This guide contains basic information to meet specific standards for pesticide applicators. The text is concerned with the calibration of dry and liquid pesticide systems for aerial application. Additionally, dispersal equipment is discussed with considerations for environmental and safety factors. (CS)
TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Acknowledgments</th>
<th>1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preface</td>
<td>4</td>
</tr>
<tr>
<td>Introduction</td>
<td>2</td>
</tr>
<tr>
<td>Dispersal Equipment</td>
<td>2</td>
</tr>
<tr>
<td>Calibration</td>
<td>3</td>
</tr>
<tr>
<td>Pattern Testing</td>
<td>4</td>
</tr>
<tr>
<td>Operations</td>
<td>5</td>
</tr>
<tr>
<td>Protecting the Environment</td>
<td>6</td>
</tr>
<tr>
<td>Safety Precautions</td>
<td>8</td>
</tr>
</tbody>
</table>
ACKNOWLEDGMENTS

This guide has been developed by North Carolina State University under U.S. Environmental Protection Agency (EPA) contract 68-01-2903. This contract was issued by the Training Branch, Operations Division, Office of Pesticide Programs, EPA. The leader of this group effort was John H. Wilson, Jr., North Carolina State University. Editors were Mary Ann Wamsley, EPA, and Donna M. Vermeire, North Carolina State University.

Contributors were:
E. A. Cancienne, Louisiana State University
Richard P. Cromwell, University of Florida
F. Farrell Pligbee, National Agricultural Aviation Association, Washington, D.C.
James L. Maxwell, President, National Agricultural Aviation Association, Washington, D.C.
George F. Mitchell, Jr., M & M Air Service, Texas
Richard F. Moorer, U.S. Environmental Protection Agency
Frank J. Murphey, University of Delaware
Richard Reade, Mid Continent Aircraft Corporation, Hayti, Missouri
Carroll M. Voss, Ag-Rotors, Incorporated, Gettysburg, Pennsylvania
Wesley E. Yates, University of California

PREFACE

Federal regulations establish general and specific standards that you must meet before you can use certain pesticides. Your State will provide material which you may study to help you meet the general standards.

This guide contains basic information for aerial applicators. Other guides are available to help you meet the specific national standards for commercial applicators in various categories of pest control. Because the guides were prepared to cover the entire nation, some information important to your State may not be included. The State agency in charge of your training can provide the other materials you should study.

This guide will give you information about:
- dispersal equipment,
- calibration of liquid and dry systems,
- pattern testing,
- operations, and
- environmental and safety considerations.
INTRODUCTION

Effective aerial application requires:
- Close cooperation between applicator and grower when planning a job,
- Consideration of the effects on the environment,
- Consideration for the safety of people, animals, and nontarget crops,
- Correct and well-maintained equipment,
- Accurate and uniform application,
- A competent pilot, and
- Adherence to the planned procedure.

Limitations of aerial application are:
- Need for correct weather conditions,
- Difficulty in treating areas containing obstructions,
- Difficulty in treating small or irregularly shaped areas, and
- Long ferrying distances.

DISPERAL EQUIPMENT

Both fixed and rotary wing aircraft are used for aerial application. Metering and dispersal equipment on the aircraft must meter correct quantities of pesticide formulations and deliver them uniformly. The equipment must be accurate so it can be calibrated correctly.

LIQUID SYSTEMS

Liquified dispersal systems consist of:
- Tank,
- Agitation system,
- Pump,
- Piping and fittings,
- Filters (screens),
- Boom, and
- Nozzles.

These systems may be wind-driven or they may be hydraulic or mechanical, powered by the aircraft engine.

Tank—The tank should be leakproof and corrosion-resistant. It should have a mechanism for emptying the contents quickly in case of emergency. The aircraft must have a gauge that measures tank contents. The tank should be fitted with an air vent—a tube type or a spring-loaded flapper valve.

Agitation System—Most pesticide formulations require some form of agitation during application.

Pump—The pump system must be able to deliver large quantities of liquid material per unit of time. Wind-driven pumps must have a workable brake.

Piping and Fittings—Main piping and fittings should have a large diameter (approximately 2 inches) in order to apply high volumes of liquids, and a smaller diameter (approximately 1 inch) for low-volume application. Smaller piping is adequate on helicopters because of their slower application speed.

Filters—Correctly sized line filters and nozzle filters (screens) will prevent nozzle clogging. Screen sizes range from 20 to 100 mesh, according to the size of the nozzle opening (larger mesh (20) for larger nozzles). Screens should be located between the tank and pump or between the pump and the boom.

Boom—The boom supports and supplies the nozzles. When the boom is located near the trailing edge of the wing, clearance between control surfaces of the wing and the boom is essential. End caps on the boom make it easier to flush the boom and nozzles. The boom should have a positive shut-off valve.

Nozzles—Special nozzles are available for use in aircraft systems. They must be equipped with an antisiphon or nondrip check valve. Manufacturer’s specifications will guide you in your choice. A uniform spray pattern depends on correct nozzle placement on the boom.

The spray pattern shifts in the direction of propeller rotation. Adjusting the distance between the nozzles on the boom helps to correct this problem (see illustration below). Placing end nozzles inboard will prevent the wingtip vortex from trapping fine droplets, causing uneven distribution and drift.
Nozzle placement on a helicopter boom may be uniform except where the spray may hit parts of the aircraft such as the skids. A rear section boom is sometimes used to help keep spray off the helicopter. The angle of the nozzle in relation to the direction of travel affects droplet size (see illustrations below). Flight speed also has an effect on the size of droplets.

An adjustable gate is frequently used to regulate flow rate. It must have a tight seal when closed. Check the gate often to be sure it is set correctly and is not leaking.

**CALIBRATION**

Calibration is adjusting your equipment to apply the desired rate of pesticide. Calibration is especially important in aerial application, since large areas are covered in a short time. Calibrate often to be sure that the equipment is adjusted correctly.

**LIQUID SYSTEMS**

Here are the basic steps in sprayer calibration:

- Determine the acres your aircraft's system treats per minute at the speed and height you plan to fly.
- Figure the gallons you must spray per minute to apply the recommended rate.
- Select the size and number of nozzle tips which will deliver the correct number of gallons per minute at the operating pressure of your system. Use the nozzle manufacturer's specifications as a guide.
- Make a trial run.
- Determine the amount of chemical to add to the tank.

The following example will explain these basic steps. Your aircraft has a 300 gallon tank. The effective swath width is 50 feet. You plan to spray at 100 mph at a height of 8-10 feet. The chemical is to be applied at the rate of 1 pint per 3 gallons of spray per acre. The operating pressure will be 40 psi.

- Determine acres per minute covered.
  
  \[
  \text{Acres per minute} = \frac{2 \times \text{swath width (ft)} \times \text{speed (mph)}}{1,000}
  \]

  In our example, \( \frac{2 \times 50 \times 100}{1,000} = 10 \text{ acres per minute} \)

  The table below will tell you the acres covered per minute when swath width and aircraft speed are known.
Acres' Per Minute for Various Speeds and Swath Widths

<table>
<thead>
<tr>
<th>Speed (mph)</th>
<th>Swath Width (Feet)</th>
</tr>
</thead>
<tbody>
<tr>
<td>30</td>
<td>35</td>
</tr>
<tr>
<td>40</td>
<td>30</td>
</tr>
<tr>
<td>50</td>
<td>2.4</td>
</tr>
<tr>
<td>60</td>
<td>3.6</td>
</tr>
<tr>
<td>70</td>
<td>3.2</td>
</tr>
<tr>
<td>80</td>
<td>4.8</td>
</tr>
<tr>
<td>90</td>
<td>5.4</td>
</tr>
<tr>
<td>100</td>
<td>6.6</td>
</tr>
<tr>
<td>120</td>
<td>7.2</td>
</tr>
</tbody>
</table>

- Determine the amount of chemical to add to the tank.

Chemical per tank = acres per tank × chemical recommended per acre

Acres per tank = gallons per tank

In our example, 300 gallons per tank

100 acres per tank × 1 pint per acre = 100 pints (12.5 gallons) per tank

**DRY SYSTEMS**

Make several test flights with the spreader installed to determine the quantity of material metered out for a given gate setting. Helicopters may use electric or hydraulic air blowers and the material can be caught and measured while running up on the ground. You should use inert (blank) granules of the same size and density as those in the formulation to be applied. Operate the spreader for a measured period of time (at least 30 seconds). Weigh the quantity needed to refill the hopper. It may take three or more trial gate settings to determine the one that will give the required discharge in pounds per minute of granular material. To find the pounds per acre being applied, divide the pounds per minute by the acres per minute.

**PATTERN TESTING**

Check the swath pattern to make sure the distribution across the swath is as uniform as possible. Both helicopters and fixed-wing aircraft create wind currents (vortices) that affect the swath pattern. The tests must duplicate the airspeed, height of flight, spray pressure, and nozzle angle and placement or gate settings that will be used for the actual application. Make pattern tests in calm air (winds less than 3 mph) to avoid distortion caused by cross-winds. The best way to test a liquid pattern is to add a tracer (dye or fluorescent material) to the water in the tank(s) of the aircraft. For dry pattern testing, use a blank (nontoxic) material with properties similar to the formulation to be applied. Collect the test material on paper (for liquids) or in buckets (for dry materials) placed across the flight path on the ground. Observation of the collected materials will show the actual swath pattern.
A rectangular pattern gives perfect distribution if flight swaths are spaced perfectly. The trapezoidal and triangular patterns are better, however, because they allow for some error in spacing swaths. They give uniform distribution across the field except for the first and last swaths.

**Ideal Swath Patterns**

- **Rectangular pattern**: gives perfect distribution with perfect spacing but is poor with imperfect spacing.
- **Trapezoidal pattern**: also gives perfect distribution with perfect spacing and less variation with imperfect spacing.
- **Triangular pattern**: also gives perfect distribution with perfect spacing and less variation with imperfect spacing.

**OPERATIONS**

**GENERAL**

When an aircraft has been calibrated, the airspeed, spraying pressure (or gate setting for dry materials), height of flight, and effective swath width are fixed. Applications must be made at the same settings.

**PRESSURE**

Pressure should be around 40-50 psi (pounds per square inch). Choose the pressure near this range that will combine with your selected swath width, airspeed, and nozzle type to give the correct rate of application and desired droplet size. With most nozzle types, droplet size decreases as pump pressure increases. Use pressure gauges to indicate boom or pump pressure.

**FIELD FLIGHT PATTERNS**

For rectangular fields, fly back and forth across the field in parallel lines. Flying parallel to the long axis of the field will reduce the number of turns. For pilot safety, start treatment on the downwind side of the field if there are low-speed crosswinds. This prevents flying through the previous swath. (See diagram below.) To prevent skips and drift, stop flying if wind speed increases excessively.

If the area is too rugged or steep for this pattern, flight lines should follow the contours of the slopes. When the area is too steep for contour work, make all applications downslope.

**SWATH MARKING**

Swaths can be marked with permanent or semi-permanent flags set above the height of the crop to guide the pilot. This method is useful if the field will be treated several times a season.

Two flagmen can help the pilot line up on the field. When the pilot has lined up on his swath, the nearer flagman starts pacing off (or counting crop rows) to the next swath. Flagmen should avoid being directly sprayed on, and they should never turn their backs toward an oncoming aircraft. When the aircraft is being flown parallel to a row crop, one flagman can identify the swath row for the pilot.

Automatic flagmen are often used. These devices, attached to the aircraft and controlled by the pilot, release weighted streamers. The streamers give the pilot a visible mark to help him judge the next swath. Helicopters on small field applications may not need flagmen. Their short turnarounds allow them to locate the next swath easily.
TURNAROUND

At the end of each swath, the pilot should shut off the dispersal equipment and pull up out of the field before beginning his turn. Complete the turn soon enough to permit slight course corrections before dropping into the field again for the next swath. (See diagram below.)

OBSTRUCTIONS

If there are obstructions (trees, power and telephone lines, or buildings) outside the field at the beginning or end of the swath, turn the equipment on late or shut it off early. When the field is completed, fly one or two swaths crosswise (parallel to the obstruction) to complete the job.

Obstructions inside the field should be treated in the same way. Skip the area around the obstruction and spot treat it later.

Areas next to buildings, residences, livestock, non-target crops, or waterways should be treated with caution:

- Fly parallel to the sensitive area.
- Leave a border of untreated crop to avoid possible drift onto the area.
- Avoid making turns over dwellings where possible.

PROTECTING THE ENVIRONMENT

CONTROLLING DRIFT

Drift is the airborne movement of spray, granule, or dust particles to places other than the target area. Properly controlled, drift may help the pesticide reach the target. Drift is harmful when it causes damage in nontarget areas.

The main factors that must be considered in controlling drift are discussed below.
Droplet Size

Droplet size is one of the most important factors affecting drift. Small droplets are a much greater drift hazard than large droplets. They stay in the air longer because they fall more slowly, and they are more easily carried by wind currents because they are lighter.

Pesticide spray systems cannot produce a completely uniform droplet size. Rather, they produce a range of droplet sizes.

Nozzle type and pressure are important factors affecting droplet size. In general, the size of droplets decreases as the size of the nozzle opening decreases or the pressure increases.

The position of nozzles on the boom also affects droplet size. (See equipment section.)

You can get chemical adjuvants which affect droplet size:
- Thickening agents may be added to spray mixtures to create larger spray particles. However, the airstream may break these large droplets into smaller ones.
- Surfactants are sometimes added to spray solutions to create smaller droplets, improve coverage, and increase wettability of the spray. Be sure that droplets are not so small that they create a drift problem.

A measurement of nozzle performance is the Volume Median Diameter (VMD) of the droplets it produces. The VMD is the droplet diameter that satisfies the condition that half of the spray volume consists of drops larger, and half consists of drops smaller.

Weather

A pesticide applicator is concerned mainly with the weather in the immediate area of application and less than 1,000 feet from the ground. The weather in this small area has a major effect on the pesticide application, including the chance for drift problems. Wind is an important weather factor affecting drift. Stop at once if wind increases excessively during application.

Other important factors are "inversion" and "lapse". These terms refer to the temperature change from the ground upward.

An inversion-layer exists in still air that:
- is coolest at the ground level,
- gets warmer up to a certain height, and
- gets cooler from that point on up.

Particles released into the cool air layer at ground level during an inversion have a minimum upward movement. The slightest air movement can cause this mass of particles to drift for great distances before they fall.

A lapse exists when the air:
- is warmest at ground level, and
- gets continuously cooler at higher elevations.

During a strong lapse, the warm air near the ground rises, carrying very small pesticide particles with it. An applicator should at least be aware of these two conditions, because sometimes they can be severe enough to cause serious drift problems.

Vaporization

Another type of pesticide movement is called vaporization (vapor drift), the volatilization of an active ingredient during or after application. You must know which pesticides are highly volatile (evaporates easily). High temperatures or other climatic conditions may cause vaporization of some active ingredients. Apply them during periods of relatively low temperature and high humidity. Use active ingredients with low volatility where vaporization might cause problems.
Protecting Bees

Honey bees and other, beneficial insects can be harmed by some pesticide applications. Beekeepers, aerial applicators, and their customers must cooperate closely to protect honeybees. You can reduce bee losses significantly by careful planning and good communications. Bees travel for long distances, so use of pesticides toxic to bees may affect hives outside the immediate vicinity of the treatment area. When using materials hazardous to bees, remind your customer to notify the beekeeper so that he may protect his bees. With few exceptions, dusts may be more hazardous to bees than sprays. Time of application is important and depends on blooming period and attractiveness of the crop. Treatment during the night and early morning before bees are foraging are the safest for the bees.

SAFETY PRECAUTIONS

GENERAL PRECAUTIONS

- Wear protective clothing and equipment appropriate for the pesticide. The label on each pesticide specifies the protection required.
- Know the pesticide being applied and how to get emergency help if needed.
- Avoid all unnecessary contact with spray or dust.
- Change clothing and bathe after each day's work.

PILOT

- Avoid loading or handling highly hazardous pesticides. Exposure to toxic pesticides could cause illness that would make it unsafe to operate the aircraft.

The signs and symptoms of illness commonly include dizziness and constriction of the pupils of the eyes (myosis). Myosis, impairs visual sharpness and can lead to fatal accidents. Direct eye contamination by organophosphate or carbamate pesticides may cause constriction of the pupils for up to 7 to 10 days without any other symptoms. A pilot who has experienced any symptoms of pesticide poisoning should not fly until he has had medical clearance.
- Make preflight aircraft check.
- Check operation and calibration of dispersal equipment periodically.
- Check target area and surroundings for safety or drift hazards before application.
- Avoid flying through drift.
- Do not apply pesticides over flagmen or other persons. Use of permanent markers and automatic flagmen eliminates the possibility of harm to flagmen.
- See that members of the ground crew know their responsibilities and are acquainted with label precautions.
- Do not fly in a manner or at a time which may create a hazard—even if customer insists.
- Warn all people in the treatment area about the application.

GROUND CREW

- Close tanks and hoppers tightly after filling.
- Remove any spilled chemical.
- Clean aircraft, especially the cockpit, frequently.
- Where possible, clean equipment on a hard-surfaced apron so that runoff can be collected and disposed of safely.
- Do not stand in runoff water without appropriate protection or allow it to splash on you.

FLAGMEN

- Warn all people in the treatment area about the application.
- When the aircraft is lined up for a pass, move over to the next position.
- Do not turn your back on an approaching aircraft.
- Stay at the field until the pilot has completed the job so you can help if an accident occurs.