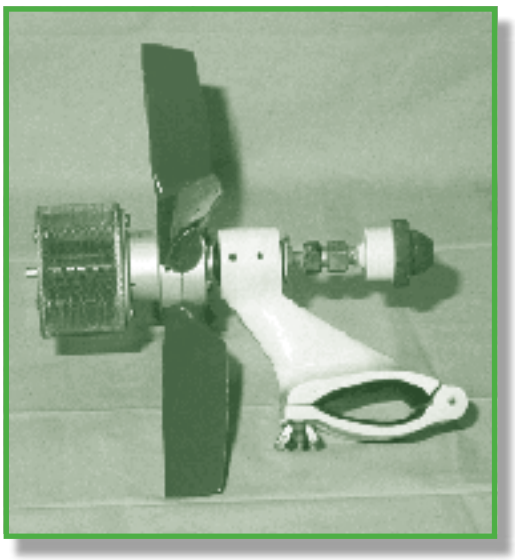
A variable orifice flood nozzle disperses liquid in a flood type wide-angle



flat fan pattern or a straight stream. The nozzle body has two manual adjustments, one for orifice size and the other for deflection angle. Four orifices can be selected, plus an "off" position. The orifice size and pressure determine the nozzle flow volume. Spray from the selected orifice hits an adjustable deflector that you adjust to produce fine, medium, or coarse spray droplets. There are two common types of variable orifice flood nozzles. One has deflection angles of 30, 55, and 90 degrees and the other has a straight stream setting and deflection angles of 5 and 30 degrees. Slower aircraft typically require larger deflection angles than faster aircraft.

Rotary Atomizers

A rotary atomizer consists of a screen mesh cylinder that rotates around the nozzle orifice. Its own fan or an electric or hydraulic motor powers this rotating cylinder. The higher airspeed of fixed-wing aircraft favors the use of fan-driven rotary atomizers. Most fan-drive units have adjustable fan blade pitch so you can achieve the optimum cylinder rotation relative to the aircraft's speed. The slower speeds of rotary-wing aircraft require motor driven cylinders.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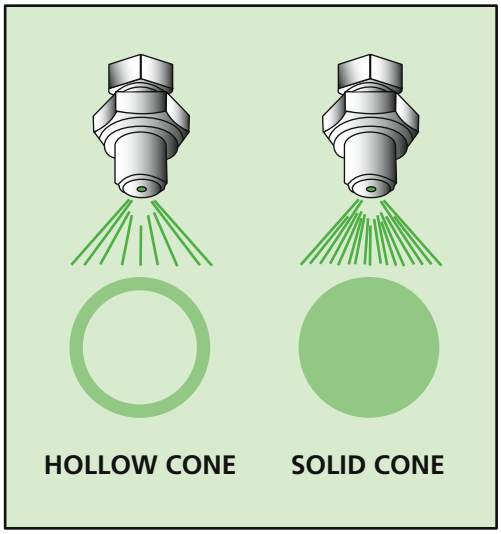
Spray droplets that emerge from the screen mesh cylinder are relatively uniform in size. Rotary atomizer nozzles deliver a wide range of application volumes. Because they have relatively large metering orifices, their nozzles do not clog as easily as conventional nozzles when applying low-volume sprays containing a high concentration of chemicals in suspension. Uniformity also depends on droplet size and nozzle spacing. The number of nozzles you need is based on how wide a swath you intend to cover. Typically, a single rotary atomizer can generate a swath of 10 to 15 feet.

Hollow-Cone Pattern Nozzles

Hollow-cone pattern nozzles include the disc-core type and the whirl-chamber type. Recent spray drift research indicates that using hollow-cone nozzles on an aerial spray boom yields a disproportionate amount of very fine, drift-prone droplets. Because cone nozzles emit spray in a conical pattern, the effect of wind shear is greater than its effect on straight stream or flat fan spray nozzles.

The orifice of a hollow-cone nozzle is located in a disc that 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 rotational spin on the liquid passing through the orifice. The size of 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. When liquid enters the nozzle

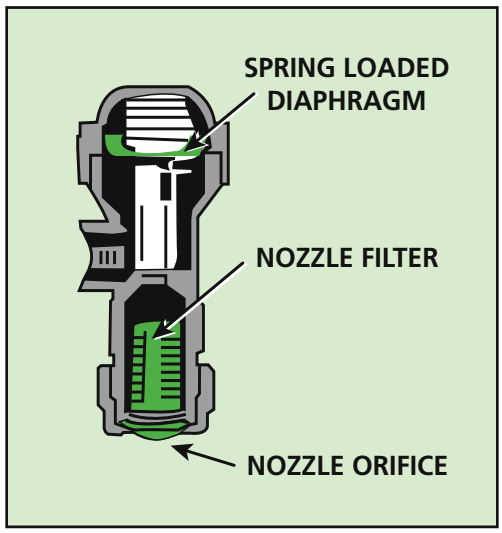


body, the interior structure causes the liquid to whirl rapidly before exiting as a cone-shaped spray pattern. Whirl chamber nozzles are relatively free from clogging problems.

Nozzle Anti-Drip Devices

Equip all the nozzles on the spray boom with check valves to prevent dripping when you shut the spray off. These valves have spring-loaded diaphragms, needles, or steel balls that stop the nozzle flow when spray pressure drops below a certain preset amount, usually about 7 psi. Use anti-drip check valves in combination with shut-off valves that have the suck-back feature. In systems where suck-back is unavailable, use a stronger spring so the nozzles seal shut when pressure drops to about 15 psi. Never switch on and off an electric motor driven pump in a rotary-wing aircraft to start or stop spraying. Using the boom valve to start and stop the spray and leaving the pump running allows the suck-back feature to work properly and provides hydraulic agitation for the spray tank.

Inspect and frequently clean check valves to assure they work properly and are not leaking. Replace diaphragms when they show wear. You can flush needle and seat types of anti-drip check valves without disassembling the nozzle by pulling on the needle, which typically clears the valve of debris and stops the leak.



ELECTRONICS

Electronic equipment such as global positioning systems, flow volume controllers, and mapping systems are important components of aircraft dispersal systems. This equipment increases precision application, reduces error and drift, and prevents waste of pesticide materials. These systems also provide permanent records of various aspects of the application for site mapping, customer billing, and environmental and regulatory reporting.

GPS Systems

Operators choose differential global positioning systems (DGPS) for their aircraft because they provide the high degree of precision needed for aerial application. The amount and kind of navigational information available for aircraft-mounted DGPS equipment depends on the features incorporated into the systems. As with other navigational devices, an FAA-certified aircraft maintenance technician must install, test, and repair DGPS equipment and components. See Appendix 5 for descriptions of types of global positioning systems and how they operate and are managed.

Before purchasing mobile DGPS hardware and software for an appli-

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cation aircraft, find out if the equipment processes signals for the type of DGPS service that is available in the area where the aircraft operates. In addition, learn what kinds of DGPS peripheral devices, such as light bars and flow controllers, the equipment accommodates.

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

- DGPS mobile receiver.
- GPS antenna.
- Light bar.
- Computer processor (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 you are spraying. It allows you to easily visualize off-track errors and quickly make flight path corrections.

The onboard DGPS receiver continuously sends about 5 updated signals per second to the light bar. These signals activate specific LEDs, with the center of the light bar indicating the aircraft is lined up with the swath centerline. The other LEDs on the left and right of center represent a certain distance away from the swath centerline. This distance is usually 2 feet per LED, but can be set to as little as 6 inches per LED.

After completing a pass, advance the GPS setting to the next swath. When the aircraft is exactly over the centerline of that 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. You correct the flight course by steering toward the illuminated LEDs. You restore the correct flight path when only the center most LEDs glow.

Once you line up the aircraft with the next swath centerline, use traditional landmark navigation to begin and perform the spray pass by selecting a distant visual object and flying toward it. Occasionally check the light bar during the spray pass to fine-tune your course.

Computers

The advantages of DGPS computer systems include mapping, waypoint navigation, and spray operation record keeping. The computer provides options for you to select a desired application pattern, such as racetrack. The computer then uses the GPS positioning data to continuously calculate and display the aircraft's location with respect to the target site and application pattern. This eliminates the need for flagging or marking devices or human flaggers.

The computer system records the precise in-field location of each spray swath. For jobs requiring multiple spray loads, its mapping system guides you to where to begin applying the next load. Throughout the spray operation, the computer system collects data and constructs records.

Flow Volume Controllers

Manufacturers of DGPS computer systems offer software programs and computer hardware interfaces that provide precision spray boom operations. The aircraft DGPS computer combines continuously updated ground speed data with the spray swath width and sends correction signals to the flow volume controller. The controller regulates boom output by increasing or decreasing pressure and/or flow volume so that it maintains a preset application

volume per acre. More sophisticated units even control output on individual nozzles. Flow volume controller systems include means for measuring, computing, and recording:

- Total liquid volume.
- Liquid pressure.
- Liquid flow volume.
- Total spray time.
- Relative humidity.

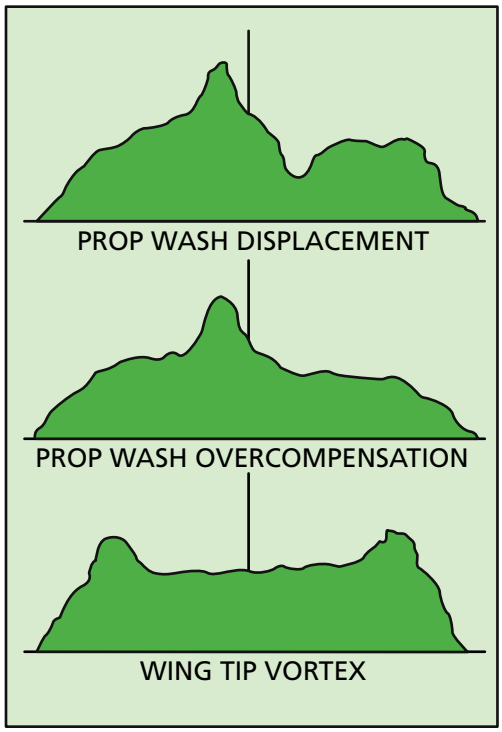
With this equipment, you can deliver the spray uniformly for the duration of the job in progress even when travel speed of the aircraft varies. You use feedback data from the flow volume controller to construct an on-site record of the output performance of the spray boom.

Mapping Systems

Producing maps of the targeted area is one of the features of the global positioning systems in many aircraft. These systems enable you to define boundaries, mark hazards, and produce as-applied maps that document your work. These maps are useful references for future applications. In addition, during an application, the on-screen map in the aircraft shows you where you turned the spray on and off. This gives you the accuracy to separate an area of the same field and fly it in a different direction to help you protect sensitive areas.

POSITIONING BOOMS AND NOZZLES

Improper positioning of nozzles along the spray boom negates the advantages derived from pilot skill, advanced electronics, other application aids, and modern nozzle engineering and manufacturing technology. Determining the proper position for each spray nozzle helps achieve uniform spray deposition. Be sure nozzles are in the aircraft's laminar airflow where there is undisturbed air. Adjust the spacing of the nozzles along the boom to compensate for uneven spray deposition caused by air movement over aircraft surfaces. After positioning the nozzles according to accepted application industry standards, evaluate the setup by conducting pattern testing of the dispersal system. Do this before making any pesticide applications.



Nozzle Adjustments

There are several factors to consider when adjusting nozzle positions.

Prop Wash Displacement

On fixed-wing aircraft, propeller rotation produces a spiral slipstream about the fuselage. This spiral slipstream moves spray particles from right to left under the aircraft. The result is a reduced application volume under the right wing and a higher application volume under the left wing. 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 noz-zles from the left side of the boom. You usually determine the correct number and location of the nozzles by trial and error, preferably

Dale Thomas—Gooding, ID

while conducting pattern testing, not during pesticide application. Generally, the nozzles that need alteration are those positioned within 3 to 6 feet of the fuselage.

Prop Wash Overcompensation

The emphasis on spray pattern distortion due to prop wash has prompted some pilots to overcompensate for propeller-induced effects. You can often correct a pronounced spray peak developing on the left of the fuselage by turning off one or more nozzles mounted within 3 to 6 feet of the right side of the fuselage. Conduct pattern testing to assure you have not overcompensated.

Wing Tip and Rotor Vortex

Wing tip and rotor vortexes usually produce spray patterns with high peaks at its edges. This pattern can occur on either fixed- or rotary-wing aircraft. The vortex captures and propels upward the spray emitted from the outermost nozzles on booms that extend to the full wing or rotor span. Spray droplets so captured do not contribute to the effective swath width, but are a significant source of spray drift. In almost every case, you can overcome a wing tip or rotor vortex induced spray pattern problem by keeping the spray boom length at 75 percent of the wingspan for fixed-wing aircraft or the rotor diameter of rotary-wing aircraft.

Rotor Distortion

Rotary-wing aircraft may display a spray pattern having a low application volume in the middle of the swath and heavier patterns at each end of the spray boom. Normally, you can correct this by adding nozzles under the aircraft between the skids.

Pattern Testing a Spray Boom

When evaluating the spray pattern and determining the effective swath of an aircraft, the application height, power setting, spray pressure, and nozzle location should 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 or convective instability. During testing, fly the aircraft directly into the wind. Conduct pattern test flights only when ambient wind speed is less than 10 mph.

One method for spray pattern testing consists of a detector (fluorometer) that reads the intensity of fluorescent dye deposited onto a string or tape positioned across a test site. A computer converts the fluorescence to data points and displays these in a graphical spray pattern representation.

California Agricultural Aircraft Association

Use this graph to assess nozzle positioning along the boom, determine spray deposition uniformity, and measure the effective swath width. You need to know the effective swath width to program a DGPS guidance system.

If computerized pattern testing equipment is not available, you can determine the spray pattern by other means. The Course Layout figure (next page) depicts a suitable test layout for spray pattern evaluation. Determine the wind direction and place several flags, visible to you from the aircraft, about 100 feet apart along the centerline of the direction of travel. Staple and sequentially number squares of water sensitive paper to small blocks of wood along an 80- to 100-foot line that runs perpendicular to the line of travel. 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.

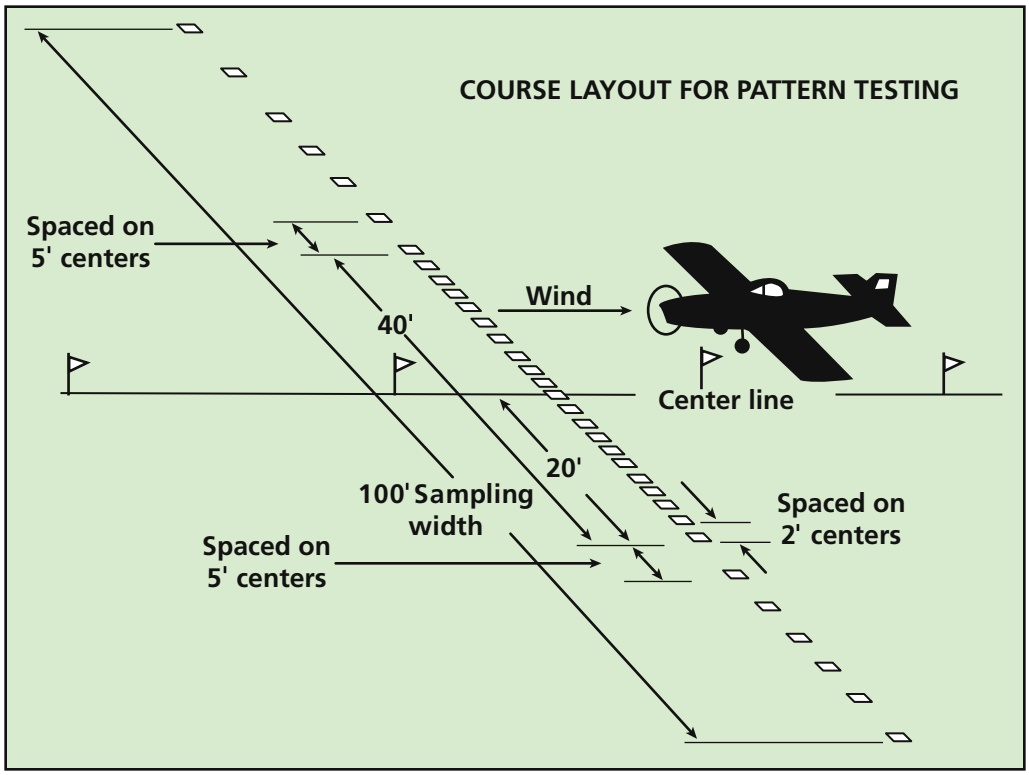
After takeoff, purge the boom and make sure that water from the system reaches the end nozzles. Align the aircraft with the centerline flags on a spray run that duplicates an actual field application. Operate the boom for at least 100 yards both before and after passing over the line of water sensitive 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 the sprayed cards in the order the ground crew laid them 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 droplet density in the vicinity of the flight centerline.
- Uneven spray droplet densities toward the wing tips, indicating prop or rotor distortion (see previous section).
- Light spray droplet density corresponding to boom hangars or other structures that interrupt airflow.

Correct uneven patterns by repositioning nozzles on the spray boom. Conduct a new pattern test to verify that you have improved the pattern.

With a proper nozzle setup, you will notice that the number of spray droplets per card is reasonably constant for some distance on each side of the centerline path and then they gradually diminish 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. In an actual application, this midpoint is the border between adjacent swaths.

Spraying System Operating Pressure

Drift reduction requires directing nozzles straight back and setting the spraying system operating pressure to match the speed of the aircraft with the exit speed of the pesticide liquid from the nozzles. A pressure of 40 to 60 psi may produce larger droplets due to less wind shear and minimizes the production of droplet sizes prone to drift. Drift prone droplets are those that are smaller than 200 microns in diameter.

When it is necessary to increase the output volume of the nozzles, you can make very small changes by increasing or decreasing the system operating pressure, often by changing the pump speed. Electronic spray volume controllers increase or decrease system pressure to change the output volume of the system when there are slight changes in the aircraft's speed. This produces an application that is more even than if the pressure remains constant as the aircraft's speed varies. However, this adjustment has limitations because, in order to double the spray output, you must quadruple the spray pressure. This will have a major impact on droplet size. In most cases, the best way to make significant changes in boom output volume is by changing nozzle tip size, nozzle orifice size, or by changing the number of nozzles in use. Typically, you should change the spray system pressure only to make minor changes (alterations of 10 percent or less) in boom output.

DRY MATERIAL SPREADERS

On fixed-wing aircraft, ram-air spreaders disperse dry formulations, such as granules or pellets. You would use these spreaders also for applications

of fertilizers and seeds. On rotary-wing aircraft, you typically use a centrifugal spreader to apply dry formulations.

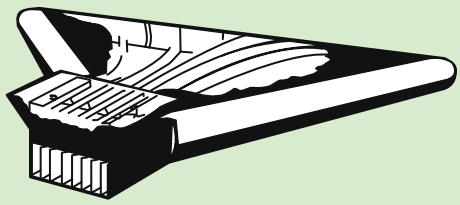
Ram-Air Spreader

A fixed-wing aircraft fitted with a properly configured ram-air spreader 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 higher engine power requirements and high aerodynamic drag, which affect aircraft performance and maneuverability.

Ram-air spreaders are comparatively simple, versatile, and reasonably priced. You would typically attach a ram-air spreader beneath the fuselage in such a way that you can remove it easily to restore the liquid spraying capability of the aircraft. The hopper is the same one used to hold liquid pesticide sprays.

An unsatisfactory distribution pattern of dry materials results from most ram-air devices if you attempt to apply more than 250 pounds per acre of material or increase the feed rate to more than 35 pounds per second.

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 spreader has either a hinged metering gate or a sliding hatch between the hopper and the spreader.

When using a spreader equipped with a hinged metering gate, you use a cable or rod to rotate the trailing margin of the gate downward to open it to whatever setting you want. 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 metering gate must provide even feed of the pellets or granules across its opening; otherwise, the aircraft will produce an uneven swath pattern. It is unreasonable to expect any combination of 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. If you meter too much dry pesticide product 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 from 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 allows you to fine tune a ram-air spreader to a particular aircraft's airflow and slipstream characteristics.

In a ram-air spreader, the material metered from the hopper flows through the ducts as a thin, sheet-

like layer of particles. Air entering the spreader inlet forces the product rearward, where it flows along the internal upper surface (ceiling) of the spreader. Spreading of this 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 helps to make the swath uniform. Airframe-induced influences are known to affect ram-air spreader performance, but that can often be compensated for by spreader inlet vane adjustment.

- Aircraft oil-cooler-induced turbulence.
- Speed ring effects.
- Propwash effects.
- Turbulence caused by a flagging device air deflector.

The propwash effect displaces material released near the right of the fuselage towards the left side of the fuselage. This results in a non-uniform swath where distribution of granules or pellets on the right side is sparse and it is 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 the right side discharge ports.

Shifting inlet vanes too far laterally causes problems, however. As you shift an inlet vane 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. Rear vane section adjustments provide 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, you only need to make small adjustments. Over-adjustment usually causes particles moving through the duct to slow down, resulting in too much 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 long axis of the fuselage. 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. Set the spreader attack angle by establishing the pitch of the spreader body during mounting.

The forward mounting points of ram-air spreaders are usually non-adjustable. Therefore, change the attack angle by changing the distance between the aircraft fuselage and the rear part of the spreader. In general, 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.
- A non-uniform 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 apart. 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. The rotary-wing aircraft carries the entire unit beneath the aircraft, suspended on a cable. The unit meters material from the hopper onto a spinning disc that distributes the pesticide, seed, or fertilizer. A hydraulic motor or gasoline engine usually drives the spinner. You control the motor via a hydraulic control cable or by an electrically activated solenoid. Typically, an operation would have two self-contained units so you can spread with one while the ground crew fills the other. Another method involves using a bag suspended from a boom that the ground crew fills while the pilot makes an application to the field with the spreader. When the hopper needs refilling, the pilot positions the unit under the bag and a ground crew member releases the contents of the bag into the hopper. The refilling operation takes only a matter of seconds while the helicopter hovers above.

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Review Questions

CHAPTER 4: Aerial Pesticide Dispersal Systems

1. **Aircraft suitable for aerial application of pesticides must be:**
   - **A.** Registered with the U.S. EPA.
   - **B.** Constructed entirely of corrosion resistant materials.
   - **C.** Equipped with DGPS navigational equipment.
   - **D.** Able to lift, transport, and disperse pesticides safely.

2. **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.

3. **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.

4. **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.

5. **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.

6. **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.

7. **To accommodate for the influence of prop wash 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.

8. **The advantage of an electronic sprayer volume 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.

9. **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.

10. **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.

REVIEW QUESTION ANSWERS ON PAGE 97

CHAPTER 5

Calibrating Aerial Application Equipment

LEARNING OBJECTIVES

Reading this chapter will help you understand:

- Why you need to calibrate dispersal equipment.
- How to calibrate liquid and dry dispersal equipment.
- How to make adjustments to the application equipment's dispersal volume or rate.

Pesticide registrants, manufacturers, and regulatory agencies use extensive research to establish proper application volumes and to develop safety precautions that you must legally follow when making a pesticide application. Registrants place this mandatory information on the pesticide labeling. On occasion, regulatory agencies identify a reason to evaluate a product's existing labeling directions, usually because of human safety concerns. As a result, they may impose regulations that supersede the product's current labeling. This may involve changing application volumes or imposing additional safety requirements.

In order to make a legal, safe, and effective aerial application, you are responsible for applying pesticide products uniformly and at the proper volume per unit of area. Pesticide product labels or local regulations prescribe maximum volumes, so exceeding these volumes violates federal and state laws.

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 you dilute and apply the pesticide active ingredient

CALIBRATION PREVENTS SERIOUS PROBLEMS

USDA ARS Image Library

according to regulations. This chapter discusses the steps to take to calibrate, test, and adjust a fixed- or rotary-wing aircraft's pesticide dispersal system. Sidebar graphics are included to detail useful calculations.

Once you calibrate the aircraft's dispersal system, check and test the equipment periodically to be sure the calibration remains accurate. Heavy workloads as well as applying abrasive pesticide formulations contribute to nozzles and other equipment becoming maladjusted or worn.

Technological advances such as DGPS systems and electronic controllers make aerial pesticide application more precise. These tools reduce calibration errors and automatically adjust the spraying system to accommodate for changes in pump output, nozzle wear, and variations in application speed. The best resources for setting up and adjusting these systems are their operation manuals. Therefore, this chapter does not cover calibrating or adjusting electronic devices.

WHY YOU NEED TO CALIBRATE EQUIPMENT

The main reason for calibration is to figure out how much pesticide to put into the tank or hopper of the aircraft so you can apply the work order recommended volume to the target site when you operate the aircraft 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.

Improper Application Rate

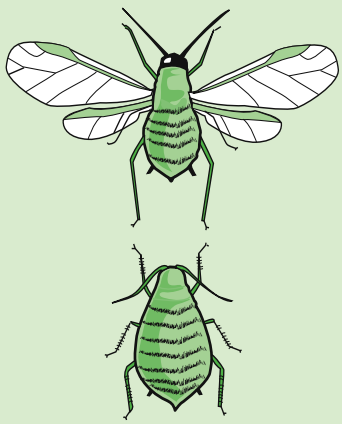
Applicators are legally liable for injuries or damage caused by improper pesticide application. Several problems are associated with applying a pesticide at a volume higher than the maximum legal rate.

Illegal Residues

Applying higher than legal volumes of a pesticide may result in residues on crop plants that exceed the legal tolerance level. If over-application results in illegal residues on plant surfaces, regulators have the authority to confiscate and destroy an entire crop to protect consumers.

Impact on Effective Pest Control

Pesticide registrants and/or manufacturers of pesticides spend millions of dollars researching ways to use their products correctly and effectively. This research includes determining the right amount of pesticide to apply to control target pests. Using less than the labeled rate is legal, but may result in inadequate control, wasting time and money. Application volumes that are too low also may lead to problems such as pest resistance and resurgence. Higher than label rates are illegal and waste pesticides. Using too much pesticide may adversely affect natural enemies of the pest being controlled.



APHID PEST

Human Health Concerns

Pesticides applied at higher than label rates could endanger the health of pesticide handlers, field workers, yourself, and other people working in or visiting an area where you applied them.

Environmental Concerns

Pesticide concentrations higher than label directions may cause serious environmental problems. Calibrating equipment to maintain application volumes within label requirements reduces the potential for contaminating surface water, ground water, and the air.

Impact on Treated Plant Surfaces

Certain pesticides are phytotoxic (injurious to plants) and damage treated plant surfaces when used at higher than label-prescribed rates. Manufacturers evaluate these potential problems while testing their products so they can determine safe concentrations.

Soil Contamination

Using too much pesticide increases the chance of building up excessive residues in the soil. A buildup of certain pesticides sometimes seriously limits the types of future crops that farmers can grow in the treated area.

Wasting Resources

Using the improper amount of pesticide wastes time and adds unnecessary costs to the application.

EQUIPMENT CALIBRATION METHODS

Pesticide materials are expensive, and the fuel, labor, and equipment wear and tear required to make extra applications are costly.

If you apply pesticides improperly, you are subject to criminal and civil enforcement actions that may result in loss of your pilot certificate, paying fines and penalties, serving imprisonment time, and the costs and lost time dealing with lawsuits.

Properly calibrating aerial application equipment is necessary to ensure uniform distribution of the pesticide materials and it helps prevent pesticide related problems. The following sections discuss different calibration techniques for liquid application equipment and granular application equipment.

Calibrating Liquid Sprayers

Calibrating liquid sprayers 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. You begin by matching the desired application volume and droplet size category with the number of nozzles, nozzle orifice size, application airspeed, and swath width. Use nozzle specifications from the manufacturer to select nozzles that, as closely as possible, produce the desired spray output and droplet size for the product you intend to apply. Arrange nozzles on the boom in such a way as to produce the desired deposition pattern when applying the material from the application height selected. Keep the application height constant during each swath run to obtain uniform coverage. Avoid adjusting application height to either change the swath width or spray pattern uniformity. Instead, replace nozzles to correct swath width and pattern uniformity.

Once the aircraft is properly set up, measure the following four factors:

- Tank capacity.
- Application airspeed.
- Flow volume.
- Effective spray swath width.

Spray pressure is a component of the flow volume because as the pressure increases or decreases the flow volume increases or decreases as well. Spray pressure must never exceed the recommendations of the nozzle manufacturer.

Check liquid spraying equipment frequently when applying abrasive pesticides, such as wettable powders, because these materials cause wear in pumps and nozzles. Pump wear decreases the amount and pressure of fluid output,

while nozzle wear increases the volume of output. Alone or in combination, these two occurrences usually lower the output pressure and may produce a poor spray pattern.

Tank Capacity

You need to know exactly how much liquid you can put into the aircraft's spray tank in order to determine how much area you can spray with each load. This requires measuring the capacity of the spray tanks, usually one time only. If you modify the tank, or remove or add components inside the tank, you will have to re-measure its 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.

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. Start adding measured amounts of clean water. Keep 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 you will always fill the tank whenever applying a full load. Once you determine the actual capacity of the tank or tanks, paint or engrave this amount onto a prominent place near the tank for permanent reference.

While filling the tank, also calibrate the tank sight gauge, or make marks on the tank as you add measured volumes of water. Once you calibrate the sight gauge or tank, 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 about half full of water (to get the best average for weight considerations), and flying at the same altitude as an actual spray application. If the aircraft spraying system is equipped with a flow volume controller, the controller will calculate the proper flow volume and make adjustments if airspeed changes. For it to make these adjustments, you must enter the application volume and the size of the effective swath width into the unit.

Flow Volume

If the aircraft is not equipped with a flow volume 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 volumes because of wear. Even new nozzles may have slight variations in actual output. Additionally, the pressure gauge in the aircraft may not be accurate, which further adds error to the output estimate determined from manufacturer charts. These charts express flow volume in gallons per minute, which you can then convert to gallons per linear mile at the prescribed swath width.

Rotary-wing Aircraft. Rotary-wing aircraft usually have electric or hydraulic powered pumps, so the aircraft does not need to be in flight to measure nozzle output. To find out the combined flow volume 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. Use a calibrated container that measures liquid ounces. Once you determine the total amount of output, convert the ounce measurement into gallons and then determine the gallons per minute and mile outputs (see *Sidebar 1*).

Fixed-wing Aircraft. Most fixed-wing aircraft use fan 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. Therefore, find

SIDEBAR 1

CALCULATING SPRAYER FLOW VOLUME PER MILE

(Rotary-Wing Aircraft)

A helicopter spray boom is equipped with 30 nozzles. Liquid has been collected from each nozzle for 30 seconds. When combined, the total amount of liquid collected is 600 ounces.

Convert the 600 ounces per 30 seconds into gallons per minute.

$$\frac{\text{total ounces collected} \times 60 \text{ seconds/minute}}{\text{seconds of collection time}} = \text{ounces/minute}$$

$$\frac{600 \text{ ounces collected} \times 60 \text{ seconds/minute}}{30 \text{ seconds}} = 1200 \text{ ounces/minute}$$

Next, convert the total ounces per minute into gallons per minute.

$$\frac{1200 \text{ ounces/minute}}{128 \text{ ounces/gallon}} = 9.375 \text{ gallons/minute}$$

In this example, the helicopter discharges 9.375 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.

Assume the helicopter is traveling at 50 miles per hour.

$$\frac{50 \text{ MPH}}{60 \text{ minutes/hour}} = 0.833 \text{ miles/minute}$$

$$\frac{9.375 \text{ gallons/minute}}{0.833 \text{ miles/minute}} = 11.25 \text{ gallons/mile}$$

the output of the sprayer over time by measuring how much water you use during several test flights. Each time you fill the tank, 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. Check for leaks around tank seals, hoses, and hose fittings. Be sure all nozzles are 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 you originally filled the tank.

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 and convert the result to gallons per mile as shown in *Sidebar 2*. For more accuracy, repeat this process two more times to get an average of sprayer output.

Swath Width

A crucial step in the calibration of an aircraft liquid dispersal system involves determining the effective

SIDEBAR 2

CALCULATING SPRAYER FLOW VOLUME PER MILE

(Fixed-Wing Aircraft)

For this example, the aircraft's spray tank is 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 36 gallons of water to refill the tank.

Calculate the gallons per minute output of the sprayer.

$$\frac{\text{36 gallons}}{\text{2 minutes}} = \text{18 gallons/minute}$$

Convert the gallons per minute into gallons per mile.

$$\frac{\text{120 miles/hour}}{\text{60 minutes/hour}} = \text{2 miles/minute}$$

$$\frac{\text{18 gallons/minute}}{\text{2 miles/minute}} = \text{9 gallons/mile}$$

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. Measure the amount of overlap leading to the effective swath width produced by an aircraft by pattern testing. Whenever you alter the spray boom in any way or change application height, 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. However, there are limits to how high you can go and get a wider swath. Spray drift management studies indicate that application height can affect the amount of off-target drift of the spray, depending on the spray droplet size. Therefore, minimizing off-target drift risk requires 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 off-target drift. High temperatures and low humidity will increase the evaporation rate.

An application height of 8 to 10 feet is usually the maximum suitable for applying spray droplets that have less tendency to drift. For application heights greater than 8 to 10 feet, you need larger spray droplets to reduce drift. The pesticide label usually provides application height limits or a range of application heights for a particular product. Flying too low can cause additional drift issues because of air turbulence hitting the ground (ground effect).

Determining the Acres per Minute Treated

To calculate the number of acres treated in one minute, use the airspeed

SIDEBAR 3

CALCULATING ACRES TREATED PER MINUTE

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 120 miles per hour. Convert this speed to feet per minute.

$$120 \text{ MPH} \times 5{,}280 \text{ feet/mile} = 633{,}600 \text{ feet/hour}$$

$$\frac{633{,}600 \text{ feet/hour}}{60 \text{ minutes/hour}} = 10{,}560 \text{ feet/minute}$$

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 10,560 feet per minute.

$$\text{feet/minute} \times \text{effective swath width} = \text{square feet/minute}$$

$$10{,}560 \text{ feet/minute} \times 50 \text{ feet} = 528{,}000 \text{ square feet/minute}$$

Convert this area into acres by dividing the square feet/minute by 43,560 square feet/acre.

$$\frac{528{,}000 \text{ square feet/minute}}{43{,}560 \text{ square feet/acre}} = 12.1 \text{ acres/minute}$$

and the effective swath width measurements in the calculations shown in *Sidebar 3*.

Determining the Application Volume per Acre

In the "Flow Volume" section, the fixed-wing aircraft example calculation (*Sidebar 2*) showed that a boom with 50 nozzles was discharging 18 gallons per minute. At 120 miles per hour, this amounts to 9 gallons per mile. *Sidebars 3 and 4* illustrate how to convert the gallons per mile to gallons per acre.

Determining the Amount of Pesticide to Put into the Tank

The label or job order prescribes how much pesticide to apply per acre. Be sure to confirm that the job order does not exceed the legal rate given on the label. You may have to adjust nozzle output or modify the application pattern to achieve this desired volume. For example, you may have to make more than one pass over a swath to apply the total number of gallons of spray or pounds of granules per acre as required by the label or job order application rate.

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 volume to find out how much pesticide will be required for the complete job.

Use tank volume and the gallons per minute figure to calculate how much time it will take for you to spray out all the liquid in the tank. Once you know this time, you can calculate the total area covered with each tank of material. The result will be the actual acres of treatment site that you can spray with

SIDEBAR 4

DETERMINING GALLONS PER ACRE

A spray boom having 50 nozzles discharges 18 gallons of spray per minute. Using the calculations from *Sidebar 3*, this aircraft covers 12.1 acres per minute.

Divide the gallons per minute by the acres per minute to get gallons per acre.

$$\frac{\textbf{18 gallons/minute}}{\textbf{12.1 acres/minute}} = \textbf{1.49 gallons/acre}$$

Therefore, the aircraft in this example will be spraying 1.49 gallons of liquid per acre when traveling at 120 miles per hour and spraying a 50 foot effective swath width.

SIDEBAR 5

DETERMINING THE AMOUNT OF PESTICIDE TO PUT INTO THE TANK

A fixed wing aircraft is equipped a with spray tank with a total measured capacity of 300 gallons. The aircraft spraying system will discharge 18 gallons per minute when flown at 120 miles per hour.

Divide the tank capacity by the gallons per minute to determine how many minutes it will take to spray 300 gallons, the tank's capacity.

$$\frac{\textbf{300 gallons/tank}}{\textbf{18 gallons/minute}} = \textbf{16.7 minutes/tank}$$

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 in Sidebar 3.

$$\textbf{16.7 minutes/tank} \times \textbf{12.1 acres/minute} = \textbf{202 acres/tank}$$

In this example, the aircraft can treat 201.7 acres with one tank of spray mixture. Assume the job order prescribes 2 pints of pesticide per acre. Knowing that one tank can cover 201.7 acres, the total amount of pesticide to put into the tank can be calculated.

Multiply the pints per acre by the acres per tank and divide this by 8 pints per gallon to determine the gallons of pesticide to put into the tank.

$$\frac{\textbf{2 pints/acre} \times \textbf{202 acres/tank}}{\textbf{8 pints/gallon}} = \textbf{50.5 gallons/tank}$$

These calculations show that 50.5 gallons of pesticide must be mixed with 249.5 gallons of water to fill the tank with 300 gallons of spray mixture.

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 mix with water in the aircraft's tank. See the calculations for this in *Sidebar 5*. You also need to calculate the area to be treated (*Sidebars 6-9*).

Changing Sprayer Output

Once calibrated, you have determined the output volume of the aircraft's spraying system for a specific speed, altitude, and pump pressure. However, there may be times during an operation when you may need to change the output volume 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.

You can make the adjustments discussed below, either alone or in combination, to effectively increase or decrease sprayer output, but only within a limited range.

Changing Speed. Typically, you should not adjust application speed in a fixed-wing aircraft to change the application volume. However, the simplest way to adjust the volume of spray (and amount of pesticide) you are applying in a

SIDEBAR 6

CALCULATING THE AREA OF A RECTANGULAR OR SQUARE APPLICATION SITE

To calculate the area of a rectangular (or square) site, you must know the:

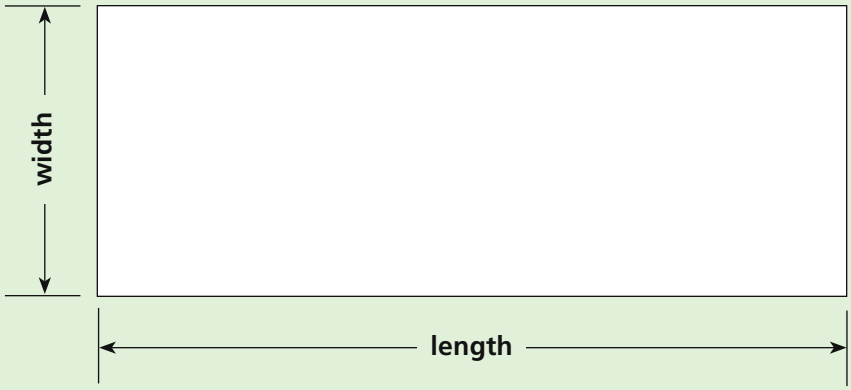
- Length of the longest side (in feet)
- Width of one adjacent side (in feet)

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 feet × 250 feet = 200,000 square feet

Convert the 200,000 square feet to acres by dividing by the number of square feet in one acre (43,560 square feet).

$$\frac{\textbf{200,000 square feet}}{\textbf{43,560 square feet per acre}} = \textbf{4.59 acres}$$



SIDEBAR 7

CALCULATING THE AREA OF A TRIANGULAR APPLICATION SITE

To calculate the area of a triangular site, you must know two dimensions, making sure both of these dimensions are in feet.

- The length of the longest side of the triangle (its **base**).
- The width of the triangle at its widest point (its **height**).

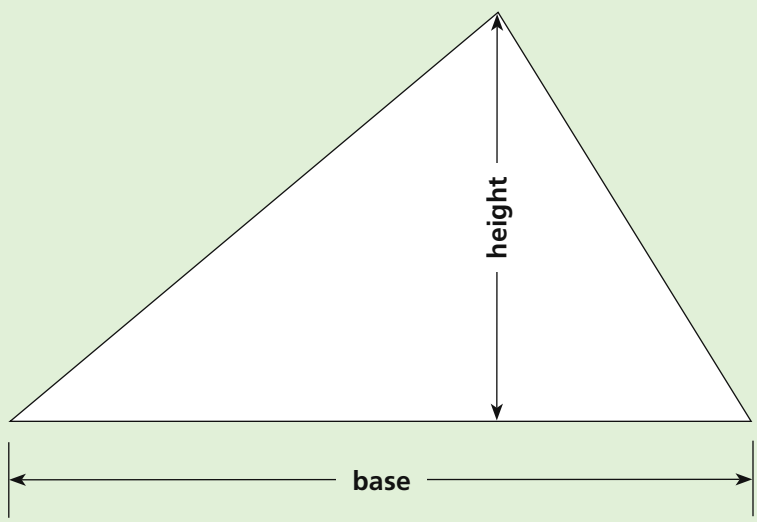
$$\textbf{area of a triangle} = \frac{\textbf{(base} \times \textbf{height)}}{\textbf{2}}$$

The longest side (base) of a triangular field measures 650 feet. The distance between this side and the point where the two other sides meet (height) is 300 feet.

$$\frac{\textbf{650 feet} \times \textbf{300 feet}}{\textbf{2}} = \textbf{97,500 square feet}$$

Divide the 97,500 square feet by 43,560 square feet per acre to find the number of acres in this triangular site.

$$\frac{\textbf{97,500 square feet}}{\textbf{43,560 square feet per acre}} = \textbf{2.24 acres}$$



SIDEBAR 8

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 in feet (see diagram below)
- The value of the constant pi (often indicated by the Greek letter π) which is 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 (π) times the square of the radius of the circle, where the square of the radius means multiplying the length of the radius by itself. Use this formula.

$$\text{area} = \pi \times r^2$$

where r is the radius and π = 3.14

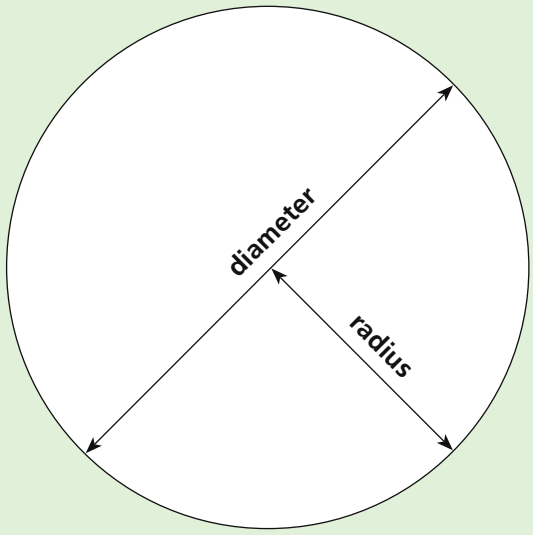
Before making any calculations, make sure the length of the radius (or the diameter) is known in feet. If only the diameter is known, divide this by 2 to get the radius.

The diameter of the circular field is 400 feet. This means that the radius is 200 feet. To calculate the area, multiply π (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.

$$\frac{125{,}600 \text{ square feet}}{43{,}560 \text{ square feet per acre}} = 2.88 \text{ acres}$$



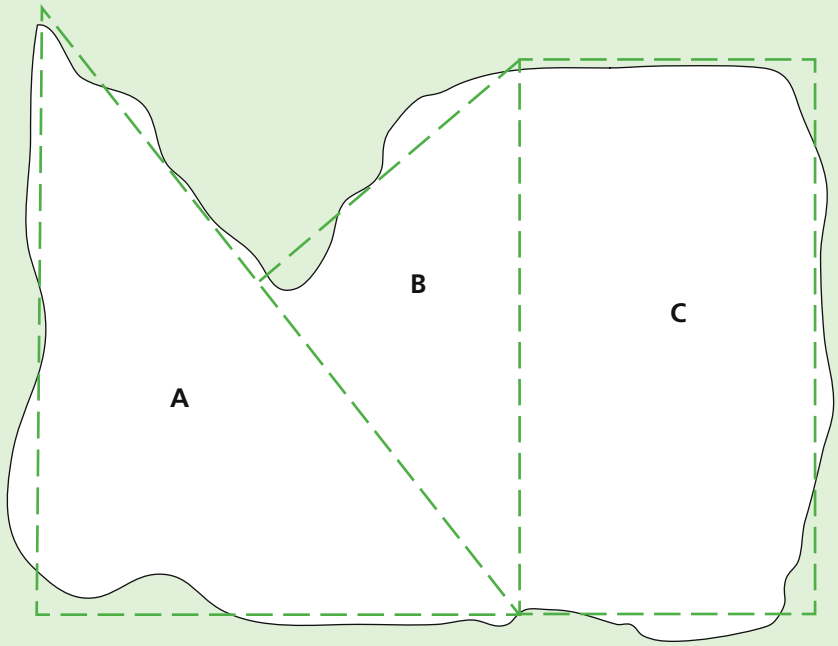
SIDEBAR 9

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. This can make an accurate area calculation difficult. 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 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.*

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. Then add together the three areas.



rotary-wing aircraft is to change the speed. A slower speed results in more material applied, while increasing the speed reduces the application volume. 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 volume. However, there are limits to the amount of speed change that you can make. Increasing speed too much is a problem because it increases the wind shear effect on spray droplet sizes, producing smaller spray droplets. In addition, faster speeds may reduce the application volume 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, and 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 as it moves less volume of spray because of the increase in space between the moving parts that normally force the liquid through the system. 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. In order to double the output volume, you must increase the pressure by a factor of four. This is usually beyond the capabilities of the spraying system and a pressure increase negatively affects the droplet size spectrum. 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 reduce the amount of small fines prone to off-target 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 from nozzle manufacturer web sites or manufacturer literature as guides for estimating output of different nozzle and orifice size combinations. When you change nozzle orifices, remeasure the output volume.

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, you generally can apply pesticides formulated as granules from greater application heights than what is suitable for liquids. Usually, higher granule application heights produce more uniform deposition patterns.

Before beginning to calibrate a granule applicator, be sure that it is clean and all parts are working properly. Measure three variables when calibrating a granule applicator:

- Application airspeed.
- Output rate.
- Swath width.

Application Airspeed

Always measure airspeed under actual working conditions with the aircraft loaded to normal operational weight and flying at the altitude that you will use when making a granule application.

Output Rate

To determine the rate of output, follow the manufacturer's guidelines

SIDEBAR 10

COMPUTING GRANULE APPLICATION RATE PER ACRE

The weight of the granules collected in all 13 pans totals 2 ounces.

Compute the pounds of granules being applied per acre as follows:

$$\frac{\text{43,560 square feet/acre} \times \text{2 ounces}}{\text{13 square feet}} = \text{6,701.54 ounces/acre}$$

Convert ounces per acre to pounds per acre by dividing by 16 ounces per pound:

$$\frac{\text{6,701.54 ounces/acre}}{\text{16 ounces/pound}} = \text{418.85 pounds/acre}$$

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-feet intervals in a straight line on the ground. Set these out 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 foam layer to help prevent any granules from bouncing out.

Swath Width

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.

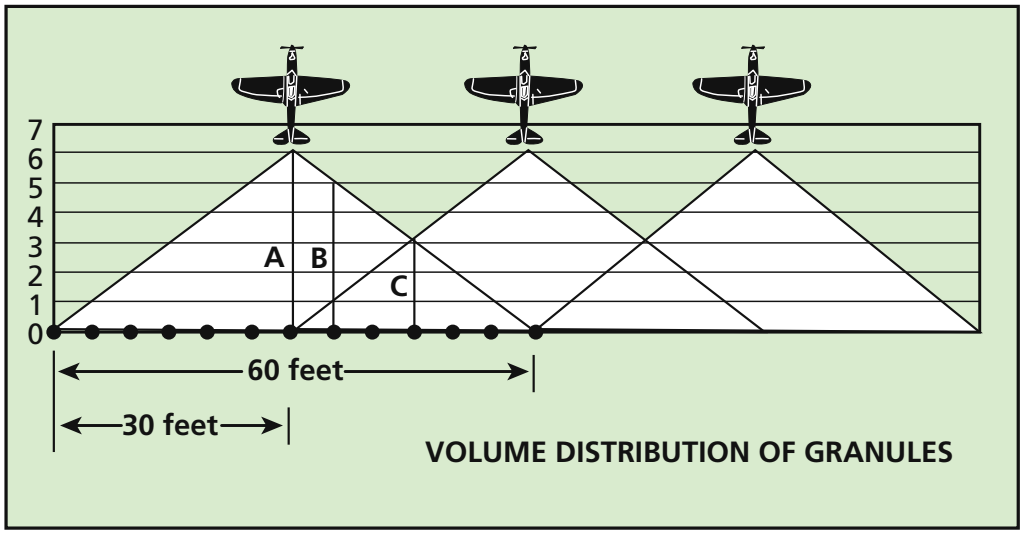
After the swath test flight, use a small graduated cylinder to collect and measure granule volume in each individual pan, progressing from left to right. Record each pan's volume on a graph in the exact order of collection. Plotting these volumes as a graph lets you visualize the distribution of your granule application across the swath. Finally, combine the granules from all the pans into another container, then 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. *Sidebar 10* shows how to calculate the granule application rate per acre.

The distribution shown in the figure on the next page is an idealized plotting of the amounts caught in 13 pans laid out 5-feet apart across a 60-foot swath. Another pass centered 30 feet to the right of the first pass produces a 50% overlap of the swaths and results in an even distribution of granules. This represents an effective swath width of 30 feet.

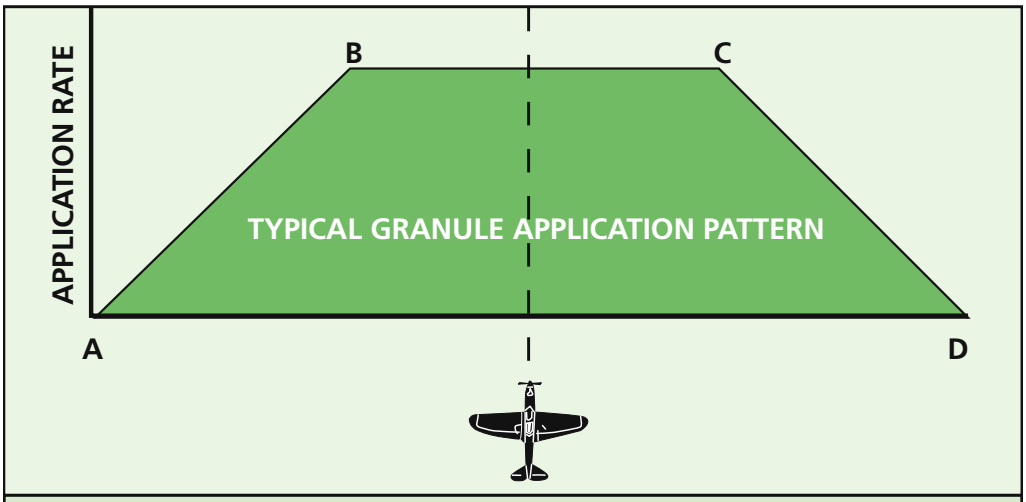
Examination of this figure shows that at point A, six units (these could be pounds, ounces, or any other unit of weight) were collected in the pan. At point B, the first swath applied five units in the pan and the second swath added one more for a total of six. At point C, each swath applied three units for six units in the pan.

The pattern shown at the bottom of the next page 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 on the next page.

Once you determine the effective swath width, you can estimate the



amount of granules, in pounds per acre. 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 calibrate dry materials accurately unless you are using the actual materials. 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



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, calculate the effective swath width.

$$\text{effective swath width} = \frac{60 \text{ feet} + 30 \text{ feet}}{2} = 45 \text{ feet}$$

In this situation, application passes should be made 45 feet apart.

centrifugal spreader gate to the desired rate per acre. This setting should result in accurate initial application rates. You can fine-tune this rate to be even more precise by calculating the amount of pesticide that you applied to a known area and comparing that to the desired rate.

Review Questions

CHAPTER 5: Calibrating Aerial Application Equipment

1. **The purpose of calibration is to:**
   - **A.** Determine the capacity of the spray tank(s).
   - **B.** Prevent off-target pesticide drift.
   - **C.** Apply the correct amount of pesticide.
   - **D.** Protect the environment.

2. **Applying a pesticide at a rate that is higher than the pesticide label rate is:**
   - **A.** Necessary.
   - **B.** Careless.
   - **C.** Illegal.
   - **D.** Useful.

3. **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 volume.
   - **D.** A decrease in the pesticide flow volume.

4. **If 1700 ounces of material is collected from nozzles on a helicopter spray boom in 90 seconds, what is the total flow volume in gallons per minute?**
   - **A.** 4.42
   - **B.** 8.85
   - **C.** 13.28
   - **D.** 17.70

5. **An aircraft spraying system has an output volume 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

6. **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.

7. **An aircraft sprays 20.2 gallons per minute. How many minutes of spraying time are needed to spray out 147 gallons of spray mixture?**
   - **A.** 6.8
   - **B.** 7.3
   - **C.** 8.5
   - **D.** 9.0

8. **Given an application rate of 11.3 gallons per acre, how many acres can be sprayed with 147 gallons of spray mixture?**
   - **A.** 11
   - **B.** 12
   - **C.** 13
   - **D.** 14

9. **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 volume of 1.5 pints per acre?**

   A. 11
   B. 15
   C. 21
   D. 24

10. **How many acres are in a rectangular field that measures 620 feet by 1280 feet?**

   A. 16.1
   B. 18.2
   C. 22.8
   D. 28.8

REVIEW QUESTION ANSWERS ON PAGE 97

CHAPTER 6

Making an Aerial Pesticide Application

LEARNING OBJECTIVES

Reading this chapter will help you understand:

- Safe ferrying techniques.
- What to check when arriving at the application site.
- How to recognize and work with weather at the application site.
- Different types of application patterns.
- Special considerations when applying granules.

The reasons for following proper aerial pesticide application methods are to make precise, safe, and legal aerial applications consistently and to minimize the off-target movement of pesticide droplets. Proper application methods include knowing how to:

- Recognize the factors and conditions that contribute to off-target pesticide drift and other offsite movement, and know how to minimize off-target pesticide drift and other offsite movement.
- Safely ferry the aircraft between home base, the loading site, and the application site.
- Inspect the application site and surrounding areas for hazards before beginning the application.
- Watch for hazards throughout the application operation.
- Fly an effective application pattern and make safe and efficient turns and passes.
- Recognize the atmospheric factors that influence the stability and maneuverability of the aircraft.
- Use DGPS or other guidance systems.

Agricultural aircraft are highly visible and noisy, and as a result, some people view aerial pesticide applications as nuisances or hazards. The sight of an aircraft flying low over fields is a serious and sometimes anxiety producing concern for some. When you make aerial applications, be aware of these concerns and, when necessary, be sure to acknowledge them by taking steps to foster better communication with the public. Notify people in the area about a planned application and make efforts to mitigate noise in areas where people

live and work during ferrying or application operations.

Preflight, departure, and application **checklists** are useful tools for you, ground crew members, and others involved in an aerial application operation (see Pages 85 and 86 for pilot and ground crew checklists). These checklists help anyone involved in the operation to organize and manage their responsibilities and they help to assure that the operation is safe and effective.

For you and the ground crew, the first and last runs of the day often call for extra attention. The first flight of the day requires that you and ground crew members be alert and mentally prepared immediately for the complexities of the operation—with 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, care, and time as every other flight during that day. However, the first flight of the day is the best time to schedule jobs that are more difficult since you and the ground crew are more rested.

FERRYING

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. 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. This tactic tends to minimize the audio and visual impact of the flights, as opposed to repeatedly flying the same route and subjecting the same people to the same level of distraction.

Tom Hoffmann—Washington State Department of Agriculture

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, especially down-wind of the site.
- Livestock are not in the application area or adjacent areas where they may come in contact with the spray.
- Crops adjacent to the application site match those identified on the work order—if in doubt, verify the type of crop with the grower before beginning an application.
- All members of the ground crew assigned to this operation are present and ready to begin their duties.
- The communication link between you, the ground crew, and the base location is functioning correctly and that you have a working backup communication plan in case of equipment failure.

- The aircraft DGPS system, if equipped, is properly functioning.

If you note any conditions in the application site or adjacent areas that the pesticide label does not permit or that you consider unsafe, and these conditions cannot be resolved quickly, abort the operation and return to your home base. If the area is clear and conditions favor an application, 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. 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.

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. Branch wires may be obscured or difficult to see, so look for a cross arm going in a different direction from the main wires. 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 someone made previous inspections or aerial applications to this particular field. For instance, crops in fields adjacent to the application site may be different from those noted on the work order. If this is the case, confirm the application site location. Also, new buildings or wells may have 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.

John Mateski—Newberg, OR

Monitor Changes

Changes that may affect the safety or effectiveness of the opeation include the following:

Weather

Wind speed may increase or decrease or the wind direction may change, creating hazards of drift or

Carol Ramsay—Washington State University

contamination of sensitive areas. Alternatively, wind may stop altogether, increasing the chances of a temperature inversion condition. 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, plants may suffer damage (phytotoxicity) from the spray material. Certain pesticide labels may have humidity restrictions for application.

Hazards

Previously unidentified hazards may become apparent to either you or the ground crew, requiring that you stop or modify the application at that site. This might include the discovery of livestock 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 sprayed or people working in adjacent fields unaware of the application operation could pass through or walk into the field under treatment. In both cases, the operation is required to stop until everyone is safely out of the area. 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 electric meter readers, delivery services, 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 escort them out of the area for their own safety.

Importance of Onsite Ground Crew During an Application

Each on-site ground crew member needs to be able to communicate directly with you, 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 an on-site ground crew member typically include:

- Acting as a liaison between you and the property manager to ensure aerial application obligations are met.

PILOT CHECKLIST

Things to consider before, during, and after any application.

- Inspect the aircraft and all of its safety equipment and your personal safety equipment for proper operation and usable condition.
- Be sure the aircraft's onboard fire extinguisher is in working condition and has a readable inspection tag.
- Confirm that the correct pesticide material is mixed with the proper amount of water and put into the aircraft's spray tank by the ground crew by rechecking the pesticide label and counting the number of empty containers.
- 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.
- If possible, avoid mixing and loading activities to reduce chances of bringing pesticide residue into the aircraft's cockpit.
- 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 and return at another time 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 volume except while over the area you are treating.
- Refuse to fly if the customer requires having any pesticide applied in a manner and at a time that may create a hazard to crops, humans, animals, and the surrounding environment.
- Make sure every application of a pesticide follows a valid label for a listed crop or site and that the label has no prohibition for application by air.
- Read the label and know the hazardous characteristics of the pesticides.
- Using a smoke generator or other device, estimate how far and in what direction some of the chemical may move away from the application site.
- Never spray over a flagger, other handlers, or anyone else working in the area.
- After making an application, if you notice any equipment malfunction or problems, securely fasten a note in the cockpit to alert other pilots and the maintenance crew.
- Prepare and keep accurate application records.

GROUND CREW CHECKLIST

Instruct members of the ground crew to take several precautions before, during, and after any application.

- Using extreme care when handling pesticides or cleaning the aircraft or other contaminated equipment.
- Reading the labels of all pesticides being mixed and wearing label- or regulation-required work clothing and personal protective equipment.
- Insuring that the correct pesticides are properly diluted and mixed before loading into the aircraft's spray tank.
- 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 around the aircraft tank 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.
- Assisting in preparing and keeping application records.

The ground crew should also be familiar with the pilot's checklist.

- Preventing 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 you and the on-site field crew supervisor or leader.
- Assisting you in pretreatment target area inspection.
- Acting as an in-field reference point for you to identify swath boundaries.
- Providing emergency response and summoning emergency services in case of a crash incident.

APPLICATION METHODS

Use safe flying procedures during all phases of the application operation. Never take risks for the thrills at the expense of good judgment or safety. To ensure that the pesticide application will be effective, follow label use directions and requirements in the label and regulations. Avoid off-target pesticide drift or other off-target movement of the pesticide material. Adhere to the methods discussed in this manual to avoid off-target pesticide drift. Visually check the spray or granule discharge while making applications to spot application problems.

Straight, parallel passes produce the most uniform spray pattern. Use a reliable method, such as DGPS, 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.

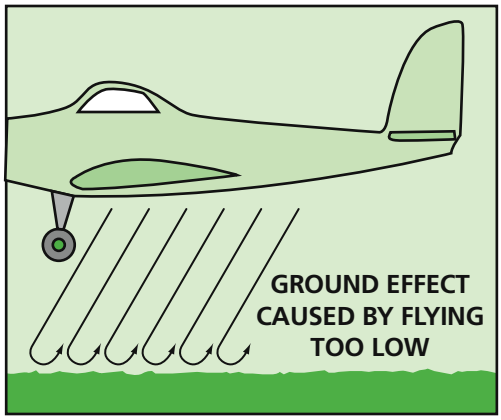
To prevent spray from contacting sensitive areas, or to avoid flying or turning over residences and other sensitive areas, you may need to wait for more favorable conditions or alter the application pattern in relation to prevailing wind direction and even contrary to logical field layout. For instance, consider a rectangular field having its longest width running east and west. Because the wind is from the north, it would appear logical to make east-west passes. However, on the eastern border of the field is a road with houses on the other side of this road. East-west passes require making turns over the road and houses. In this situation, make shorter, north-south passes over the field—even though this requires making more turns.

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 unless you are using an electronic flow volume controller to compensate for speed changes. Flying crosswind or 45 degrees to the crosswind during an application avoids the adverse effects of head- and tail-winds on the application volume.

Altitude

Notwithstanding legal requirements in the label, in law, or in regulation, the type of pesticide you apply usually determines application altitude. For example, liquid pesticides are most effective and off-target drift is less of a problem when you make applications 8 to 12 feet above the crop or tree canopy. Flying lower will reduce



off target drift because the droplets are closer to the ground, however flying too low may cause uneven streaking due to not allowing enough time for the spray pattern to fill in. 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. Ground effect occurs when the aircraft is less than ¾ the wing or rotor span from the ground. This upward moving air entraps and lifts some of the spray and contributes to off-target pesticide movement. Trees and other plants with dense foliage may lower the ground effect risk.

Application altitude also depends on atmospheric conditions. It is common for an aircraft to fly higher in calm conditions and lower when the wind is higher. As the aircraft gets lower, the induced drag decreases, reducing drift. Wing tip vortices, which will increase drift, are dependent on aircraft configuration, speed, and weight. Slower and heavier aircraft will have larger wing tip vortices due to increased induced drag.

Keep the application height constant during each application pass to maintain the effective swath width that you determined during calibration of the dispersal equipment. Failure to do so will result in difficulty obtaining uniform coverage.

Obstructions

If you encounter obstructions at the beginning or end of a swath run, turn the spray on or shut it off one or two swath-widths from the beginning or

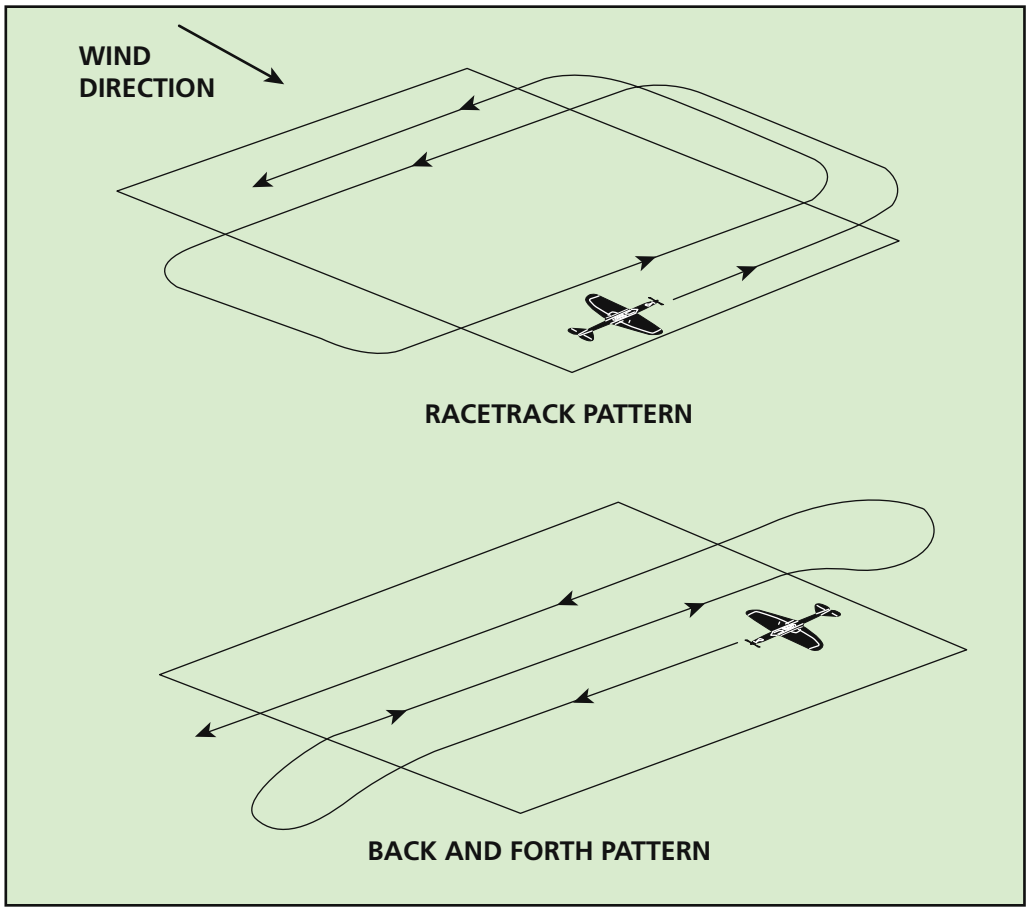
end of the field. Then, when you finish all parallel swaths, fly one or two swaths crosswise to the rest of the application direction to finish out the field. Never disperse materials while dropping in or pulling out of a field because this distorts the deposition pattern. Should this happen, the pesticide 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.

There are two methods for working around trees, poles, or other obstructions in the middle of a field. One is to treat them 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's 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. The second method is to stop spraying and pull up as you approach the obstacle, make a 360° turn, fly over the obstacle, drop down, and continue spraying.

When a high enough wire crosses a swath that has trees at one end, fly under the wire if possible, and then pull up and fly over the trees. This is safer than entering the field over trees and then passing under the wire.

FLIGHT PATTERNS

One flight pattern for aerial application is the adjacent swath or back and forth pattern, applying swaths over the target in straight, parallel lines. In areas that



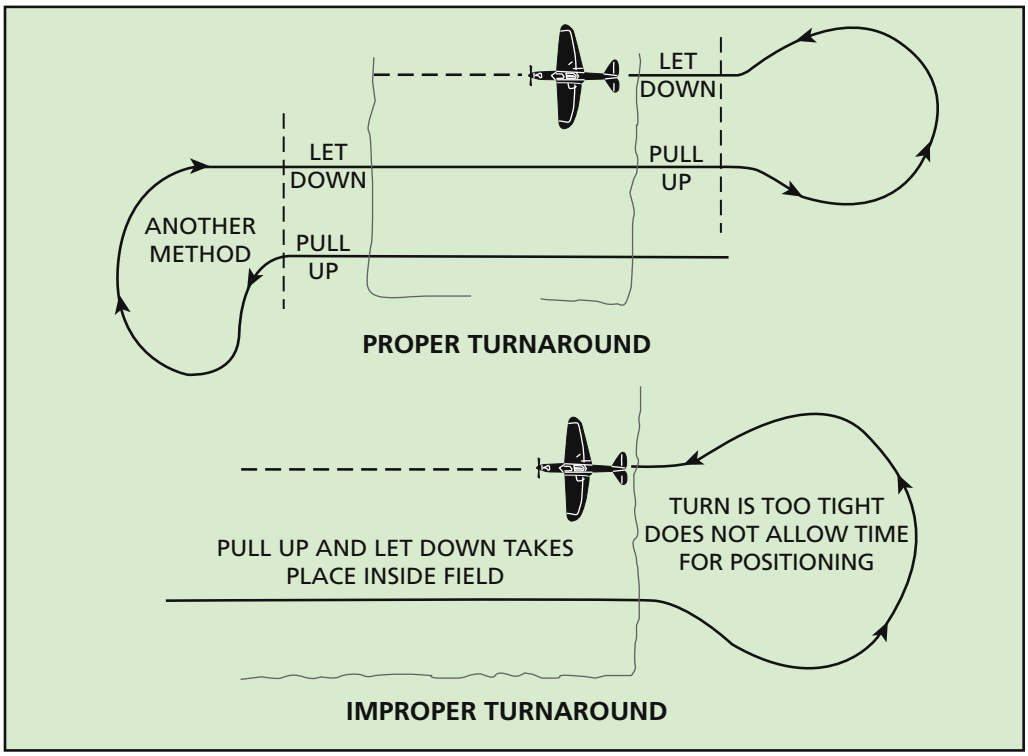
are too rugged for uniform altitude and speed, follow the contours of the slopes during application passes. In hilly terrain, or where hills or mountains confine the application area and do not permit contour flying, make all passes in one direction, down slope. Upslope spraying can be dangerous.

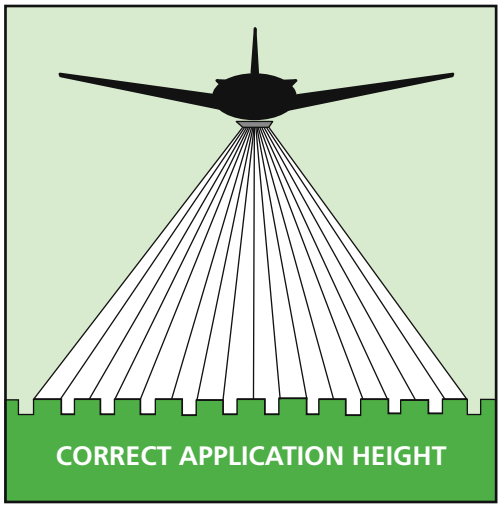
Usually, the racetrack pattern is the most energy-efficient. This pattern maximizes application time and lessens the time required for turns. It also allows time for the spray to settle, reducing the chance of flying through it. This pattern often minimizes pilot fatigue. Whether flying a racetrack or back and forth pattern, it is important to start and stop spraying at the right time when entering or leaving the field. Starting too soon or stopping too late causes spray to be applied to off target areas. Starting too late or stopping too soon may result in improper coverage to field ends.

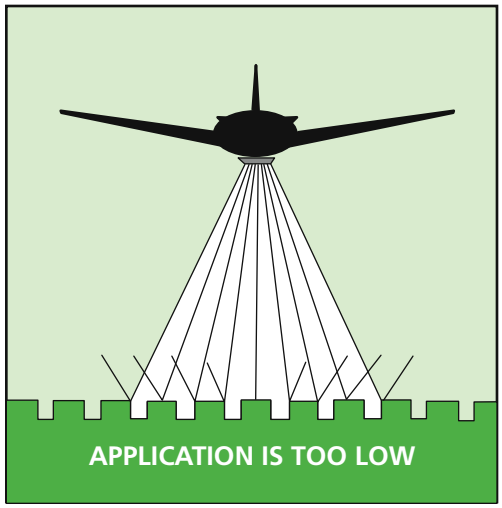
The Turnaround

When flying back and forth or racetrack swaths in a fixed-wing aircraft, be careful when executing turnarounds. This is 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 enough initial turn downwind that will provide sufficient room for a smooth turn around. Then level off for several seconds before completing the turn back into the treatment area. 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 wing over turns. When making a turn by going upwind first requires more space and time to complete the turn. Any turning while dispensing a spray or granules distorts the distribution pattern resulting in uneven application 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. Avoiding these areas mitigates or minimizes nuisance from noise or sight of the aircraft.

Applying Granules

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 and aircraft, this is in the range of 45 to 70 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 dissipates. 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 volume 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.

FACTORS INFLUENCING THE AIRCRAFT

Density altitude as well as local weather conditions and load weight can affect the stability and maneuverability of an aircraft during an application operation. Weather conditions such as wind can affect the stability and handling of the aircraft and contribute to uneven swaths and off-target pesticide drift.

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:

- 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.
- 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.

Here is an example. The elevation at the application site is 2,342 feet.

1. Divide the elevation by 1,000.

$$\frac{2{,}342}{1{,}000} = 2.342$$

2. Multiply 2.342 by 3.5.

$$2.342 \times 3.5 = 8.197$$

3. Subtract 8.197 from the sea level standard temperature of 59°F.

$$59 - 8.197 = 50.803$$

4. The standard temperature at the application site is 50.8°F. In this example, assume that the current temperature at the application site is 97°F. Subtract the standard temperature at the application site from this.

$$97 - 50.8 = 46.2$$

5. Divide this difference by 10 degrees (for each 10°F above standard).

$$\frac{46.2}{10} = 4.62$$

6. Multiply 4.62 by 600 (600 feet per 10 degrees).

$$4.62 \times 600 = 2{,}772$$

7. Add this correction factor of 2,772 feet to the field elevation of 2,342 feet at the application site.

$$2{,}772 + 2{,}342 = 5{,}114$$

The density altitude for the application site when the temperature is 97°F is 5,114 feet. This means that you should handle the aircraft at the application site as you would on a standard day at 5,114 feet elevation.

Humidity also affects available engine power and aircraft performance because higher humidity is an increase in 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.

Density Altitude

Density altitude is a condition where air molecules spread or thin out, becoming less dense, changing aircraft flight characteristics such as lift and maneuverability. In addition, thinner air means that less oxygen is available for optimum engine performance and this reduces horsepower unless the aircraft has a turbocharged engine. Factors that influence the density of air molecules include pressure (the effect of altitude) and temperature. The higher the altitude, the less dense air becomes because the air molecules are further apart, leaving fewer molecules to provide lift for the aircraft. Warmer air temperature also causes air molecules to move further apart, making the air less dense as well.

Density altitude, as well as high air temperatures, affects the stability and maneuverability of the aircraft for making applications, takeoffs, and landings. It also changes stall thresholds and influences 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 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, or absolute altitude.

In high elevation areas, usually between mid-morning and mid-afternoon, high temperatures sometimes have such an effect on density altitude that normally safe aerial application operations 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. However, early mornings are typical times for temperature inversion conditions in many areas.

OPERATION S.A.F.E.

(Self Regulating Application and Flight Efficiency)

One U.S. Department of Agriculture scientist characterized the growing public concern over possible effects of spray drift by stating: "Drift control is the key to survival of aerial application in agriculture."

In response to this concern, members of the National Agricultural Aviation Association (NAAA), the organization of professional aerial applicators and pilots, developed Operation S.A.F.E. The word S.A.F.E., important in any pilot's vocabulary, is an acronym for Self-Regulating Application and Flight Efficiency.

The intent of Operation S.A.F.E. is to clearly demonstrate that ag aviation recognizes its responsibility to minimize the potential for adverse health and environmental effects of agricultural chemical application. The program was approved by the NAAA Board of Directors in 1981.

Because the performance of one aerial applicator reflects on all others, participation in Operation S.A.F.E. is not limited to NAAA members. Any licensed operator or agricultural aviator is welcome to participate in Operation S.A.F.E. In order to qualify for the S.A.F.E. emblem, the participant must be a current member of the NAAA.

Operation S.A.F.E. is a comprehensive program of education, professional analysis of application, and commitment to the principles outlined by the NAAA Board of Directors. NAAA is convinced that full implementation of Operation S.A.F.E. offers substantial advantages to the operator, customers, and the producers of chemicals applied by air. These advantages are found in economy of operation and application, as well as in increased safety and reduced health and environmental concerns.

The backbone of Operation S.A.F.E. is the Professional Application Analysis Clinic—the Operation S.A.F.E. Fly-In. Professional application analysis clinics are a key part of Operation S.A.F.E. Participation in an NAAA-approved swath analysis equipment, under the direction of an authorized analyst, is essential to qualify for the Operation S.A.F.E. emblem. The emblem is affixed to an individual aircraft only when the aircraft, its pilot, and the operator have each met Operation S.A.F.E. guidelines.

Fly-ins have long been a popular activity among pilots. Their objectives traditionally range from getting together to swap experience and stories to socializing. However, among ag pilots, fly-ins have long been seen as a learning experience, an opportunity to improve their own performance and increase their professionalism.

The key to the effectiveness—and acceptance—of aerial application is the spray pattern of the aircraft itself and the dedication of operators to its accuracy. Swath study and analysis have been a part of aerial application since the first plane dusted an Ohio catalpa grove in 1921. Since that time, scientists from land grant universities and private corporations, and aerial applicators have been active in improving the state-of-the-art of aerial application. Chemical manufacturers have worked on chemical

(continued on next page)

Paul Newby—Bozeman, MT

formulations and additives to improve the pilot's ability to put the product on the target.

Today, equipment is available to provide the operator a precise picture of swath characteristics, and to provide it quickly. Thus, the Operation S.A.F.E. fly-in becomes a professional application analysis clinic. The Operation S.A.F.E. clinic gives the operator and pilot the opportunity to test equipment with a trained analyst to help interpret the information and to recommend changes to improve performance. A follow-up test is immediately available, so the operator can be certain improvement does exist.

NAAA expects all applicators to remain informed of and comply with all pertinent legal requirements. In addition, participating applicators agree to submit voluntarily to an inspection of their equipment and operating procedures to determine:

- Compliance with manufacturers' mixing rates, application recommendations, and label requirements of agricultural chemicals.
- Adequacy of safety procedures in storing and handling agricultural chemicals.
- Compliance with flight safety procedures.

The NAAA urges every operator and pilot to participate in an Operation S.A.F.E. clinic yearly. Check with your state ag aviation association to see when a clinic will be offered in the area. Display the Operation S.A.F.E. sticker and yearly decals on the aircraft with pride. Let customers know that you have taken advantage of this opportunity to check equipment and refresh your skills prior to taking on their job.

Review Questions

CHAPTER 6: Making an Aerial Pesticide Application

1. **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 be to the most challenging field of that day's operation.

2. **Varying the application speed without changing flow volume during an application will:**
   - **A.** Provide a more even application.
   - **B.** Accommodate for wind direction changes.
   - **C.** Result in uneven coverage.
   - **D.** Increase off-target drift potential.

3. **The application pattern that helps to avoid flying through spray from a previous swath is the:**
   - **A.** Race track pattern.
   - **B.** Back and forth pattern.
   - **C.** Alternate swath pattern.
   - **D.** Upslope pattern.

4. **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.

5. **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 1/8 to 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.

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 volume.

7. **Too wide or too narrow overlapping of spray passes will result in:**
   - **A.** Flight hazards.
   - **B.** Increased chances of off-target drift.
   - **C.** Uneven application patterns.
   - **D.** Disabling of the DGPS system.

8. **To avoid the adverse effect of headwinds or tailwinds on an application volume, 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.

9. **Which of the following would have little effect on the safety and effectiveness of an application if changes occur during the operation?**

   A. Moving the operation to a different mixing-loading location.

   B. Wind intensity increases.

   C. Delaying the application until field workers leave the area.

   D. Leaving a buffer area adjacent to a sensitive area.

10. **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.

REVIEW QUESTION ANSWERS ON PAGE 97

Review Question Answers

CHAPTER 1

1. B
2. D
3. B
4. A
5. D
6. A
7. C
8. A
9. B
10. C

CHAPTER 2

1. A
2. B
3. D
4. C
5. A
6. A
7. C
8. D
9. D
10. C

CHAPTER 3

1. C
2. B
3. C
4. A
5. C
6. D
7. B
8. C
9. D
10. C

CHAPTER 4

1. D
2. C
3. C
4. B
5. C
6. B
7. C
8. B
9. A
10. C

CHAPTER 5

1. C
2. C
3. B
4. B
5. A
6. C
7. B
8. C
9. C
10. B

CHAPTER 6

1. C
2. C
3. A
4. C
5. B
6. C
7. C
8. D
9. A
10. B

APPENDIX 1

PESTICIDE REGULATORY AGENCY CONTACT INFORMATION

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Alabama Department of Agriculture and Industries
P.O. Box 3336
Montgomery, AL 36109-0336
(334) 240-7236

Alaska
Environmental Health
Alaska Department of Environmental Conservation
555 Cordova
Anchorage, AK 99501-2617
(907) 269-1099

Arizona
Environmental Services Division
Arizona Department of Agriculture
1688 West Adams Street
Phoenix, AZ 85007-2617
(602) 542-3575

Arkansas
Arkansas State Plant Board
P.O. Box 1069
Little Rock, AR 72203-1069
(501) 225-1598

California
California Department of Pesticide Regulation
1001 I Street
P.O. Box 4015
Sacramento, CA 95812-4015
(916) 445-4000

Canada
Pest Management Regulatory Agency
Health Canada
2720 Riverside Drive D765
Ottawa, ON K1A 0K9
Canada
(613) 736-3662

Colorado
Division of Plant Industry
Colorado Department of Agriculture
700 Kipling Street, Suite 4000
Lakewood, CO 80215-8000
(303) 239-4138

Connecticut
Waste Engineering and Enforcement Division
Department of Environmental Protection
79 Elm Street
Hartford, CT 06106-5127
(860) 424-3264

Delaware
Delaware Department of Agriculture
2320 South Dupont Highway
Dover, DE 19901-5515
(302) 698-4570

District of Columbia
Department of Health
Environmental Health Administration
Toxic Substance Division
Pesticide Program
51 N Street NE, 3rd Floor, Room 3003
Washington, DC 20002
(202) 535-2280

Florida
Department of Agricultural Environmental Services
Florida Department of Agriculture and Consumer Services
3125 Conner Blvd - Suite F, Room 130 - C16
Tallahassee, FL 32399-1650
(850) 488-3731

Georgia
Plant Industry Division
Georgia Department of Agriculture
Capitol Square
Atlanta, GA 30334-4201
(404) 656-1265

Hawaii
Plant Industry Division
Hawaii Department of Agriculture
1428 South King Street
Honolulu, HI 96814-2512
(808) 973-9535

Idaho
Division of Agricultural Resources
Idaho Department of Agriculture
P.O. Box 790
Boise, ID 83701-0790
(208) 332-8531

Illinois
Bureau of Environmental Programs
Illinois Department of Agriculture
P.O. Box 19281
Springfield, IL 62794-9281
(217) 785-2427

Indiana
Indiana State Chemist Office
175 South University Street
Purdue University
West Lafayette, IN 47907-2063
(765) 494-1492

Iowa
Consumer Protection and Industry Services Division
Iowa Department of Agriculture and Land Stewardship
Wallace Building, 502 East 9th Street
Des Moines, IA 50319-0051
(515) 281-8610

Kansas
Kansas Department of Agriculture
901 South Kansas Avenue
Topeka, KS 66612-1281
(785) 296-3556

Kentucky
Division of Consumer and Environmental Protection
Kentucky Department of Agriculture
107 Corporate Drive
Frankfort, KY 40601-1108
(502) 573-0282

Louisiana
Pesticide and Environmental Programs
Louisiana Department of Agriculture and Forestry
P.O. Box 3596
Baton Rouge, LA 70821-3596
(225) 925-3763

Maine
Board of Pesticides Control
Maine Department of Agriculture
28 State House Station
Augusta, ME 04333-0028
(207) 287-2731

Maryland
Office of Plant Industries and Pest Management
50 Harry S. Truman Parkway
Annapolis, MD 21401-7080
(410) 841-5870

Massachusetts
Division of Regulatory Services
Massachusetts Department of Agricultural Resources
251 Causeway Street, Suite 500
Boston, MA 02114-0009
(617) 626-1771

Michigan
Pesticide and Plant Pest Management Division
Michigan Department of Agriculture
P.O. Box 30017
Lansing, MI 48909-7517
(517) 373-4087

Minnesota
Pesticide and Fertilizer Management Division
Minnesota Department of Agriculture
625 Robert Street North
St. Paul, MN 55155-2538
(651) 201-6615

Mississippi
Bureau of Plant Industry
Mississippi Department of Agriculture and Commerce
P.O. Box 5207
Mississippi State, MS 39762-5207
(662) 325-8789

Missouri
Plant Industries Division
Missouri Department of Agriculture
P.O. Box 630
Jefferson City, MO 65102-0630
(573) 751-2462

Montana
Agricultural Sciences Division
Montana Department of Agriculture
P.O. Box 200201
Helena, MT 59620-0201
(406) 444-2944

Nebraska
Nebraska Department of Agriculture
Bureau of Plant Industry
301 Centennial Mall
P.O. Box 94756
Lincoln, NE 68509-4756
(402) 471-2394

Nevada
Division of Plant Industry
Nevada Department of Agriculture
350 Capital Hill Avenue
Reno, NV 89502-2923
(775) 688-1182

New Hampshire
Division of Pesticide Control
New Hampshire Department of Agriculture, Markets, and Food
P.O. Box 2042
Concord, NH 03302-2042
(603) 271-3640

New Jersey
Pesticide Control
Coastal and Land Use Enforcement
New Jersey Department of Environmental Protection
P.O. Box 411
Trenton, NJ 08625-0411
(609) 984-2011

New Mexico
Division of Agricultural and Environmental Services
New Mexico Department of Agriculture
P.O. Box 30005, Department 3AQ
Las Cruces, NM 88003-8005
(505) 646-2133

New York
Division of Solid and Hazardous Materials
New York State Department of Environmental Conservation
625 Broadway, 9th Floor
Albany, NY 122337250
(518) 402-8651

North Carolina
Structural Pest Control and Pesticides Division
North Carolina Department of Agriculture and Consumer Services
1090 Mail Service Center
Raleigh, NC 27699-1090
(919) 733-3556

North Dakota
Plant Industries
North Dakota Department of Agriculture
600 East Boulevard, 6th Floor
Bismarck, ND 58505-0020
(701) 328-4756

Ohio
Division of Plant Industry
Ohio Department of Agriculture
8995 East Main Street
Reynoldsburg, OH 43068-3399
(614) 728-6383

Oklahoma
Consumer Protection Services Division
Oklahoma Department of Agriculture, Food, and Forestry
P.O. Box 528804
Oklahoma City, OK 73152-8804
(405) 522-5879

Oregon
Pesticides Division
Oregon Department of Agriculture
635 Capitol Street, NE
Salem, OR 97301-2532
(503) 986-4635

Pennsylvania
Bureau of Plant Industry
Pennsylvania Department of Agriculture
2301 North Cameron Street
Harrisburg, PA 17110-9408
(717) 772-5217

Puerto Rico
Analysis and Registration of Agricultural Materials
Puerto Rico Department of Agriculture
P.O. Box 10163
Santurce, PR 00908-1163
(787) 796-1710

Rhode Island
Division of Agriculture and Resource Marketing
Rhode Island Department of Environmental Management
235 Promenade Street
Providence, RI 02908-5767
(401) 222-2782

South Carolina
Regulatory and Public Service Programs
Clemson University
109 B Barre Hall
Clemson, SC 29634
(864) 656-1234

South Dakota
Office of Agronomy
Division of Agricultural Services
South Dakota Department of Agriculture
Foss Building, 523 East Capitol
Pierre, SD 57501-3182
(605) 773-4432

Tennessee
Tennessee Department of Agriculture
Division of Regulatory Services
P.O. Box 40627, Melrose Station
Nashville, TN 37204-0627
(615) 837-5152

Texas
Texas Department of Agriculture
Pesticide Programs Division
P.O. Box 12847
Austin, TX 78711-2847
(512) 463-7504

Utah
Utah Department of Agriculture and Food
350 North Redwood Road
P.O. Box 146500
Salt Lake City, UT 84114-6500
(801) 538-7180

Vermont
Vermont Agency of Agriculture, Food, and Markets
116 State Street, Drawer 20
Montpelier, VT 05620-2901
(802) 828-2431

Virgin Islands
Division of Environmental Protection
Department of Planning and Natural Resources
Cyril E. King Airport
St. Thomas, VI 00802
(340) 774-3320

Virginia
Office of Pesticide Services
Virginia Department of Agriculture
and Consumer Services
P.O. Box 1163, 102 Governor Street, Room 149
Richmond, VA 23218-1163
(804) 371-6561

Washington
Pesticide Management Division
Washington Department of Agriculture
P.O. Box 42589
Olympia, WA 98504-2589
(360) 902-2011

West Virginia
Regulatory and Environmental Affairs Division
West Virginia Department of Agriculture
1900 Kanawha Boulevard East
Charleston, WV 25305-0190
(304) 558-2208

Wisconsin
Agriculture Resource Management Division
Wisconsin Department of Agriculture
Trade and Consumer Protection
P.O. Box 8911
Madison, WI 53708-8911
(608) 224-4567

Wyoming
Technical Services
Wyoming Department of Agriculture
2219 Carey Avenue
Cheyenne, WY 82002-0100
(307) 777-6574

APPENDIX 2

FAA REQUIREMENTS FOR AGRICULTURAL AIRCRAFT OPERATORS

The FAA's approach for evaluating and determining your ability to comply with Part 137 and other applicable regulations focuses on three categories: the pilot, the aircraft, and the operation. You must successfully satisfy each of the following five phases in the evaluation process to become a certified agricultural aircraft operator:

- Pre-application.
- Formal application.
- Document compliance.
- Demonstration and inspection.
- Certification.

For complete and helpful information on the process to follow to obtain an FAA pilot certification for agricultural operations, refer to FAA Advisory Circular 137-1A—Certification Process for Agricultural Aircraft Operators. You may obtain this document and application forms from the local Flight Standards District Office (FSDO). For the nearest FSDO office, check the FAA listing in the United States Government section of the local telephone directory.

The Pre-Application Process

Pre-application involves an informal meeting to provide you with an overview of the certification process and identify the necessary resources helpful to you as you go through the certification process. If you are familiar with all of the requirements of the agricultural aircraft operation's certification process and the required documentation (e.g., if you have previous experience as an agricultural aircraft operator), you may not need a pre-application meeting.

During the meeting, an official from the FSDO will determine if you meet the eligibility requirements for obtaining an operator certificate by asking you about the following:

- Your area of operation.
- Location of your home base of operations.
- Location of probable satellite sites for your operation.
- Type of operation—private or commercial.
- Your experience with dispensing pesticides or other agricultural materials.
- Whether you are operating as an individual, a corporation, or a partnership.
- Your previous experience as an agricultural aircraft operator.
- Category and class of aircraft you are operating (rotary- or fixed-wing).
- Qualifications and experience of your chief supervisor.
- Applicability of parts 91 and 137 to the proposed type of work.
- Any previous or pending enforcement action pertaining to you, your management personnel, or chief supervisor.

Depending on the size and scope of your proposed operation, you may need to prepare a letter of intent as part of the required documentation for your application. When required, the letter of intent must include:

- The specific type of agricultural aircraft operator certificate for which you are applying (commercial or private).
- The legal company name of your company and any "doing business as…" names.
- Address of your home base of operations.
- Primary airport address, mailing address, and telephone numbers.

- Type of aircraft proposed for the operation.
- The estimated date when operations or services will begin.
- The names and addresses of all management personnel or chief supervisor.
- Names of three people you designate to provide certificate letters, in order of preference.
- A copy of the articles of incorporation if the operation is a corporation.

Formal Application

The next step is to fill out and submit three copies of FAA Form 8710-3—Agricultural Aircraft Operator Certificate Application, along with your Letter of Intent (if applicable) and other requested documents to the appropriate FAA Flight Standards District Office. You may obtain this form from the local FSDO or download it from the FAA web site (http://www.faa.gov) by typing in "FAA Form 8710-3" in the search box.

Document Compliance

A certification team assigned to you will review your application and associated documents within 30 business days of receiving it. They will notify you in writing whether the formal application is accepted or rejected. If the application is inaccurate, not completed properly, or does not include all the required documentation, the team returns the application to you with a letter outlining unsatisfactory items. You must correct these items before your certification process continues.

Demonstration and Inspection

This phase includes inspection of your facilities and aircraft. The team inspects your home base of operations for compliance with applicable operating procedures. The size and complexity of your operation determines the extent of the inspection required at your base. You must demonstrate to inspectors that you can conduct operations to the highest degree of safety.

You must provide for inspection at least one certificated and airworthy aircraft that is equipped for aerial agricultural work that you will use in your or your employer's pest control operation. An Airworthiness Inspector verifies that the aircraft is properly certificated and airworthy, its inspection status is current, and it is safe for operation.

Inspectors look at five areas during this inspection:

- The commercial applicator record keeping system being used.
- Methods used for informing personnel of their duties and responsibilities.
- Aircraft condition and airworthiness.
- Facilities (if applicable).
- Your knowledge and skills.

If you work as a pilot-in-command for an agricultural operator, then the operator or a person designated by that operator determines your knowledge and skills. Once you successfully demonstrate that you have the necessary knowledge and skills, the operator provides you with an endorsement letter.

Application Record Keeping

You must show examples of a record keeping system you have in place for your aerial application operation. The law requires you to keep these operation records for at least 12 months or longer. Since record keeping requirements vary by state, check the requirements in the state where you are conducting business. These records should include the:

- Name and address of each person for whom agricultural aircraft services were provided.
- Date of the service.
- Name and quantity of the pesticides and other agricultural material dispensed for each operation conducted.
- Name, address, and certificate number of each pilot used in agricultural aircraft operations and the

date that pilot met the knowledge and skills requirements of 14 CFR § 137.19(e).

- Additional information depending on state requirements.

Informing Personnel of Their Duties and Responsibilities

You must provide inspectors with documentation that shows how you have informed each person employed in your agricultural aircraft operation of their duties and responsibilities for the operation. The EPA Worker Protection Standard mandate for documenting pesticide handler training in agricultural operations satisfies some of these requirements.

Aircraft

An Airworthiness Inspector inspects the aircraft, aircraft records, and dispensing equipment. The inspector verifies the following to determine the aircraft is safe to conduct the proposed operation:

- You have up-to-date and complete aircraft maintenance records.
- The aircraft complies with all applicable airworthiness directives.
- The aircraft meets certification and airworthiness requirements.
- The aircraft inspection is up-to-date.
- The aircraft has approved and properly labeled seat belts and shoulder harnesses installed for each pilot station.
- The aircraft is appropriately equipped for agricultural operations.
- If the aircraft is equipped to release the tank or hopper as a unit, it is equipped to prevent inadvertent release by the pilot or other crewmember.
- The aircraft is in a condition for safe operation.

Should questions arise concerning the load jettisoning capability of the aircraft used in congested-area operations, you must present jettisoning test data that show the aircraft is equipped with a device capable of jettisoning at least one-half of the aircraft's maximum authorized load of agricultural materials within 45 seconds. Jettisoning does not apply to rotary-wing aircraft.

Facilities

FAA regulations do not specify the type of facilities you must have as an agricultural operator. State and local regulations and, to some extent, EPA regulations address requirements for facilities. The FAA facilities inspection verifies that the practices and procedures at the base of operations conform to FAA regulations.

Knowledge Test

The Operations Inspector conducts a knowledge and skills test during initial certification. As required by § 137.19(e), you or your designated chief supervisor will be the testing candidate. This requirement applies to applicants who seek either a private or a commercial operating certificate.

The objective of the knowledge and skills test is to evaluate the pilots in an operation and to assure that they are qualified to act as pilot-in-command of an agricultural aircraft. A pilot who was previously qualified under part 137 may not have to take the knowledge and skills test if proper documentation is available.

The pilot must have adequate knowledge of the aircraft's operating limitations to be used under the applicable requirements contained in 14 CFR part 91, § 91.9. Weight and balance information receives special emphasis. Knowledge of the aircraft's performance capability is required and includes:

- Stall speeds at maximum certificated gross weight, straight ahead, power off, and flaps up.
- Best rate and best angle of climb speed.
- Maneuvering speeds.
- Density altitude and its effect on performance.

- Performance capabilities and operating limitations of the aircraft to be used.
- Takeoff distance required to clear a 50-foot obstacle at maximum certificated gross weight with zero wind.

In addition, you must demonstrate your knowledge of the following limitations and restrictions applicable to agricultural aircraft operations:

- Passenger carrying.
- Weight and balance.
- Operating without position lights.
- Dispensing in congested areas.
- Not observing standard airport traffic patterns.
- Altitude during ferrying to and from dispensing sites.

Before an applicator credential is awarded for dispensing pesticides, you must demonstrate a thorough knowledge of methods to protect a pilot against contamination and methods of safe pesticide use and handling. The knowledge test may be written or given orally, and consists of the following subject areas:

- Steps to take before starting operations, including surveying the area to be treated.
- Handling pesticides and proper disposal of used containers.
- Pesticide hazards and precautions when handling and applying pesticides.
- Recognizing symptoms of pesticide exposure, appropriate first aid, and how to contact a poison control center.
- Safe flight and application procedures.
- State-specific laws and regulations.

Skills Test

You perform the skills test with the aircraft's tanks or hoppers loaded, using a suitable inert material such as water, lime, or sand. The examiner evaluates your piloting skills and operational judgment in the following areas:

- Ground crew coordination and loading procedures.
- Engine start, warm-up, and taxi procedures.
- Fixed-wing aircraft short-field and soft-field takeoffs, directional control, liftoff, and climb.
- Approaches to the working area.
- Flareout.
- Swath runs.
- Pull ups and turnarounds.
- Clean-up swath or trim passes.
- Jettisoning of remainder of load after swath runs in the event of in-flight emergency.
- Rotary-wing aircraft rapid deceleration or quick stops.
- Approach, touchdown, and directional control on landing.
- Taxi, engine shutdown, and securing of aircraft.

Certification

The FAA awards you the Agricultural Aircraft Operator's Certificate after the FSDO certification team concludes that you meet the qualifications listed above and you demonstrated that you have the necessary knowledge and skills or have a knowledge and skills endorsement from the operator of the firm for whom you are working.

APPENDIX 3

HEAT STRESS

Heat stress occurs when the body is subjected to a level of heat with which it cannot cope. With heat stress, the heat, not pesticide exposure, causes certain symptoms. 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.

Avoiding Heat Stress

Several factors work together to cause heat stress. Before beginning a pesticide-handling task, think about whether any of the following conditions are likely to be a problem that might lead to heat stress:

- Heat factors—temperature, humidity, air movement, and sunlight.
- Workload—the amount of effort a task takes.
- Personal protective equipment (PPE).
- Drinking water intake.
- Scheduling.

Heat and Workload

High temperatures, high humidity, and sunlight increase the likelihood of heat stress, although 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 while working on foot than while driving a vehicle. Lifting or carrying heavy containers or equipment also increases the likelihood of overheating.

Signs and Symptoms of Heat Stress

Heat stress, even in mild forms, makes a person feel ill and impairs his or her 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 you cool a heat stress victim quickly, he or she 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 type of work.

Learn the signs and symptoms of heat stress and take immediate action to cool yourself or another person down if these symptoms 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).

Heat cramps are another type of heat stress. These are painful 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 pesticide-related rather than caused from salt loss, get medical help right away.

First Aid for Heat Stress

It is not always easy to tell the difference between heat stress illness and pesticide poisoning because many signs and symptoms are similar. Get medical help right away rather than wasting time trying to decide what is causing the illness. First aid for heat stress includes:

- 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.
- If conscious, have the victim drink as much cool water as possible.
- Keep the victim quiet until help arrives.

Severe heat stress (heat stroke) is a medical emergency. Unless you cool the victim immediately, brain damage and death may result.

APPENDIX 4

STEPS TO FOLLOW IN CLEANING UP A PESTICIDE SPILL

The following steps should be taken whenever a pesticide spill takes place. For large spills, contact local authorities for assistance in management, prevention of injuries, and protection of the environment.

- Refer to the pesticide label to determine the PPE required for cleaning up a spill.
- Clear the area and keep unprotected people from coming near the spill.
- Administer first aid and obtain medical care for anyone who received, or possibly received, a pesticide exposure.
- Prevent fires by extinguishing sources of ignition and providing adequate ventilation.
- Control the release. Use any strtegy available to stop the flow of the spill.
- Contain the release. Use sand or other absorbent to keep the pesticide confined. Patch the leaking container or transfer its contents to a sound container.
- Clean up the spilled pesticide and absorbent and any contaminated objects. Place these materials into a sealable and suitable holding container.
- Clearly label containers holding spilled pesticide and contaminated soil and other objects. Include the pesticide name, signal word, and name of responsible party.
- Manage the contaminated area. Consult the product label and Material Safety Data Sheet (MSDS) for the particular product. Consult with the state regulatory agency on how to properly manage the release and how to properly dispose of recovered product and other items such as contaminated soil and absorbents.

APPENDIX 5

GLOBAL POSITIONING SYSTEMS

A global positioning system (GPS) provides one of the most accurate meth-ods of navigation for aerial pesticide applications. A receiver installed in the aircraft picks up satellite signals that let you know the speed of the aircraft, direction of travel, and its altitude and location. Because of the usefulness of this information, GPS equipment, in most cases, is an essential tool for precision aerial application. Recent studies indicate that at least 92 percent of agricultural pilots in the U.S. use GPS equipment.

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

The U.S. Department of Defense created the Global Positioning System program in 1973. The original intent of this program was to provide a satellite-based navigational system for military purposes. Although various aspects of GPS technology are now readily accessible to the public, the U.S. Department of Defense continues to fund and manage the GPS program.

The Global Positioning System 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.
- User Segment—individual GPS signal receivers owned and operated by users.

Space Segment

The Department of Defense began launching Earth-orbiting GPS satellites in February 1989 and completed this task in June 1993 with 24 satellites in orbit. Each satellite completes one orbit around the Earth every 12 hours, remaining in one of six orbital paths. Relative to the Earth's surface, the six orbital paths are equidistantly spaced at 60-degree intervals and each orbital path is inclined approximately 55 degrees relative to the Earth's equatorial plane. This satellite arrangement enables a GPS user to access between five and eight satellites at any one time.

Control Segment

The control segment 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, and in Colorado Springs, Colorado.

The Colorado Springs location is the master station. All the tracking stations monitor the satellites and determine precise orbit location data. The Colorado Springs master station sends corrections for orbital location and clock 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. Seagoing vessels, trains, trucks, mass transit busses, cars, farm equipment, motorcycles, commercial airliners, general aviation aircraft, and agricultural air-

craft use GPS signals for navigation. In addition, 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 under local zero visibility conditions.
- The ability to provide aircraft speed and location in real time for agricultural aircraft to automatically and continuously regulate spray output as a function of the actual travel speed and position of the aircraft.

Differential GPS

Each GPS satellite broadcasts signals over two microwave frequency channels. One channel carries a strong signal that only the military uses. The signal of the second channel, known as the coarse acquisition (C/A) signal, is less robust. This signal is available for nonmilitary GPS use, although calculations based on it do not provide pinpoint precision of the GPS receiver location. C/A signals typically provide location precision in a range of ± 100 feet horizontal accuracy. This level of precision is not accurate enough for aerial pesticide application.

To improve accuracy of the C/A signal, a technology known as Differential GPS (DGPS) provides greater precision. DGPS technology with a strong differential correction signal reduces the horizontal error range down to between less than three feet and rarely more than ten feet. Aerial applicators use DGPS systems.

Regular GPS relies on a single receiver, but DGPS technology requires two. One receiver remains fixed at an accurately surveyed location, and serves as a reference point. Aircraft have the second receivers installed in them. Both of these receivers detect the same C/A-signals from orbiting satellites, but the stationary receiver transmits data to refine the mobile receiver's positioning information. Although the stationary receiver cannot determine which particular GPS satellites a mobile receiver uses, it detects all accessible satellites, computes the timing signal correction factor for each, and transmits the correction data to the aircraft's mobile receiver, which sorts out the satellite data.

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 link together and 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 correction message that they transmit 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 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 their 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 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 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 3 feet per 90 miles. Because of this distance-related decay in accuracy, you should obtain GPS satellite signal corrections from the closest Maritime DGPS reference station for the most accurate positioning data. The Nationwide DGPS program is incorporating the Maritime DGPS program into its system.

Nationwide DGPS Service

A 1997 federal law 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 will provide every area in the continental United States with double coverage DGPS correction data 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 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.

GLOSSARY

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.

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.

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.

application pattern. The course the pilot follows above the area being treated with a pesticide. *See also* **back and forth application pattern** and **racetrack application pattern**.

application swath. *See* **swath** and **swath width**.

area of a circle.
Area = 3.14 × radius × radius ($A = \pi r^2$)

area of a square or rectangle.
Area = length × width

area of a triangle.
Area = base × height divided by 2

back and forth application 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.

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.

boom. A structure attached to an aircraft to which spray nozzles are attached.

buffer area (or zone). A part of a pest-infested area that is not treated with a pesticide to protect adjoining areas from pesticide hazards.

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.

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.

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 for hire who make pesticide applications by air.

commercial applicator. A person who, for hire, uses or supervises the use of a restricted-use pesticide and this definition varies among states.

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; and an increase in the concentration of the mixture applied.

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.

conventional application volume. For aircraft, the conventional application volume 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.

coverage. The degree to which a pesticide is distributed over a target surface.

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.

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.

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 200 microns in diameter or smaller.

droplet spectra. A classification of spray droplets into eight categories based on the volume median diameters of spray droplets. The eight categories are extra fine, very fine, fine, medium, coarse, very coarse, extra coarse, and ultra 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.

environmental contamination. Spread of pesticides away from the application site into the environment, usually with the potential for causing harm to organisms.

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.

Federal Aviation Administration (FAA). 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. A 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.

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 200 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.

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 general 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. A navigational device that uses signals from satellites to determine the receiver's position.

granule. A dry formulation of pesticide active ingredient and inert materials compressed into small, pebble-like shapes.

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 involved with 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; and

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. The handler definition does not include local, state, or federal officials performing inspection, sampling, or other similar official 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.

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.

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.

labeling. The pesticide product label and all other written, printed, or graphic matter accompanying the pesticide. Labeling may not necessarily be attached to or part of the container.

light bar. An accessory to the aircraft mounted global position 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 volume. 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.

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.

micron. A very small unit of measure: $^{1}/_{1,000,000}$ of a meter; represented by the greek symbol μ.

MSDS. *See* **material safety data sheet**.

non-target organism. Animals or plants within a pesticide-treated area that are not intended to be controlled by the pesticide application.

off-target pesticide drift. Pesticide drift that moves outside of the application area during or immediately following a pesticide application.

off-target pesticide movement. Any movement of a pesticide from the location where it was applied. Off-target movement occurs through drift, volatilization, percolation, water runoff, crop harvest, blowing dust, and by being carried away on organisms or equipment.

output volume. The amount of a pesticide mixture discharged by an aircraft over a measure period of time. The usual output volume for aircraft liquid sprayers is measure 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.

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 eye wear, 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**.

phytotoxic. Injurious to plants.

pilot-in-command. The Journeymen Pest Control Aircraft Pilot supervising or conducting a pesticide application.

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.

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 of which they control.

private applicator. An individual who uses or supervises the use of a pesticide for the purpose of producing an agricultural commodity on property owned, leased, or rented by him or her or his or her employer.

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.

racetrack application 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.

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 of time 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.

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.

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.

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.

swath (or swath width). The area covered by one pass of the pesticide application equipment.

temperature inversion. *See* **inversion**.

ultra low volume (ULV) application volume. 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.

wide area augmentation system (WAAS). A highly accurate GPS navigational system used for precision flight positional determination.

wing tip vortex. The circular or spiral swirling of air caused by the wing tips of an aircraft, and resulting in entrapment of spray droplets affecting the dispersal

pattern. Keeping the fixed wing aircraft boom length at approximately 75 percentage 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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