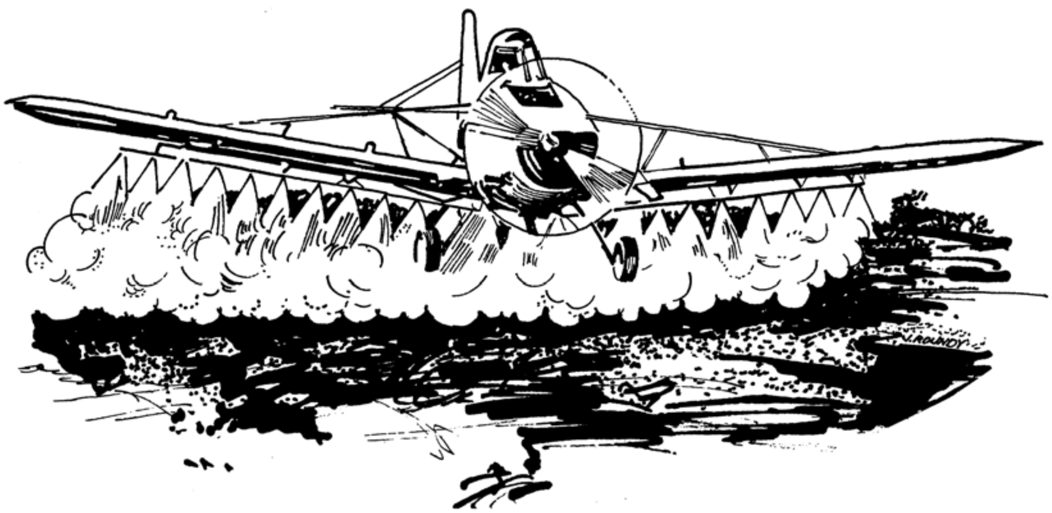
AERIAL APPLICATION PEST CONTROL

**PESTICIDE APPLICATION
AND
SAFETY TRAINING
STUDY GUIDE**



UTAH DEPARTMENT OF AGRICULTURE
DIVISION OF PLANT INDUSTRY
350 NORTH REDWOOD ROAD
BOX 146500
SALT LAKE CITY, UTAH 84114-6500

Volume 1, October 1996

STUDY GUIDE FOR
AERIAL APPLICATION PEST CONTROL

The educational material in this study guide is practical information to prepare you to meet the written test requirements. It doesn't include all the things you need to know about this pest-control subject or your pest-control profession. It will, however, help you prepare for your tests.

Contributors include the Utah Department of Agriculture and Utah State University Extension Service. This study guide is based on a similar one published by the Nebraska Department of Agriculture. The information in this manual was adapted from the following sources: Aerial Application, Cooperative Extension Service, University of Wisconsin. 1993. Aerial Applicator Training Manual, Cooperative Extension Service, University of Florida. 1992. Pattern Your Ag Spray Plane, Cooperative Extension Service, University of Arkansas. Agriculture Aircraft Calibration and Setup for Spraying, Cooperative Extension Service, Kansas State University. 1992. Aerial Application of Pesticides, Cooperative Extension Service, University of Georgia. 1992. Aerial Pest Control for commercial/noncommercial pesticide applicators (category 12): Aerial Application is a adapted with permission from Iowa Commercial Pesticide Applicator Manual, Category 11, Aerial Application, published by Iowa State University. Editors were: Clyde L. Ogg, Extension Assistant, and Larry D. Schulze, Extension Pesticide Coordinator, University of Nebraska. Special thanks to William W. Lyon, Director of Operations, Department of Aeronautics for providing valuable comments after reviewing this manual.

Other topics that may be covered in your examinations include First Aid, Personal Protective Equipment (PPE), Protecting the Environment, Pesticide Movement, Groundwater, Endangered Species, Application Methods and Equipment, Equipment Calibration, Insecticide Use, Application, Area Measurements, and Weights and Measures. Information on these topics can be found in the following books:

1. **National Pesticide Applicator Certification Core Manual,** Published by the National Association of State Departments of Agriculture Research Foundation.

2. **The Workers Protection Standard for Agricultural Pesticides – How to Comply: What Employers Need to Know.** U.S. EPA, Revised September 2005, Publication EPA/735-B-05-002.

These books can be obtained from the Utah Department of Agriculture or Utah State University Extension Service. Please contact your local Utah Department of Agriculture Compliance Specialists or Utah State University extension agent.

TABLE OF CONTENTS

INTRODUCTION

Aerial application of pesticides offers several advantages over ground application:

You can cover large areas quickly. You can treat crops or areas (such as mid-season corn or forest stands) for which ground equipment isn't suitable. The application cost per acre is comparatively low.

To reap the full benefit of these advantages, you and your client must cooperate to develop a pest-control plan that will ensure a safe and effective operation. Your plan must be based on full knowledge of the pest-pesticide relationship, pesticide activity and restrictions, and the capabilities and limitations of your aircraft under prevailing conditions. You must also be aware of hazards to people, livestock, other crops, and the environment.

Several factors limit the use of aerial application. These include weather conditions, fixed obstacles such as power lines, field size, and the distance from the landing strip to the target area. Your challenge is to know when and how you can overcome these limitations and, just as importantly, when these limitations make aerial application impractical.

PESTICIDE LAWS AND REGULATIONS

This part of the manual presents laws and regulations pertaining specifically to the aerial application of pesticides. However, when you prepare for and make such applications, you must understand and comply with all the pertinent pesticide laws and regulations.

Note that in explaining the following laws, we only paraphrase the actual laws and rules. You should consult the laws and rules themselves if you have questions about them.

FAA REGULATIONS

The application of agricultural chemicals, including pesticides, from aircraft is regulated in part by the Federal Aviation Administration (FAA). The regulations that govern aircraft operations are in the Code of Federal Regulations, Title 14, Aeronautics and Space. This code includes regulations that deal specifically with agricultural aircraft operations.

Before applying pesticides by aircraft, you must have a valid pilot's certificate, and you or your employer must have a valid agricultural aircraft operator's certificate issued by the FAA. Also, your aircraft must be certified as airworthy.

CERTIFICATION REQUIREMENTS

You must be certified in the Aerial Pest-Control Category prior to commercially applying pesticides in Utah.

Aerial pesticide-application operations conducted in Utah must be certified by the Utah Department of Agriculture.
Certification in this category includes applicators applying pesticides by aircraft to control agricultural, forest, health- related, or any other pests. **Applicators are also required to be certified in categories of intended application.**

HANDLERS

You must make sure that employees who mix or load pesticides into your aircraft have had appropriate pesticide-safety training. Such employees must be either certified as applicators or have received pesticide-safety training for pesticide handlers as required under the Worker Protection Standard (WPS).

Anyone who is certified as a pesticide applicator in any commercial category or as a private applicator or who has been trained as a pesticide handler according to the requirements of the WPS may mix or load pesticides. Such a person would require certification in the Aerial Pest-Control Category only if he or she intended to apply pesticides aerially in addition to mixing or loading pesticides.

PESTICIDE OVERSPRAY AND DRIFT

Pesticide overspray is defined as applying pesticide beyond the boundaries of the target area. **Overspray is considered an inherently negligent action that**

can't be excused under any circumstance; it's flatly prohibited.

Pesticide drift, like overspray, often implies a lack of proper care on the part of the pesticide applicator. Drift is defined as the movement of pesticide in air currents or by diffusion onto property beyond the boundaries of the target area. Applicators are responsible for confining pesticide applications to the target area and for taking precautions to prevent other persons or their property from being exposed to the pesticide you are applying.

APPLICATION EQUIPMENT

Equipment for aerial application of pesticides must be able to lift, transport and disperse pesticides safely and accurately to the target area. You need to understand how your equipment affects the application so that you can ensure effective treatment under any conditions you encounter.

CHOICE OF AIRCRAFT

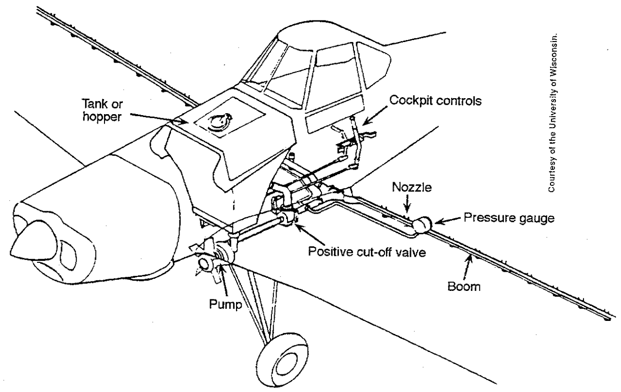
You can apply pesticides aerially using either a fixed-wing airplane or a helicopter, although most applicators use airplanes. Airplanes are fast, maneuverable, and have a large payload capacity per dollar invested. Helicopters are even more maneuverable, can be operated over a range of speeds, and may be operated in almost any area because a regular landing strip isn't needed. However, helicopters are more expensive to operate per unit of flying time, so the pilot must minimize the time lost in turnarounds and refilling.

DISPERSAL SYSTEMS

Metering of spray material is a key function of all agricultural aircraft dispersal systems. Metering and dispersal equipment must deliver the labeled rate of a liquid or solid pesticide accurately, uniformly, and in a short period of time.

LIQUID DISPERSAL SYSTEMS

Liquid dispersal systems are the most widely used in agricultural aviation. They consist of a hydraulic circuit, including a tank, pump, hose, pressure gauge, boom, screens, flow regulators and nozzles. More and more applicators are finding that flow meters are valuable in monitoring system output and improving application performance.



Dispersal systems may be wind-driven or powered directly from the aircraft engine.

A typical system is shown in Figure 1.

Figure 1. The components of a liquid dispersal system on a Piper Brave airplane.

Tank or Hopper

The tank should be corrosion-resistant; most are made of fiberglass. Most tanks can be filled through an opening in the top. However, it's preferable to fill through a pipe, equipped with a quick-coupling valve, which comes out the side of the fuselage. The tank should also have a large emergency gate through which the load can be dumped in a matter of seconds. The aircraft must have a gauge that measures tank contents.

The tank should have an air vent that will prevent a vacuum from developing that would alter or stop the normal flow of the liquid. Tanks are also fitted with baffles to limit the sloshing of liquid during flight.

Airplane spray tanks. On an airplane, the tank is usually mounted in front of the cockpit and as close as possible to the center of gravity of the plane so that the trim won't be affected as the tank empties.

Helicopter spray tanks. The spray tanks on helicopters are usually mounted in pairs on each side of the fuselage. A pipe connects the tanks so that the spray is drawn equally from both tanks to keep the helicopter balanced. The tanks on most helicopters used in aerial application have relatively small capacities in comparison to airplane tanks.

Pumps

The pump is necessary to ensure uniform and proper flow rate, produce the desired atomization from nozzles, and maintain suspensions. The majority of pumps on airplanes are powered by a fan mounted under the aircraft in the slipstream of the propeller. Many fans are equipped with variable-pitch blades so the pump speed can be changed. Pumps must be able to produce the desired nozzle pressure (plus five psi for friction loss in the line) to handle nozzle output and agitation requirements. Air shear across the nozzle pattern helps break the liquid into spray, so high pressure isn't required for atomization.

Carefully consider the size of the pump. A pump with too little capacity will require reducing the swath spacing to assure adequate deposition on the crop. If you use a centrifugal pump that has a capacity much greater than required, the impeller may cavitate; this allows air into the system and calibration becomes erratic.

Centrifugal pump. The pump most widely used for spraying is the centrifugal pump (Figure 2). It's available in many sizes, handles all kinds of liquid formulations with minimum wear, and can be operated without a pressure-relief valve.

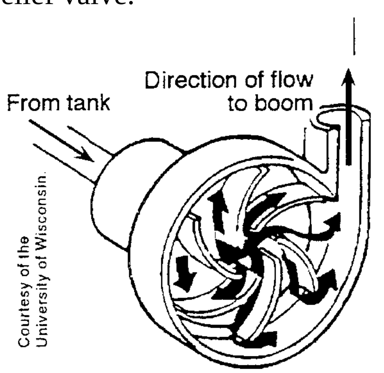


Figure 2. A centrifuge pump.

Centrifugal pumps that deliver a high flow rate when using a low operating pressure are generally used. Such pumps are preferred because the spray-system pressure is usually low (in the 20 to 50 psi range), and a high flow rate is required even for relatively low application rates because the number of acres sprayed per unit of time is high.

Rotary gear pump. If high pressures are needed, a rotary gear pump is often used (Figure 3). Gear pumps deliver a low flow rate, but can produce as high as 200 psi. Gear pumps that deliver the gallons per minute needed for most aerial spraying jobs weigh much more than a comparable centrifugal pump. A pressure-relief valve or bypass must be incorporated into the spray system to relieve the pressure or bypass the chemical when the spray valve is turned off. Gear pumps are subject to excessive wear with certain formulations such as wettable powders. For these reasons -- extra weight, rapid wear when pumping abrasive formulations, and the need for a pressure relief valve -- gear pumps are used only where high pressure is needed.

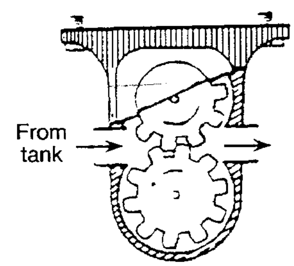


Figure 3. A rotary gear pump.

ULV applications. Ultralow volume (ULV) applications (0.05 to 0.5 gallons per acre) need only a minimum- capacity pump. If your aircraft will be used only for ULV spraying, use a small centrifugal, gear, or other rotary pump that can provide the required flow rate at 40 psi to assure uniform flow and optimum nozzle performance.

If your aircraft is equipped for high-volume spraying and you want to do ULV spraying too, a minor modification will be required. Many high-volume pumps are capable of pumping 75 gallons per minute. ULV applications may require only 2 gallons per minute. Bypassing 73 gallons back into the spray tank will aerate the spray solution or cause excessive foaming of some materials. In either case, accurate calibration of the spraying system is impossible.

Installing a modification will make it possible to use the same spraying system for high-volume and ULV applications.

Agitation System

Many pesticide formulations require some form of agitation during application to maintain the spray mixture.

Recirculation of the spray mixture during ferrying to the worksite and during turnarounds is usually enough. When the aircraft is used to treat long fields where turnarounds are limited, the pump must have sufficient capacity to supply the boom and provide adequate bypass agitation. The return flow should wash the bottom of the tank to help prevent settling of pesticide residue.

Plumbing

Aerial spray equipment must be designed with valves, piping, fittings and screens that are big enough for rapid dispersal of spray material.

Piping and fittings. Main piping and fittings should have a large diameter (up to three inches) to apply high volumes of liquids and a smaller diameter (about one inch) for low-volume application; smaller piping can often be used with helicopters because their slower speed makes it possible to get by with lower flow rates. The piping must be able to handle the pump pressure.

Hoses should be large enough to carry the desired flow and should be corrosion-resistant. They are less likely to blow off if the ends of the tubes are beaded or double-clamped. Avoid sharp bends in hoses as much as possible, and change hoses when they swell or develop surface cracks.

Screens. Correctly sized line and nozzle screens must protect components from damage and nozzles from clogging. The screens should be cleaned daily during spray operation or whenever flow or pressure indicates clogging.

Nozzle screen sizes of 20 to 100 mesh or an equivalent slotted strainer should be used, depending on nozzle orifice size and materials being applied. The 20-mesh screens have the largest openings and would be used with nozzles having a relatively large orifice. Nothing finer than 50-mesh screens should be used with wettable powders.

Line screens should be of coarser mesh than nozzle screens and should be located between the tank and pump and/or between the pump and boom. Locating the line screen between the tank and pump will protect the pump from damage; this screen, located in the suction line, should have large mesh openings.

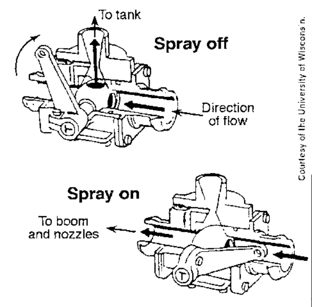


Figure 4. A positive cut-off spray valve.

Valves. Use a positive cut-off valve in the line to eliminate dripping when shutting off the spray at the end of the runs or when flying over pastures, lakes, streams, and other sensitive areas. A positive cut-off valve that incorporates the suck-back feature (Figure 4) reduces the risk of dripping nozzles. (Nozzle check valves will be discussed later.) Suck-back is lost if the tank is empty or the pump is off.

Pressure gauges. Attach the pressure-gauge sensing line near or at the boom to more accurately determine nozzle pressure. The ideal location for the pressure gauge is in a position where you can easily monitor pump performance from the cockpit. Because the flow of the liquid is related to the pressure, the pressure should be maintained throughout a spraying operation. Pressure gauges can malfunction or the sensing line can partially plug. Check gauges periodically against a gauge you know is accurate.

Pressure gauges are obviously valuable instruments for monitoring pump and nozzle performance. However, don’t rely solely on pressure gauges to calibrate an aircraft. Nozzle manufacturers' tables give the gallons per minute of water emitted by a particular nozzle at various pressures, but the actual output will vary from aircraft to aircraft. An applicator who calibrates an aircraft using nozzles and pressure settings from catalog values will often be in for a surprise. Field checking your aircraft's spray output and pattern is always advisable.

Booms

The boom supports nozzles along the wingspan of an airplane. It may be round, airfoil-shaped or streamlined. Booms should be located behind and below the trailing edge of the wing to reduce drag and to place the nozzles in cleaner airflow. Drop booms are often used to help keep nozzles in clean air. Research shows that the lower position is likely to give a better deposit pattern. End caps for booms should be removable for cleaning.

A boom about three-fourths as long as the wingspan is preferable, because nozzles placed farther toward the tip have a large amount of their output entrained in the wing-tip vortex and contribute to drift problems. Location of outboard nozzles on booms is critical, because wing tip and main rotor vortices (discussed in the next section) influence pattern width and drift. Research has shown that nozzles placed outboard of the three-fourths wingspan point contribute little toward increasing swath width.

Nozzles

In ground application, the spray pattern from each individual nozzle is a major factor in distributing spray uniformly across the swath. In aerial application, spray distribution across the swath is affected considerably by aircraft wake; thus, it's the overall pattern of all nozzles, rather than the individual pattern of each nozzle, which is important. Therefore, nozzle features affecting spray droplet size, droplet distribution, flow rate, and tendency to clog are more critical than they would be for a ground sprayer.

Usually, the same nozzle tips, discs and cores, caps and screens are used on both aerial- and ground-application equipment. The most commonly used spray system for higher application rates is a boom with hydraulic cone nozzles. The cone nozzles used most often in aerial application are the disc-core type and the whirl chamber type. For ULV applications, flat-fan nozzles or rotary atomizers are often used.

Position the nozzles (and booms) so the spray won't strike any part of the aircraft or the boom attachments. If the spray does strike any structural member of the aircraft, it will:

- Collect and fall off in large drops.
- Distort the spray pattern.
- Waste material.
- Cause corrosion of aircraft parts.

Ideally, the boom should have an end nozzle. However, if the outermost nozzle isn't at the end of the boom, make provisions to purge the air trapped in the outer ends of the boom. Trapped air will cause the spray to continue flowing after the spray valve is closed. To eliminate trapped air, use a tee to attach each outboard nozzle to the boom and connect a small bleed line from the tee to the end of the boom. This will ensure rapid filling of the boom, immediate flow from each nozzle, and quick and positive cutoff when the spray valve is closed.

Rotary atomizers. Rotary nozzles allow you more control over the size of the droplets released. Spray droplets are formed by toothed, grooved, spinning discs or cups. Centrifugal force generated by the spinning action causes the release of spray droplets. The speed at which the nozzle turns and the liquid flow rate control the size of the droplets. Rotary nozzles reduce the range of droplet sizes being applied, so very small and very large droplets are eliminated. However, they can generate a range of droplet sizes, enabling you to use the same nozzles for coarse or fine sprays. Control of droplet size with rotary spray nozzles is especially significant when oil carriers are used.

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

You may need to fly up to 25 feet above the target to obtain a uniform deposit pattern. Uniformity also depends on how fine the spray is and the spacing of the nozzles. For low-level work, six or more nozzles are required to provide a uniform swath.

Microfoil boom A microfoil boom can be used on helicopters to control droplet size. It's most often used for treating rights-of-way. This boom consists of a series of six-inch-long, airfoil-shaped nozzles. Sixty needlelike tubes project from the trailing edge of each nozzle. Spray pressure and orifice diameter control droplet size. Droplets are formed on the needlelike tubes and pulled off by the airstream, then they enter the non-turbulent air behind the nozzle. The microfoil boom is specifically designed for helicopters, because droplet size can't be maintained at high speeds. It can't be used for high-viscosity sprays or wettable powders, because the orifices tend to clog.

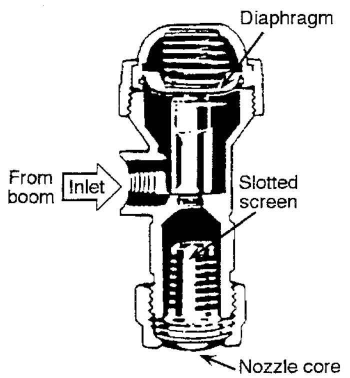


Figure 5. An anti-drip nozzle system.

Nozzle anti-drip device. Equip each nozzle with a check valve to prevent dripping when the spray is shut off. The diaphragm check valve is the most widely used type (Figure 5). When the pressure drops to about seven psi, the spring force is greater than the hydraulic force on the opposite side of the diaphragm, and the diaphragm closes off the hole in the barrel leading to the orifice. These check valves must be used in combination with in-line valves that have the suck-back feature to prevent dripping. In systems where suck-back is unavailable such as on helicopters, a 15-pound spring is commonly used.

Clean check valves often. If you use diaphragm check valves, change the diaphragms at regular intervals.

DRY (GRANULAR) DISPERSAL SYSTEMS

Dry materials are dispensed from an airplane hopper through a spreader mounted below the fuselage. The hopper walls should slope enough to ensure uniform flow of material to the spreader. The hopper should be vented properly to ensure a more uniform flow, especially when the hopper and loading door have airtight seals.

The gate that controls the flow of material from hopper to spreader should move freely, provide a tight seal to prevent leakage when closed, and provide a uniform flow to all portions of the spreader. Inspect the gate often to make sure it doesn't allow leaks.

The hopper should be equipped with an agitator when sticky, lumpy or fine (less than 60-mesh) materials are to be dispersed. A properly designed and functioning agitator promotes uniform flow of the hopper contents.

Dispersal systems for applying pesticide granules are primarily ram-air spreaders for airplanes and centrifugal or fan-powered air-flow spreaders for helicopters.

Ram-air spreaders. The same hopper that is used to hold the liquid spray is used to hold dry materials when they are spread with an airplane. Ram-air spreaders (Figure 6) are mounted under the belly of an aircraft in such a manner that they can be quickly removed when the aircraft must revert to spraying.

The amount of dry material fed into the ram-air spreader is determined by the opening in the metering gate between the hopper and spreader. Ram-air spreaders have internal vanes that impart a sidewards velocity to the air that enters the throat of the spreader. This feature increases the effective swath of the spreader.

Ram-air spreaders can uniformly spread material over a limited range of application rates. When too large an amount of dry material is metered into the spreader, the spreader becomes choked off and less air is able to enter the unit. A large amount of dry material entering the spreader requires more air, not less, to convey the material through the spreader and achieve a wide, uniform swath.

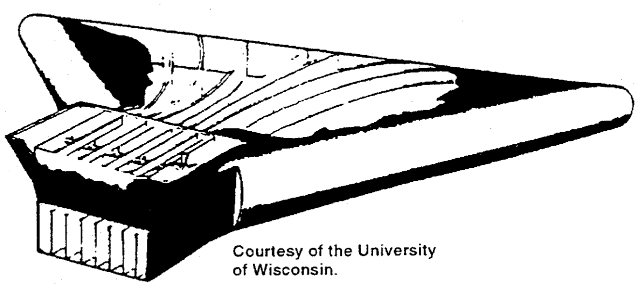


Figure 6. A ram-air spreader for applying materials by airplane.

Ram-air spreaders have a number of drawbacks, such as the limited range of application rates. They adversely affect aircraft performance because of the high drag load resulting from their unavoidably being placed in the high-speed airstream, though some new spreaders have less drag than the pump and booms produce. However, ram-air spreaders have survived a long list of "new, improved designs" because they are simple, versatile, and reasonably priced and do a fairly good job of spreading dry materials.

Centrifugal spreaders commonly used by helicopters are self-contained units having their own hoppers. The unit is suspended from the helicopter by a cable and hook (Figure 7). The spinners that the dry material is metered onto are usually driven by a hydraulic motor and, in some cases, by an integral gasoline engine.

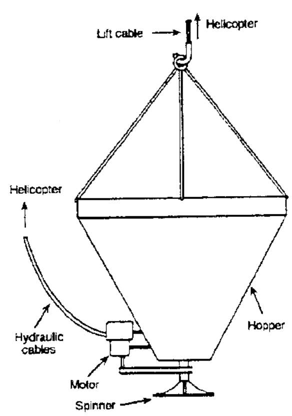


Figure 7. A centrifugal spreader for applying dry materials by helicopter.

The units are controlled with hydraulic control cables or radio frequency. Usually, two self-contained units are used so that the pilot can spread with one while the other is being refilled.

CALIBRATION

Dispersal equipment you use must be accurately calibrated in order to perform any operation. The best pilot flying the best aircraft can't properly treat an area if the equipment dispenses the incorrect amount of material in a variable pattern. Proper calibration not only helps ensure effective treatment, but it also helps prevent pesticide drift. Improper calibration, on the other hand, will result in dissatisfied customers and perhaps even an angry public.

(Note: Some formulas used in this unit contain numbers that are constants, numbers that remain unchanged whenever you use the formula. To make calibration easier for you, we provide you with the constants rather than going through the complex calculations from which the constants are derived.)

BASIC FORMULAS FOR AIRCRAFT CALIBRATION

Calibration is used to determine how much liquid solution nozzles must deliver to deposit the required amount of product active ingredient (AI) per acre. Only changes in ground speed or flow rate can change the amount of material an aircraft applies. Never use swath width to change the application rate without physically changing the nozzle configuration. The basic steps of aircraft calibration are:

STEP 1

A. Determine the acres your aircraft system treats per minute at the speed and estimated swath width you plan to fly. The effective swath width should match that determined by pattern testing.

Equation 1: Acres per minute
.00202 X swath width X speed = acres per minute

Example using 60-ft. swath width and 120 mph:

.00202 X 60 ft. X 120 mph = 14.54 acres/minute

B. Determine the gallons you must spray per minute to apply the recommended gallonage rate.

Equation 2: Gallons per minute
Acres per minute X application rate = gpm

Example using 10 gallons per acre:

14.54 a/min. X 10 gpa = 145.4 gpm

C. Once you have determined the flow rate, select the nozzle orifice size and number of nozzles needed to deliver the correct number of gallons per minute within the allowable operating-pressure range of your system. It's generally recommended that spray pressures remain greater than 18 psi and less than 40 psi (preferably 18 to 30 psi to minimize drift).

STEP 2

Determine the number of nozzles to use. Assume you are using a nozzle with a flow rate of 3 gpm at 25 psi.

Equation 3: Nozzles needed
Total flow ÷ gpm per nozzle = number of nozzles needed

145.4 gpm ÷ 3 gpm per nozzle = 48.46 nozzles needed

To obtain the desired application rate at a three-gpm flow rate, you would need 48 operating nozzles. Position each nozzle and test the system pattern to verify distribution pattern uniformity and required nozzle-pattern changes.

STEP 3

Determine what nozzle tip size to use. For this calculation, you must select the total number of nozzle-outlet positions on the boom or the total number of positions before calculations begin. Assume that 66 nozzles are needed.

Equation 4: gpm per nozzle
Total flow ÷ number of nozzles = gpm per nozzle

145.4 gpm ÷ 66 nozzles = 2.2 gpm per nozzle

Based on this calculation, select a nozzle that has a flow rate close to 2.2 gpm in the desired pressure range of 18 to 30 psi.

Once individual nozzles are mounted on a boom system, calculating flow rates is hard, especially if you're equipping an aircraft for high application rates. Individual nozzle flow rates vary depending on location, turbulence in the boom, and the number of boom restrictions. After you place the nozzles on the boom, make a trial run to be sure you are applying the correct rate and depositing the spray uniformly.

A high number of larger nozzles (larger orifices) results in high fluid velocities inside the boom and a large pressure drop from the center of the boom to the end of the boom where the last nozzle is located. This pressure differential may result in narrower effective swath widths. Full three-inch liquid systems (no restrictions smaller than three inches from the pump outlet on) are recommended for field applications greater than nine gpa. The exact flow rate (gpm) or pressure (psi) needed for a particular nozzle may not be listed in the available tables. If you know the flow rate at one pressure, you can calculate the pressure or flow rate for other pressures or flow rates by using the following equation:

Equation 5: Flow rates and pressures
gpm_1 ÷ gpm_2 = square root of psi_1 ÷ square root of psi_2

If you know the desired pressure, you can calculate the unknown nozzle flow rate by rearranging the above equation as follows:

Equation 6: gpm at desired pressure
(square root of gpm *known*) X (square root of psi *desired*) ÷ square root of psi *known* = gpm *unknown*

Or, if you know what flow rate you want, you can find the pressure you need by rearranging Equation 6 as follows:

Equation 7: Pressure at desired gpm
[(gpm *desired* X (square root of psi *known*) ÷ (gpm *known*)]^2 = psi *unknown*

This relationship between pressure and flow rate is accurate for most hydraulic nozzles.

For example, if you use 6530 flat fan tips in step 3 above, and the nozzle catalog lists the flow rate of this nozzle at 40 psi as 3.0 gpm, you can calculate the needed pressure as follows:

[(2.2 gpm X square root of 40 psi) ÷ 3.0 gpm]^2 = 21.51 psi

Using equation 7, you would find that the pressure needed to provide a flow rate of 2.2 gpm with this nozzle is 21.51 psi. This is within the acceptable range for this nozzle.

The above calculation assumes that all nozzles receive the same pressure. This is usually not the case, especially on higher volume applications. Pressures often have to be increased about ten percent to compensate for flow restrictions and pressure loss along the boom.

Install inboard and outboard pressure gauges to check for significant (one to two psi or more) pressure drops along the boom at high flow rates. Switch gauge positions to check for gauge error. Make a trial run to be sure the aircraft is dispersing the desired application rate.

PATTERN TESTING FOR LIQUIDS

Perhaps the greatest difference between calibrating air and ground application equipment is how you ensure that the pesticide is applied uniformly over the target area. Ground-equipment nozzles are spaced uniformly along a boom in an attempt to get the same output and spray pattern from each nozzle. The pattern doesn't vary drastically among different pieces of application equipment.

In aerial application, the very movement of the aircraft causes differential airflow across the length of the boom. Thus, the pattern of an individual nozzle, tested at no movement, is of minor importance to the overall distribution of the applied pesticide. Droplet size, droplet distribution, flow rate, and tendency to clog are very important factors. For these reasons, no standard configuration of nozzles along a boom provides uniform distribution. The ideal configuration varies with each aircraft (even the same model aircraft), delivery system, and application rate.

When you evaluate the pattern and determine the effective swath of an aircraft, then spray height, speed, spray pressure, and nozzle location should duplicate field conditions. The best time for testing is early in the morning before the sun heats the ground and causes thermal turbulence. Fly the plane directly into the wind and limit testing to days when the wind speed is less than ten mph.

Pattern-testing is such an important part of achieving good aerial application that computerized pattern-testing equipment has been developed for this purpose. One system consists of a fluorometer that reads the intensity of fluorescent dye that an aircraft sprays onto a 100-foot long paper tape or cotton string in the field. The dye intensity is recorded by a computer that gives a relative reading of intensities and also determines the swath spacing that would yield the best pattern uniformity for the pattern on the tape being analyzed.

Computerized pattern-testing equipment may be too expensive for you to buy for personal use. However, you can get an idea of the pattern applied by your aircraft by using the general layout shown in Figure 8 to pattern-test. This figure shows a layout used for pattern-testing dry materials. For liquids, use a continuous piece of adding machine paper or water-sensitive cards rather than evenly spaced collection pans. (We will discuss pattern-testing for dry materials later in this section.) The pattern line should be at least 80 feet long. Determine the wind direction, and place flags about 100 yards on each side of the pattern line along the flight path (center line).

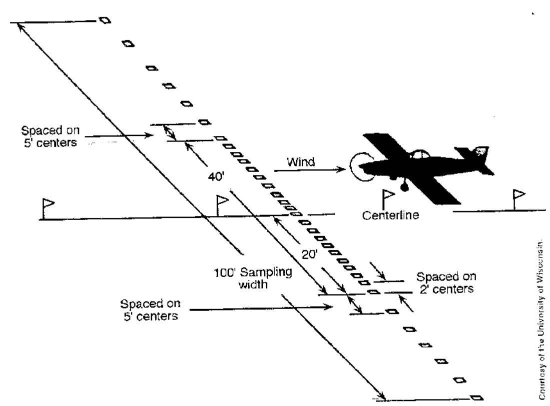


Figure 8. General layout for testing deposition pattern when calibrating aircraft.

Regardless of which testing system you use, make sure that the boom and all nozzles, screens, and other parts of the spraying system are clean and rinsed before you test the aircraft. Fill the spray tank with about 30 gallons of water, and add enough water-soluble dye to make a dark solution. Fly a short pass to purge the boom of any clear water and check for leaks.

You could also do this on the ground by attaching a garden hose to the end of the boom. The hose, using external pressure, will force water containing dye through the boom and out of the nozzles. Turn off the hose and see if any nozzles continue to drip after the pressure is off. The dye will make any leaks or plugged drop-pipes easy to spot.

After takeoff, purge the boom and make sure that dye leaves the end nozzles. Align the aircraft with the flags on a spray run that duplicates the actual field practices. Spray at least 100 yards on both sides of the pattern line while maintaining straight and level flight to ensure a representative spray pattern. Repeat the test to make sure the run was representative of typical spray deposition.

Visual evaluation requires some experience, but you should be able to identify common problems with spray uniformity and swath width. Watch for light drop-density areas around the centerline and uneven densities toward the wing tips.

The effective swath width will be considerably narrower than the distance between the outside samples where dye is evident (Figure 9). The amount of dye is reasonably constant for some distance on each side of the flight path and then begins to reduce until there is no dye evident. The effective swath width is the distance between the two points on the sloping ends of the pattern where the dye level is one-half the amount at the beginning of the slope.

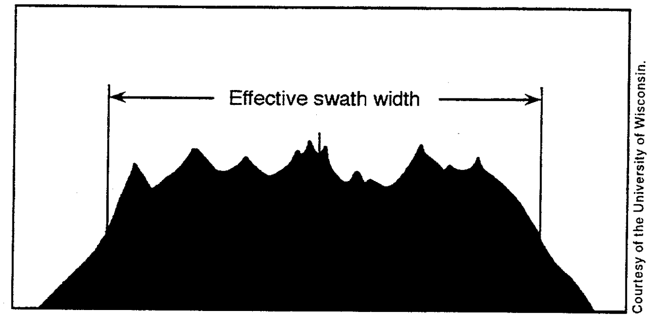


Figure 9. Effective swath width of a typical deposition pattern.

FACTORS THAT AFFECT DISPOSITION PATTERN

A number of factors influence swath width and application uniformity. Some, such as wing tip or rotor vortex, result from equipment design and must always be taken into consideration. Others, such as nozzle problems, are maintenance problems that can be corrected. You can detect each of these problems with pattern testing. Next we will discuss how to diagnose, compensate for, or correct these and other common causes of non-uniform spray deposition.

Leaks. The dye makes it relatively easy for you to detect system leaks. If there are indications of system leaks, such as very large drops of dye on the paper used for pattern evaluation, check the spray system thoroughly.

Nozzle problems. It’s normal for small and large droplets to appear on the sampling paper when pattern testing, because all atomizers generate a range of droplet sizes. If the range of droplets varies tremendously between locations in the pattern, different-sized or badly worn nozzles may be the problem. (You will generally find finer droplets in the center of the pattern that are caused by the increased shear action of the high-speed prop blast.)

Sometimes, you may put different-sized nozzles on the boom on purpose. For example, you may use a few nozzles with larger openings to counter prop wash displacement. Nozzle wear usually doesn't affect spray pattern significantly. You are likely to notice that you are spraying too great a volume before the wear gets bad enough to have a significant impact on the pattern.

Incorrect droplet spectrum. It's impossible to determine the size of droplets that are generated by an atomizer by measuring the droplet stain on the sampling paper. However, an experienced operator can determine whether droplet size is appropriate for the job to be done. Generally, coarse droplets are used for applying herbicides, small to medium for insecticides, and small for fungicides.

EFFECTS OF EQUIPMENT DESIGN AND CONFIGURATION

Airplanes and helicopters must move air to fly. The resulting air movement isn't uniform, but it's somewhat predictable. Your challenges are to understand how air moves around and under the aircraft and to compensate for this movement in order to apply pesticides uniformly across the swath.

Again, although we mention some general guidelines for producing a uniform spray pattern, remember that the actual placement of nozzles varies with each individual aircraft. There's no standard configuration of nozzles that will provide a uniform pattern.

Prop and rotor wash. Prop-wash turbulence, which is the result of the clockwise propeller air helix spiraling into the fuselage, carries droplets from nozzles to the right of the fuselage and deposits them on the target located beneath or to the left of the fuselage. Counterclockwise-rotation propellers (used with counterclockwise-rotating engines such as the PZL) have similar but reversed prop-wash problems, with the excess deposit on the opposite right side of the aircraft.

Prop wash results in a lack of spray deposit reaching targets from the center to about six feet right (or left in the case of the PZL engines) of the fuselage. Historically, a high percentage of the aircraft tested during aerial- application workshops have required compensation for this problem. The seriousness of prop-wash spray shift depends on factors that include aircraft fuselage and aerodynamics, propeller length and rotation speed, and special cowlings such as speed rings, spray droplet size, and spraying height.

Helicopters exhibit similar rotor-wash characteristics. The rotation of the rotor creates a swirling, cone-shaped helix that descends, trailing the direction of flight. This rotating air mass traps small spray droplets and transports them, resulting in a distortion of the spray deposit away from the leading rotor and in the direction of the trailing rotor. This shift may be influenced by many factors, including aircraft aerodynamics, location of boom mounting, spray droplet size, forward flight speed, and weight of the aircraft.

Prop wash is anticipated in propeller aircraft, especially those with larger radial engines. Some compensation is possible if nozzles are located correctly. Install extra nozzles to the right of the fuselage, in line with or just inboard of a point directly behind the center of the propeller.

To determine this point, align the propeller horizontally, and visualize a line parallel to the line of flight rearward to the spray boom. Radial-powered Ag Cats typically require more nozzles on the right than other types of aircraft. Engine speed rings alter the airflow around the engine and result in different distortions to the deposition patterns than the same aircraft without a speed ring. The deposition pattern of the large Melex Dromader aircraft is especially sensitive to the addition of third-party-manufactured speed rings. After adding or relocating any nozzle position, pattern-test the aircraft to verify the change in deposition uniformity (Figure 10).

Wing-tip vortex. Wing-tip vortex originates in the turbulence behind the wing as the airstream moves quickly from the high-pressure area under the wing and meets the low-pressure air from the top of the wing surface. The air mass travels the shortest route, which causes part of the air to slip outward from under the wing and introduces a large amount of turbulence and rotation. Visualize this rotation as a spinning cone of air with the highest velocities toward the center of the cone.

The highest-velocity (strongest) vortex action is produced by heavy, slow-moving aircraft. Bi-wing aircraft produce vortices at each of the wing tips that quickly combine into a single vortex behind the aircraft.

The combined vortex is about equal in strength to that produced by a monowing aircraft of the same weight and air speed.

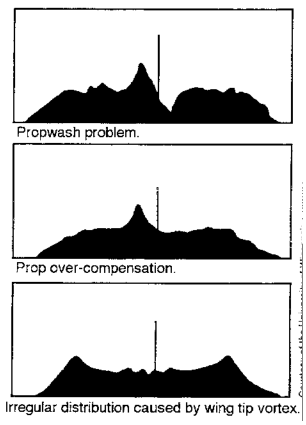


Figure 10. Effect on spray pattern caused by propwash and wing-tip vortices.

Larger droplets released inboard and well below the wing are least influenced by the wing-tip vortex. Wing-down wash airflow causes the pattern spray to spread.

Wing-tip vortices are also partially responsible for a swath wider than the aircraft wingspan. However, spray must enter only the outer, gently swirling air during its second or third rotation rather than the eye of the vortex. The outer portion of the vortex has a downward and outward motion that carries primarily the smaller droplets down to the crop outside the wingspan. The eye of the vortex traps all but the largest droplets and rotates them above the aircraft wing level. These droplets may be suspended long enough that the pesticide carrier (water) evaporates or moves off target (Figure 11).

Helicopters produce rotor vortices in much the same way as fixed-wing aircraft, except that the rotor blade changes the angle of attack as it travels around in a circular path. The rotor vortices form just below and behind the blade tip. The maximum strength exists where the rotor blade is at the highest angle of attack.

Place nozzles inboard of the rotor-blade tips to help prevent entrainment of the spray in the vortex. Toe-mount booms produce less rotor distortion than do skid- or heel- mounted booms.

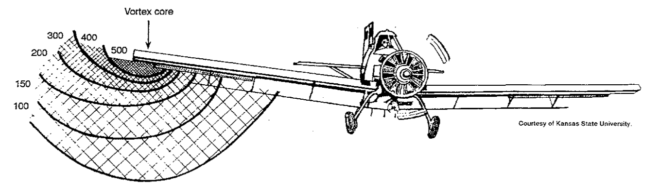


Figure 11. Wing tip vortex zones where smaller droplets can become trapped (droplet diameters shown in micronsF).

Placing nozzles inboard and/or below the trailing edge of the wing reduces the amount of spray trapped in the vortex circulation. Recent NASA research on fixed-wing aircraft indicates that removing nozzles inboard from the wing tips until a ten-percent reduction in effective swath width is noted reduces potential driftable lines by up to 90 percent.

Fly-in pattern-testing has verified that drift-hazard reduction is maximized by not placing a nozzle within six to ten feet of the wing tip. Normally, the swath width of conventional aircraft isn't reduced by reducing the boom length to 70 or 75 percent of the wingspan. The effect of reducing boom length more than 70 percent depends on the aircraft, nozzle pressure, and spray-droplet size.

Applicator tests using rotary nozzles (that is, Micronair) indicate that the outermost nozzle position may be positioned inboard as much as 55 percent of the wingspan to ensure that material isn't entrained in the wing-tip-vortex circulation.

Nozzle stoppage, improper swath width, and other factors can cause poor distribution. Strips of poor weed control, called streaking, indicate poor distribution. However, identifying the cause and remedying this problem from field results occurs strictly by chance.

If you wait for problems to show up in a field situation, the damage has already been done and is hard to remedy. Complete pattern-testing and make calibration adjustments to the aircraft to obtain uniform deposition before you make annual applications.

CALIBRATION CALCULATIONS FOR SOLIDS

Give equal attention to calibrating equipment that dispenses solids and liquids. The type of spreader, type of granular material, rate per acre, and amount of swath overlap all affect calibration accuracy. If one condition changes, you must repeat the calibration procedure. For example, the size, shape, density and flowability of a granular material affects the swath width, application rate and pattern. Also, except at low rates, swath width is inversely proportional to application rate; that is, if you increase the rate, you decrease the swath width.

If the spreader manufacturer provided an owner's manual that specifies gate settings for different delivery rates and for different formulations, use this data as a starting point. Determine the actual pounds per minute by conducting a hopper-refill test during the application of the first few swaths of material. (Hopper-refill tests are discussed later in this section.)

Assume a swath width based on previous experience with similar equipment. Once you know the flying speed, you can calculate the desired rate per minute.

Equation:
3600 ÷ mph = seconds to fly 1 mile

Example:
If you assume a speed of 90 mph and a swath width of 50 feet:

3600 ÷ 90 mph = 40 seconds

Equation:
Swath width (feet) ÷ 8.25 = acres covered per mile

Example:
50 ÷ 8.25 = 6.06 acres per mile

You can then calculate acres per minute as follows:

Equation:
[(acres per mile) X 60] ÷ seconds to fly 1 mile = acres per minute

Example:
(6.06 X 60) ÷ 40 = 9.09 acres per minute

If the label calls for 10 pounds per acre, the desired flow rate is:

Equation:
(pounds per acre) X (acres per minute) = pounds per minute

Example:
(10) X (9.09) = 90.9 pounds per minute

If you don't have information regarding proper gate settings, do some preliminary work on the ground. Time the flow of 100 pounds of granules through the gate opening. The flow rate will be about twice as fast during flight; use this to make an estimate, and adjust the gate for the desired rate per acre.

For example, suppose in your ground test, it took two minutes for 100 pounds to flow through the gate opening. That would correspond to 100 pounds per minute while in flight. This output is too high; readjust the gate opening and try again. When the value obtained in the ground test is acceptable, check the distribution by doing a test run.

PATTERN TESTING FOR DRY MATERIALS

You can determine the distribution pattern only by setting out pans across a line of flight. The setup is similar to that shown for liquid sprays in Figure 8 on page 14. The pans should be at least four inches deep and padded inside with a thin layer of foam. The inside area should be sufficient to catch a measurable amount of material. (For example, a 16-square-foot pan will catch up to half an ounce if you apply granules at 100 pounds per acre.) Place them at two-foot intervals for 20 feet on each side of the swath centerline and at five-foot intervals for an additional 30 feet on each side. Do this on flat ground, and be sure the total width is greater than the expected swath width.

Perform the test during minimum wind conditions. Orient the pans at right angles to the wind and fly into the wind.

Fly at 30 to 50 feet above the ground surface, which is normal for granular applications.

DETERMINING SWATH WIDTH

After the run is completed, move from one end of the test strip to the other, collecting the granules from each pan, and transfer them into a small-diameter glass tube (test tubes do nicely). Use a separate tube for each pan and keep the tubes in order.

When you're finished, place the tubes in sequence on a wooden base to display distribution visually. Use the display to determine the shape of the distribution curve and estimate the overlap you need in order to provide even coverage.

Your estimate will be more accurate if you plot the height of the granules in each tube, in sequence, on a piece of graph paper. If necessary, cut out the graph, duplicate it, and align the two to give the most uniform distribution; 50 percent overlap is common. The effective swath width is the total width minus the distance of overlap.

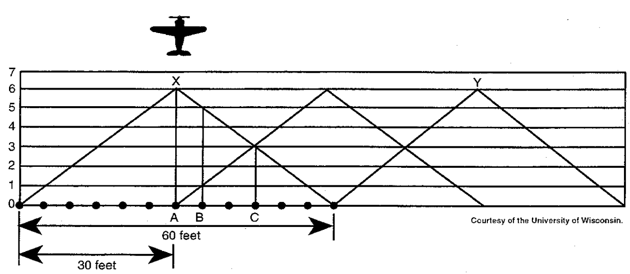


Figure 12. Triangular deposition pattern of dry material across a swath.

The distribution shown in Figure 12 is an idealized plotting of the amounts caught in the pans laid out across 60 feet. This triangle is a perfect pattern for a 30-foot swath spacing. Another pattern centered around a point 30 feet from the first flight path would result in an even distribution between the two patterns.

Figure 12 shows that at point A, 6 units (pounds or other unit of weight) were applied with the first swath, and none with the second. At point B, 5 units were applied with the first swath and 1 with the second for a total of 6 units. Likewise, the two swaths applied a total of 6 units (3 + 3) at point C. Thus, a distributor with a triangular pattern can make an even application if you use half of the width of the pattern as the swath spacing.

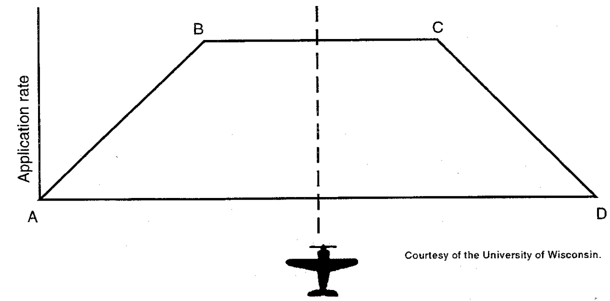


Figure 13. Trapezoidal deposition pattern of dry material across a swath.

The trapezoid shown in Figure 13 is a common pattern generated by granular spreaders. The swath spacing for a pattern of this shape is determined by the following equation:

(AD + BC) ÷ 2 = swath spacing

Zero granules were caught at points A and D. The amount caught was the same for each pan between points B and C. If the distance between A and D is 60 feet, and the distance between B and C is 30 feet, then:

(60 + 30) ÷ 2 = 45 feet

SWATH IRREGULARITIES

These examples show that you can't just fly two swaths over the collection pans and take half the distribution pattern as the swath width. Instead, you must plot each point on a single pass and determine the pattern and swath from the plottings of multiple passes. After you achieve an even pattern, you can determine the swath width and calculate the rate per acre.

The examples of the triangle and trapezoid patterns cited earlier represent ideal situations. In practice, though, some irregularities in the distribution pattern always occur.

After you plot the sample and determine the swath, check to see if the distribution of the granules remains within acceptable tolerances (that is, where the amount within each collection pan is within five percent of the average).

Non-symmetrical distribution pattern. A common type of irregularity in the swath is non-symmetrical distribution; that is, for any given swath, the pattern on the right side of the aircraft is different from that on the left.

If you fly all passes in the same direction in a race track pattern, and there is 50 percent overlap, the left wing pattern comes over the right wing pattern (or vice versa) and results in a perfect total pattern. If you fly a back-and-forth pattern, the left wing overlaps the left wing and the resulting pattern isn't acceptable.

The goal of calibration is to make distribution patterns as even as possible and the same on both sides of the aircraft. If you must adjust the pattern halfway out on the left side, adjust the flow at the gate halfway left to center. Or you may have to adjust the spreader vanes halfway left from center.

Determine the actual application rate. After checking the swath width, pattern and calibration of the spreader, measure the application rate per acre. To do this, load a known weight of pesticide product into the hopper. Fly a known number of passes of known length (minimum four passes, two in each direction), then weigh the remaining material. The initial weight minus that of the remaining material is the amount you applied.

You can determine the acres covered in the test run as follows:

Number of swaths X field length (ft.) X swath width (ft.) ÷ 43,560 sq. ft. per acre = acres covered

The application rate is:

Pounds of material applied in the test run ÷ acres covered in the test run = pounds per acre

Once you determine the swath width and pattern, they usually won't change for the same plane, spreader and formulation. They also won't change appreciably from ten to 20 pounds per acre. Thus, the same swath width can be used for this range of application rates, and an annual check will be sufficient, provided that the equipment isn't changed or damaged.

Still, you should check the application rate whenever you get a chance. Such checking shows exactly how many pounds were applied for each job. Calculate the rate per acre to check on the gate setting several times a day, and keep records of your checks. Many things can happen to affect the rate, including these:

- Foreign material may enter the hopper and plug a gate or spreader opening.
- Moisture may condense in the hopper overnight. The resulting sticky material would affect application rate.
- Water may splash onto the spreader during taxi or take-off and cause wet areas around the openings, thus reducing the flow of granules.

By continually checking your delivery rate and correcting any problems, you will consistently make effective and accurate applications.

FIELD OPERATIONS

Scout the field from the air before actually starting spray operations. Circle the field at a very low altitude, but high enough to clear all obstructions by at least 50 feet. Look for wires and other obstructions (trees, buildings, windmills, radio antennas, road signs, pipeline markers and fences) in and near the fields to be treated. Be aware that trees may conceal power lines. Regard any break in the cultivation pattern in the field with suspicion.

After you circle the field and note the obvious hazards, fly just above and to one side along each power or phone wire and check each pole. Look for branch wires, guy wires, and transformers. Many times a wire is hard to spot from above, but if you look at the pole tops you can see the insulators that attach these wires to the pole. Transformers usually have a branch wire that goes to a house, well or other structure. If a house is near the treatment area, look for a line coming in from somewhere to determine by what route it gets its power. 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.

Always remember that conditions change. The wire you flew under last year (or last week, for that matter) may have a new one under it today. You may be able to get under a wire in the spring when a crop is first planted, but not later in the year when the crop is taller. And a field that had no lines last week may have power or phone lines today. Heat expands wires, making them lower to the ground during hot summer days.

FLIGHT PATTERNS

Practice safe flying procedures during application to protect you, your ground crew, and the environment and to ensure that the pesticide you are applying will be effective.

In field. Pilots normally fly back and forth across the area being treated in straight, parallel lines (Figure 14). However, a race-track pattern may be more energy-efficient for some fields or more appropriate in situations where it allows the aircraft to avoid sensitive areas. Remember that an airplane can't deliver a uniform spray pattern if the flight line isn't straight.

In mountainous terrain, where areas are too hemmed in to permit back-and-forth flying, make all treatments downslope. Upslope treatments are extremely dangerous.

Mark each swath to ensure uniform coverage and to avoid excessive overlap or stripping of the area. Whenever possible, make the flight lines or swaths crosswind to assist in overlap and coverage uniformity. Begin treatments on the downwind side of the areas so that you can make each successive swath without flying through chemicals suspended in the air from previous swaths (Figure 14). Also try to make the flight lines lengthwise to the treated area to reduce the number of turnarounds.

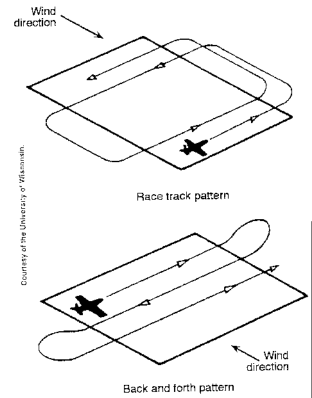


Figure 14. Routine turnaround flight patterns for aerial application.

Speed. Maintain constant airspeed during aerial application. Remember that calibration of dispersal systems depends on flow rate (gallons or pounds per minute) and flight speed. No device is available that changes flow rate automatically and proportionately as the flight speed changes. Therefore, once the dispersal apparatus has been properly calibrated, you must keep the speed constant during each swath to ensure uniform coverage of the area This is another reason to apply pesticides crosswind. By doing so, you avoid the adverse effects of head- and tailwinds on application rate.

Altitude. Altitude is usually determined by the formulation of material being applied. For example, liquid pesticides must be applied from a low height (up to one-half the wingspan) to reduce drift. Granular pesticides are usually applied from wingspan height.

You must keep the selected height constant during each swath run to obtain uniform coverage of the treated area. Maintain the same height you used when you checked the pattern of deposition and determined effective swath width.

APPLICATION AROUND OBSTRUCTIONS

Power and telephone lines. If a wire is close to trees, it's safer to fly under the wire and then pull up and go over the trees than it is to enter the field over trees and then go under the wires. In the latter situation, you must judge the pull out at the ground and determine then if there is room to get under the wire. This is very dangerous. Don't fly under wires that have fences or other objects under them.

Obstructions beside and at end of field. If obstructions (trees, power and telephone lines, or buildings) are located at the beginning or end of the swath, turn the spray on late or shut it off early, perhaps one or two swath-widths from the end of the field. Then when the field is completed, fly one or two swaths crosswise (parallel to the obstruction) to finish out the field. Even though you may be over the target area, you mustn't disburse materials when dropping in or pulling out of the field. The deposition pattern will be distorted and the pesticide will be likely to drift.

If there are obstructions along the sides of a field, fly parallel and as close to the obstruction as you safely can. Leave an untreated border strip adjacent to buildings, residences, and livestock areas to help avoid pesticide drift. You may treat obstructed borders when the wind is blowing toward the target area.

Obstructions within a field. Approach a tree, pole, or other obstruction that is within a field the same way you would if it were at the end of the field -- stop spraying one or two swath widths from the obstruction. After pulling up, make a 180-degree turn before dropping in on the other side. This will allow you to control the speed sufficiently to avoid overshooting the other side. Work past the obstruction, then run one or two swath widths on each side of it to complete the treatment around it.

THE TURNAROUND

The turnaround is performed more often than any other maneuver during aerial applications. When executed poorly, it's a major cause of accidents. The pullup and downwind turn puts the aircraft in a low-speed, high-drag situation, so it must be executed carefully. You should never look back; accomplish orientation for the next swath before the pullup.

If possible, start the turnaround at the end of each swath after pulling up over obstructions. When applying pesticides in the back-and-forth pattern, start the turnaround by turning 45 degrees downwind, leveling off for several seconds, then making a smooth coordinated reversal of 225 degrees (Figure 14). The number of seconds you spend in level flight is determined by the swath spacing or distance the aircraft must move over, maneuverability of the aircraft, power, load remaining, wind, temperature and elevation.

As you complete the turn, orient yourself to line up for the next swath. Pilots often encounter difficulty during this part of the turn, so pace yourself. Avoid fast or intricate maneuvering to get into position. Complete the turnaround before dropping in over any obstructions on the next swath. Any turning while dispensing will distort the distribution pattern and make even application impossible.

Avoid snapping reversal, lowball or wingover turns. When you must make a turn by going upwind first, you need more space and time to complete the turn.

Avoid turnarounds over residences, farm buildings, penned poultry or livestock, watering places, ponds and reservoirs. Flying in a racetrack pattern may help you avoid these sensitive areas. Always stop the discharge before pulling up or making turnarounds.

APPLYING GRANULES

Airspeeds of 100 to 120 mph (faster for some airplanes, slower for helicopters) are recommended when applying granules. These speeds maintain good airflow through the spreader and obtain proper distribution and maximum swath width. The flying height, airspeed, and correct ground track must be held 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 flying height required. Head or tail winds affect ground speed, and adjustments in flow rate and/or airspeed may be required to give uniform distribution on alternating upwind-downwind passes. Monitor operating conditions and weather changes carefully when you apply these materials, because a no-wind condition is seldom encountered for any length of time.

You can obtain maximum swath width at a certain wheel height above the crop. This height varies with the density, size and grading of the particles of material being applied. For most materials, this is in the range of 40 to 60 feet wheel height. Effective wheel 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 spanwise direction. Flying above this height achieves no increase in swath width because particles fall vertically after the lateral energy is dissipated. Don't fly higher than necessary, or you may experience problems with increased swath displacement and difficulty in maintaining desired ground-track height.

FERRYING

Fly at an altitude of at least 500 feet during ferry flights between the airstrip and worksite, whether the tanks are loaded or empty. Avoid flying over farm buildings, scattered residential areas, and penned poultry or livestock. Too often, because of the noise they make or their mere presence, agricultural aircraft are accused of damaging or contaminating property. If you must make many trips back to the same area, avoid taking the same route each time. Deviate one-eighth to one-fourth mile off direct course to avoid flying close to the same areas each time.

PROPER HANDLING AND USE

Every pesticide comes with its own set of risks to humans and the environment. Everyone in your operation has a responsibility to understand and avoid these risks. If the risks are realized, you must know how to respond to them.

PILOTS

The pilot is responsible for efficient and successful aerial application. Training, ability, skill, judgment and competence can't be overemphasized. A pilot must:

! Determine the best direction in which to spray a block and adeptly maneuver an aircraft that is loaded to its maximum legal weight.

! Be trained in crop recognition, not only to ensure that the correct field is treated but, more importantly, to ensure that any drift damage to adjacent crops is minimal.

! Read the label, and comply with application rate and safety precautions.

! Be acquainted with each chemical used, knowing how to handle it safely, what clothing and devices should be worn for protection, antidotes that are required in the event of accidental overexposure, special precautions that must be observed when applying chemicals, where chemicals can be used safely, and the hazards if chemicals are applied incorrectly or in the wrong places.

! Know how weather affects the application of sprays and granules to crops.

! Master his or her aircraft, using only the maneuvers that can be performed safely and avoiding others, and know the maximum load limit from short, rough, temporary airstrips.

Above all, the pilot must be aware of his or her own limitations in the aircraft.

Pilots should use extreme caution when loading aircraft with pesticides. It's hard, even with normal protective clothing and equipment, to load without some exposure. Accumulated exposures may bring on mild pesticide symptoms, including dizziness and fixed contraction of the pupils (miosis) of the eye. The latter has been reported to cause diminished visual acuity, especially at night.

These mild symptoms may not be as serious to ground applicators or the ground crew, but they are potentially fatal to a pilot, especially during night applications. If pilots are exposed when dispensing pesticides and during loading operations, they may accumulate enough dosage to trigger symptoms. When crosswinds occur, the pilot should begin application on the downwind side of the field to avoid flying through the previous swath.

There is evidence that accidental, direct eye contamination by organophosphates may cause contraction of the pupils for from seven to ten days without any other symptoms. There have been several reports of fatal injury to agricultural pilots who were directly exposed to organophosphates. Miosis was definitely identified following the crash.

It's very hard to prove that "pilot error" crashes were caused by pesticide exposure, but present evidence suggests pesticide exposures should be kept to a minimum. Pilots who exhibit symptoms characteristic of pesticide poisoning shouldn't fly until the symptoms disappear.

Remember, your body will tolerate small amounts of most pesticides. But if you accumulate doses of pesticide from various operations -- flying, loading, mixing or cleaning, symptoms will begin when you reach a certain level.

There have been a number of air crashes after the pilot was drenched with pesticide from a ruptured spray tank. Many pesticides are rapidly absorbed through the skin as well as entering through the respiratory route. Always remove contaminated clothing as soon as possible, then **run** for the nearest water for washing -- whether that is a ditch, creek, pond or hose. This isn't the time for modesty. The California Department of Health reported one pilot who, though not critically injured in the crash, was splashed with TEPP and phosdrin. He died of organophosphate poisoning 20 minutes later.

Use a filter- or canister-type respirator appropriate for the chemical being applied. If you need one for extended periods during hot weather, use a respirator and crash-helmet combination that is ventilated with fresh air.

PROTECTIVE CLOTHING AND EQUIPMENT

The unit in *Applying Pesticides Correctly* provides an excellent discussion of the types of, and need for, protective clothing and equipment. The Worker Protection Standard (WPS) requires pesticide manufacturers to list minimum personal protective equipment and clothing requirements on the label. The label must specify the type of gloves to wear (such as nitrile) and, if applicable, the type of respirator to use and the respirator's MSHA/NIOSH approval-number prefix. (For example, the label might say to use an organic-vapor-removing cartridge and pre-filter with MSHA/NIOSH approval number prefix TC-23C.)

The WPS requires you to wear the protective gloves required by the labeling when entering or exiting an aircraft whose exterior is contaminated by pesticide residue. Once inside the cockpit, you must keep the gloves in an enclosed container to prevent contamination of the cockpit's interior.

Under the WPS, pilots may substitute certain protective gear for label-specified personal protective clothing and equipment. The substitutions that are allowed depend on whether the cockpit is enclosed or open.

Enclosed cockpits. Persons in enclosed cockpits are not required to wear personal protective clothing or equipment, but they must wear long-sleeved shirts, long pants, shoes and socks.

Open cockpits. Persons in open cockpits must wear the personal protective clothing and equipment required for a ground applicator using that product, except that chemical-resistant footwear isn't required. You may substitute a helmet for chemical-resistant headgear and a visor for protective eyewear.

GROUND OR LOADING CREW

Most pesticides are toxic in varying degrees. The loading or ground crew has the most direct contact with pesticides and must wear protective clothing and equipment. The label on the pesticide specifies the protection needed.

When you work around chemicals:

! Don't breathe fumes from the mixer when you pour concentrated chemicals into mixing equipment. Wear your respirator and face shield as required.

! Don't eat your lunch or smoke around mixing equipment. Move out of the loading area, then wash your hands thoroughly.

! Don't carry cigarettes or anything you eat in your pocket while you load dust or liquid; they absorb chemical fumes.

! Chemicals can poison you by absorption through the skin, eyes or mouth or by breathing fumes. Protect yourself at all times.
! Triple-rinse or pressure-rinse chemical containers immediately after emptying them.

! Never leave emptied chemical containers on an unattended runway. Bring all containers back to where you normally dispose of them. Keep them under lock and key, full or empty.

! Stand upwind of mixing equipment when you pour chemicals or while you wait for the airplane to return for another load.

Wear protective clothing when you handle chemicals:

! Never handle insecticides without good, clean, unlined rubber gloves.

! Wear enough protective clothing to keep as much of the body unexposed to the chemical as possible. Liquid Category I and II chemicals require that you also wear a waterproof apron when you mix and load.

! Don't wipe your hands on your clothes; this will contaminate them. Take a clean change of overalls to the job with you.

! Don't wear dirty or contaminated clothes on the job or home. Wash your clothing regularly.

! Wear good rubber footwear to avoid contamination with chemicals that are on the ground in the loading area.

! Dispose of emptied pesticide containers properly.

! Wash thoroughly with soap and water immediately if you accidentally spill chemicals on yourself.

Believe what you read on all labels. If you don't comply with them, you place yourself and others at grave risk.

AIRSTRIP OPERATION

A well-organized airstrip ensures that the aircraft spends the minimum amount of time on the ground and the maximum time spraying. Airstrip layouts vary, but fuels and pesticides must be kept well apart and protected from sunlight and environmental extremes.

Point the airplane toward the runway while it's being loaded to avoid making sharp turns with a fully loaded airplane. Locate mixing tanks so that prop blast doesn't blow sand or debris toward them. A wide, circular turnaround area with the chemical storage and mixing area in the middle is often used. The fuel may also be in the middle of the circle so you can refuel while loading; however, remember to keep fuel and pesticides well apart.

Load the aircraft via a closed-transfer system. Do all ground work on an impervious surface that allows any accidental spills to be contained, properly recovered, and used or disposed of.

You may need to reduce the aircraft payload from the manufacturer's maximum specification to compensate for airstrip conditions or for the effect of atmospheric conditions.

AERIAL-APPLICATION CHECKLISTS

We suggest that pilots and crew, including flaggers, review a checklist at least weekly to help them avoid becoming complacent and careless.

Pilot checklist. The pilot should do the following **before, during and after** any application:

1. Don't load or handle highly toxic pesticides, especially hazardous formulations, during any operation.

2. Turn off the engines during loading operations.

3. Wear an approved safety helmet, long-sleeved shirt, long pants, shoes, socks, and other protective equipment specified on the pesticide label.

4. Check the field and surrounding area before you apply chemicals 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.

5. Don't fly through the suspended spray of an application.

6. Stop treatment if winds rise and create a drift hazard.

7. Don't turn on dispersal equipment or check the flow rate except in the area to be treated.

8. Refuse to fly if the customer is the flagger. Also, refuse if the customer insists on having pesticide applied in a manner and at a time that may create a hazard to crops, humans, animals, and the surrounding environment.

9. Read the label, and know the hazardous characteristics of the pesticides.

10. Know how far and in what direction the chemical will drift (that is, use smoker).

11. Don't spray over the flagger or anyone else.

12. After you complete a job, don't dump remnants on the field. Carry it to the loading area so the crew can store it in a safe manner for reuse as make-up water.

Ground crew checklist. The ground crew should do the following **before, during and after** any application. Also, the ground crew should be familiar with the pilot's checklist.

1. Clean aircraft often, especially the cockpit.

2. Tightly seal tanks and hoppers so the chemicals won't blow back over the pilot.

3. Cover the hopper as soon as loading is completed.

4. Remove any chemical spilled near the fill opening.

5. When handling pesticides or cleaning aircraft or other equipment, use extreme care, and wear protective clothing.

6. Don't stand in runoff water or allow it to splash on you.

7. Change clothing after handling pesticides or washing the aircraft and contaminated equipment.

CLEANING EQUIPMENT

Clean application equipment adequately, so that it operates properly. This helps prevent cross-contamination, which may result in plant damage or illegal residues. Generally speaking, it's easier to remove fungicides and insecticides than herbicides. Therefore, when possible, schedule daily operations so fungicides are applied first, followed by insecticides. Apply herbicides last, so they can be thoroughly washed out at the end of the day.

Pesticides vary considerably, so adapt rinse procedures. You can usually remove water-soluble powders and emulsifiable concentrates with water. However, you may have to rinse certain oil formulations of 2,4-D with kerosene or another solvent **before** you wash them with water and detergent or other additives, such as charcoal. Follow the manufacturer's recommendations on the product label to develop acceptable washing procedures for specific pesticides. Wash tanks and hoppers adequately inside and out to prevent carryover of pesticides and damage to sensitive crops.

Provide a specific area in which to flush and clean equipment. Locate it away from the office and tiedown area so the equipment maintenance area will be protected from contamination. A pad of concrete or other impervious material three feet to five feet wider than the wingspan of the aircraft is ideal. Slope it to a central collection sump that's equipped with a pump to transfer waste to a suitable storage tank. Cover the pad to prevent the collection of rain.

Follow these procedures for equipment on the collection pad:

Emulsifiable concentrates and wettable or soluble powders

1. Drain excess spray solution from the tank or hopper.

2. Add a small amount of water and detergent to tank, then circulate and discharge it completely.

3. Add clean water to the tank, circulate it, and discharge it completely again.

4. Check nozzles and screens and, if necessary, disassemble them, clean them thoroughly, and reassemble them.

5. Clean the outside of equipment, and collect and properly dispose of the wash water.

Phenoxy herbicide. Herbicides, especially ester formulations of 2,4-D and related products, are hard to remove. Even in tiny amounts, they pose serious problems of phytotoxicity to sensitive crops.

Amine formulations (water-soluble)

1. Drain excess spray from the tank.

2. Flush the system with a small amount of water-detergent mixture, and collect the waste.

3. Fill the tank with a solution containing one quart of household ammonia per 25 gallons of water. Agitate it and pump enough out to fill the hoses and boom. Let this stand for 12 to 24 hours.

4. Check the nozzles and screens, disassemble them if it's necessary, clean them, and rinse them thoroughly.

5. Drain the ammonia solution and rinse it thoroughly with clean water. Dispose of contaminated liquids in an appropriate manner.

6. Clean the outside of equipment. Dispose of contaminated liquid in an appropriate manner.

Ester formulations (oil-soluble)

1. Drain any excess spray from the tank.

2. Rinse the tank with kerosene instead of water, flush it, and dispose of liquids in an appropriate manner.

3. Fill the system with water containing two ounces of laundry detergent and four ounces of activated charcoal for each ten gallons of water.

4. Agitate it thoroughly for at least five minutes, pump the solution through the hoses, and dispose of liquids in an appropriate manner.

5. Rinse the system thoroughly with clean water, and dispose of liquids in an appropriate manner.

Important: **These procedures don't take precedence over any specific instructions that may appear on a pesticide product label. Label instructions must always be followed explicitly.**

Even these cleaning procedures don't guarantee that all traces of pesticide have been removed. Therefore, before treating a sensitive crop with equipment previously used to apply herbicides, you may want to fill the equipment with water and apply it to a small crop area to determine the phytotoxic potential.

PESTICIDE CONTAINERS AND DISPOSAL

It's against the law to open-dump pesticide containers, whether they are rinsed or not. Pouring rinse water, unused mixtures, or unused concentrates onto the ground or water is illegal. These generate hazardous waste.

Container disposal. In order for pesticide containers to be classified as solid waste rather than hazardous waste, the pesticide containers must be properly rinsed. Once the container is classified as a solid-waste product, it can be legally disposed at a sanitary landfill.

Liquid pesticide containers must be rinsed immediately after they have been emptied. After the container is cleaned, puncture and/or crush it. Applicators have two options available to clean containers, pressure-rinse or triple-rinse.

Pressure-rinse. A pressure-rinse nozzle screws onto a hose as does a garden nozzle, but it's much heavier, has a sharp point for puncturing the container, and sprays water in several directions to ensure good rinsing.

To pressure-rinse, allow the container to drain into the spray tank for 30 seconds. While holding the container over the tank opening, insert the probe of a pressure-rinse nozzle into the bottom of the container.

For plastic containers, insert the probe near the corner or edge of the bottom. For metal containers, especially larger than five gallon sizes, make the initial hole through the bottom with a punch or chisel, then insert the probe through the hole.

Turn the rinse unit on to rinse the container. Rotate the nozzle slowly, allowing water to reach all sides of the container. Continue to flush for a sufficient time (20 to 30 seconds) to adequately rinse the container.

Turn the water off. Drain all rinsed contents from the container into the spray tank. Remove the nozzle from the container. The container has been sufficiently cleaned.

Triple-rinse method. Drain the container into the spray tank for 30 to 60 seconds. Fill the container one-fourth to one-fifth full of water. Replace the cap and vigorously shake it for 30 seconds. Remove the cap, and drain the contents into a spray tank for 30 seconds. Repeat this rinsing two more times. Puncture and/or crush the container to ensure it won't be used again.

Bag disposal. Empty the content of the pesticide bag into the applicator tank or hopper until all the pesticide has been removed.

Tear open the container to make sure it's completely empty. Wrap the container in paper, and place it in a solid-waste collection system, or carry it to a sanitary landfill.

Disposing of unused mixtures. Try not to mix more than is needed. If some spray mixture is left, spray it on a labeled crop or site. You can spray rinsate over a labeled crop or site, or transfer it into a rinsate holding tank. If you store rinsate, you must have proper hazardous-waste storage permits. Label the tank by chemical type. Use it as make-up water for later tank mixtures of the same product formulation. Only 20 percent of rinsate can be used for make-up water; the rest must be clean water.

Cleaning out sprayer tanks, lines and nozzles. If it isn't desirable to spray unused mixtures over a labeled crop or site, dilute four to 12 gallons of mixture with 40 to 70 gallons of clean water, and spray it over the labeled site or crop. Otherwise, collect the spray mixture, and hold it in rinsate tanks.

Warning: It's possible that local landfills may have further restrictions on pesticide-container disposal. Locally owned or run landfills have the right of refusal.

FLAGGERS

Use permanent or electronic markers to eliminate the possibility of harm to flaggers. However, if flaggers must be used, no person other than flaggers should be in the field to be treated. Your flaggers should:

! Know which chemical is being applied so they can wear appropriate protective clothing and equipment and so they react properly in case of emergency. Flaggers must wear chemical-resistant headgear if the application may result in overhead exposure.

! Always start flagging on the downwind side and flag into the wind, never with the drift. Once the aircraft has achieved a satisfactory heading on its swath run, the flagger should move to the next swath in order to maintain a safe separation from the aircraft. The pilot can maintain additional separation by working a swath behind the flagger.

! Avoid flagging near power lines or fences. If you cut the wires or snag the fence, the trailing wires could hurt a flagger. Flaggers should never direct you toward a guy wire.

! Watch the aircraft at all times, and never turn their backs on an approaching aircraft.

! Move over to the next position after the aircraft is lined up for a pass.

! Stay at the job site until the application is completed so they can help in case of an emergency.

! Advise you of any hazard or problem he or she sees.

Flaggers are considered pesticide handlers under the Worker Protection Standard. Thus, you or their employer must provide them with the personal protective clothing and equipment, safety training, decontamination site, and other provisions as required by the WPS.

IF AN AIRCRAFT CRASHES

Train the ground crew and flaggers in the proper procedures to use in the event of a crash. Share the following information with them, and develop a crash response plan. The ground crew and flaggers must remember the following:

! Don't panic. Stay calm, and try to help the pilot as much as possible.

! If a radio is available, call for additional help.

! Have a fire extinguisher available at all times. Take it to the aircraft immediately.

! If the aircraft is on fire, stay out of the smoke. Get the pilot out, and moved him or her to a safe distance. If it isn't too dangerous, try to extinguish the fire.

! See if the pilot is injured. If so, serious injuries demand immediate attention. Don't move a pilot who is seriously injured or unconscious unless the aircraft is burning. Check for strangling, choking or bleeding. If an artery is cut in an arm or leg, use direct pressure on a pressure point. Use a tourniquet only as a last resort. Call an ambulance and rescue squad. Give your precise location. Then call your company to apprise them of the situation. Accompany the pilot to the hospital.

! If the pilot isn't seriously injured but has been exposed to the pesticide, help him or her to the decontamination site or the nearest water source. Wash several times -- with soap, if possible. In a number of air crashes, the pilot has been drenched with pesticide from a ruptured spray tank. This exposure may cause more harm than the physical injuries suffered in the crash, so you must act quickly. Take the pilot to a doctor or hospital, whether or not there was any exposure to pesticides. If it's more appropriate, call a rescue squad. Accompany the pilot to the doctor, taking a copy of the label or material safety-data sheet with you. This will tell the doctor what pesticide was being used and what, if any, medical treatment to provide.

DRIFT

Drift is the air-borne movement of pesticide to areas outside the target area. Reducing drift is a significant aspect of pesticide application. Pilots who ignore the reality of drift do so at their own risk and to the detriment of the entire aerial application industry.

We discuss drift in detail in a unit in your *Applying Pesticides Correctly* manual.

Because this is such an important topic for aerial applicators, we'll review some basic facts about drift and present additional information specific to the problem of drift in aerial applications.

FACTORS THAT CAUSE DRIFT

We can separate the factors that cause drift into two main categories: weather-related (wind velocity, temperature inversions, air stability, and relative humidity) and application-related (nozzle spray, placement of nozzles on boom, nozzle orientation, airspeed, spray heights, operating pressures, and choice of formulation).

WEATHER-RELATED FACTORS

Weather conditions at the time of application greatly affect whether, and to what extent, drift will occur. While you have no control over these conditions, you can choose not to spray when conditions favor drift. To make the proper decision, you must understand what conditions affect drift and how they do so.

Wind velocity. Obviously, the distance that spray droplets travel, and the chances that they will leave the target area, increase with wind velocity. A simple anemometer (an instrument that measures wind speed) should be part of your ground equipment. Use the anemometer as a safety measure, and keep a record of wind speed as a legal reference.

Normally, the aircraft flies with a side wind of two to ten mph and works upwind across the field. Under such conditions, some larger spray droplets (>100F in diameter) may settle on the target area more than 150 feet downwind of the flight path. You can plan for this swath displacement and apply the pesticide accordingly.

However, droplets smaller than 100F may settle much further away, perhaps well beyond the target area. This drift is unacceptable. Thus, even though swath displacement occurs whenever there is even the slightest wind, the actual drift is greater than that which you see.

Apply pesticides when wind speed is low to minimize this risk. (However, as we'll discuss later, you should also avoid applying pesticides when the air is almost calm.) Even when the wind is low, don't apply pesticides if it's blowing toward residences, livestock areas, or other sensitive places.

Temperature inversions. Under normal conditions, temperature decreases with increasing altitude. A temperature inversion exists when temperature increases with altitude to some point before it becomes cooler.

Temperature inversions are usually caused by rapid cooling of the soil surface, coupled with evaporative cooling of crops. The lost heat radiates upward, causing the air above the ground surface to be warmer than air at or near the surface. The cooler air, since it's heavier than the warmer air, remains as a layer near the ground.

Maximum inversions occur when cool night temperatures follow high day temperatures. The inversion reaches its peak in the early morning. It then disappears as the sun warms the land. This causes the air to warm at the soil surface and re-establishes the normal temperature gradient.

Temperature inversions provide the greatest opportunity for drift. During a temperature inversion, the air is highly stable. Small spray droplets can become trapped in the cool air beneath the inversion ceiling. They can move laterally far enough and in sufficient amounts to cause damage outside the target area. It's unfortunate that inversions are most likely to occur in the early morning, a time when wind speeds are usually low and thus more conducive to spraying.

Don't make an aerial application when a temperature inversion exists. To detect an inversion, measure the air temperature near the ground and at some higher altitude (at three and 32 feet above the ground). An inversion is present if the temperature near the ground is less than the temperature at the higher altitude. Because inversions tend to be localized, be sure to check conditions at the job site.

Smoke is more practical to detect inversions. Inject oil onto the hot exhaust manifold while flying at a low altitude to release a cloud of smoke. An inversion is present if the smoke levels off and travels laterally instead of rising. It's your responsibility to be aware of an inversion by using a suitable detection technique.

Air stability. Air movement largely determines the distribution of spray droplets. We recognize the importance of lateral air movement, but often overlook vertical air movement.

As the ground warms up throughout the day, the temperature at the ground surface is significantly higher than that above the ground. The warm air rises and may set up convection and thermal air currents that lift small particles. As the air becomes more severely unstable, vertical air currents become stronger and the size of particles that are drift-prone increases.

Because these particles can be carried long distances before they settle out, you should also avoid spraying under these conditions. This, along with generally higher wind velocities, is part of the reason that pesticides are not usually applied in the middle of the day.

Generally speaking, conditions are best for spray deposition when the air is mildly unstable and there is a mild but steady wind. Mildly unstable air is desirable because it prevents the buildup of harmful concentrations of drift-prone particles.

It's undesirable to spray in perfectly calm conditions, because there's no positive displacement of the drift-prone particle cloud. Without positive movement, an aircraft can't avoid flying through the cloud. It's also not possible to know where the drift cloud will go when air movement begins.

Relative humidity. Relative humidity (RH) affects the rate of evaporation of water from liquid drops. The lower the RH, the faster the loss of water and the smaller the drop becomes. The smaller the drop, the slower it falls and the farther it drifts. In addition, rate of evaporation increases with decreasing droplet size; thus, the effect of low RH is most significant when there is a large proportion of small droplets in the spray.

While RH isn't one of the most important factors contributing to drift problems, its importance becomes greater as the size of the droplet spectrum decreases. RH doesn't affect the rate of loss of petroleum- or oil-based liquids. (The evaporation of these liquids varies with temperature and each liquid's vapor pressure.)

You can't control the RH, but you can avoid spraying when it's very low. Also, you can select and operate spray equipment so as to produce few small droplets, and you can use low-volatile solvents and carriers. We will discuss these topics in more detail later.

Application-related factors. In many cases, smaller droplets provide better coverage and are more effective than larger spray droplets. However, the smaller the droplet, the more likely it is to drift.

This is because smaller droplets take longer to settle out and are subject to the effects of wind for a longer period of time.

Droplets that are of most concern are those that are less than 100F (1/254 of an inch) in diameter. These droplets are hardly visible and remain airborne for a significant amount of time. Thus, your goal should be to produce the coarsest spray that will provide an effective treatment and to minimize the total volume of these smaller droplets in particular. Essentially, each application-related factor we'll discuss involves reducing the proportion of small droplets in the spray spectrum (Figure 15).

One way to describe the coarseness of a spectrum of spray droplets is to use the volume median diameter (VMD). This is the diameter for which half of the total spray volume is of droplets larger than the VMD and half is of droplets smaller than the VMD. Generally speaking, the larger the VMD, the smaller the proportion of the small, drift-prone droplets in the droplet spectrum (Table 2).

Table 2. Basic Droplet Guide

Application	**Droplet Size Based on Volume Median Diameter, VMD (F)**
Fungicide	150-250
Insecticide	150-300
Contact herbicide	250-400
Phenoxy and incorporated herbicide	400+

Nozzle spray. Droplet size generally increases and the percentage of small droplets decreases as the size of the nozzle opening increases. For example, with an operating pressure of 50 psi, changing from a D4-45 to a D6-46 nozzle will increase the VMD from about 150 to about 280.

Placement of nozzles on boom. Nozzles must be properly distributed along a boom to account for prop-wash displacement and wing-tip vortices. Correct distribution is important to ensure a uniform dispersal pattern and to prevent drift that may result if too much spray is caught up in the vortices. This topic, including the implications on drift, was covered in the unit "Calibration."

Nozzle orientation. Orientation of nozzles relative to the direction of flight affects the droplet sizes produced by the nozzles (Figure 15). This is attributed to the difference in the relative velocity between the air and spray liquid resulting from various nozzle orientations.

When the nozzle is pointed back (in the same direction as the airflow), the air shear forces that break up the spray are less than at any other orientation. The droplet spectrum produced will be relatively large. A nozzle pointed down will produce a smaller droplet spectrum because of the higher shear forces.

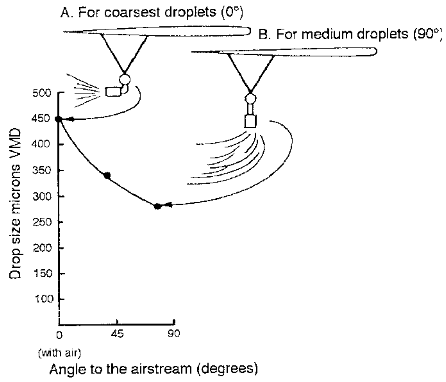


Figure 15. Droplet size is greatly affected by nozzle orientation. More or less shear and liquid break-up may be obtained by varying orientation of nozzles with direction of flight.

The maximum shear forces and smallest droplets would be generated if the nozzle was oriented forward into the airstream. This is normally not done except in situations where extremely fine droplets are desired (for example, applications in forested areas). Also, doing so tends to bathe the aircraft in chemical spray. To give you an idea of how important nozzle orientation is in reducing drift, let's look at some data.

Spray droplets less than 100F in diameter are the droplets that are most likely to drift and thus cause damage outside the target area. When a D6-46 nozzle is oriented straight back under specific conditions to obtain the data, the VMD of the droplet spectrum is 450F, and droplets less than 100F account for 0.2 percent of the total spray volume. If the nozzle is oriented straight down under the same conditions, the VMD becomes 290F, and droplets less than 100F now account for 2 percent of the total spray volume. This is a ten-fold increase in the volume of spray that has the potential to cause damage outside of the treatment area. Obviously, orienting the nozzles straight back is a simple and effective way to greatly reduce drift.

While it helps to know the VMD, it's important to know the total spectrum produced by an atomizer. For example, a D8-46 nozzle, used under specific conditions to obtain the data, produces the same VMD (355F), whether directed straight back or back and down 45 degrees. While that means that at each position, one-half of the total spray volume is in droplets less than 355F, it doesn't mean that the size distribution of those droplets is the same. In fact, a greater proportion of the droplets are less than 100F when the nozzle is oriented back and down 45 degrees. In this case, the result is a four-fold increase (from 0.3 percent to 1.2 percent) in the volume of droplets that are less than 100F.

To further explain the last example, suppose only three droplets were produced when the nozzle was directed straight back: one large droplet, containing 50 percent of the total spray volume, and two equal-sized smaller ones, each containing 25 percent of the total spray volume. Because the small droplets add up to 50 percent of the total volume, the VMD is somewhere between the size of the large and the small droplets.

Now suppose you change the nozzles to back and 45 degrees down, and now the spray consists of seven droplets: one large droplet, the same size as before and still containing 50 percent of the spray volume; one smaller droplet, containing 25 percent of the spray volume and the same size as before; and five even smaller droplets, each containing five percent of the spray volume (the five adding up to 25 percent of the spray volume). The VMD has not changed, but in the latter case there are even smaller droplets, which will be more prone to drift.

This is an oversimplified example, but it illustrates the point that the size distribution of droplets can change markedly, even if the VMD changes only slightly or not at all.

Airspeed. Droplet size decreases as airspeed increases because of the greater wind shear forces acting on the droplets emitted by the atomizer.

Spray height. It's a common misconception that increasing the aircraft spray height will result in a wider swath. Actually, swath width will increase only up to a height of about 15 feet. However, the crosswind effect increases the displacement of the swath as height is increased. Not only must droplets fall farther and thus be exposed to the crosswind longer, but wind velocity tends to increase with height above the crop.

In general, you should use the lowest spraying height consistent with aircraft safety and effective coverage.

Operating pressure. Increasing operating pressure usually reduces droplet size and increases the potential for drift. Thus, you should use the lowest pressure necessary to get the job done properly. However, by using a solid cone nozzle pointed straight back, increasing pressure increases droplet size because it decreases the wind shear on the droplet.

If you need to increase your spray volume significantly, you should use nozzles with larger openings or use more nozzles on the boom, because an increase in pressure doesn't result in a proportional increase in output; you must increase pressure fourfold to increase output twofold.

Formulation. While granules drift less than liquid sprays, they aren't available for many of the applications you make. However, even when you must use a liquid, you can reduce the likelihood of drift by selecting an appropriate formulation or product. Use low-volatile sprays to prevent vaporization; oil-based sprays also reduce the rate of vaporization. (Remember, vaporization increases with increasing temperature and/or decreasing RH.) Vaporized spray will move with air currents and may cause damage outside the target area.

You can also use adjuvants, which act as thickening agents and increase the proportion of large droplets in the spray spectrum. The benefits of using an adjuvant will be largely negated if you don't orient the nozzles back (at worst, back and 45 degrees down) or if you use inappropriate nozzles or excessive operating pressure.

Always check the product label before adding any adjuvants to the spray tank.

THREATENED AND ENDANGERED SPECIES

The Endangered Species Act (ESA) was passed by Congress to protect certain plants and wildlife that are in danger of becoming extinct. This act requires EPA to ensure that these species are protected from pesticides.

Formulation of the Utah Threatened and Endangered Species/Pesticides Plan is a cooperative effort between federal, state, and private agencies and producers/user groups, and is a basis for continuing future efforts to protect threatened and endangered species from pesticides whenever possible. Furthermore, this plan provides agencies direction for management policies, regulations, enforcement and implementation of threatened and endangered species/pesticide strategies.

EPA has therefore launched a major new initiative known as the Endangered Species Labeling Project. The aim is to remove or reduce the threat to threatened and endangered species from pesticide poisoning. EPA has the responsibility to protect wildlife and the environment against hazards posed by pesticides. The ESA is administered by the U.S. Fish and Wildlife Service (FWS) in the U.S. Department of Interior. The Fish and Wildlife Service will determine jeopardy to threatened and endangered species and report to EPA. EPA and FWS will work cooperatively to ensure that there is consistency in their responses to pesticide users and to provide necessary information. The Utah Department of Agriculture is acting under the direction and authority of EPA to carry out the ESA as it relates to the use of pesticides in Utah.

Maps will show the boundaries of all threatened and endangered species habitats in affected counties. The maps identify exactly where, in listed counties, use of active ingredients in certain pesticides is limited or prohibited. Product labels will be updated as necessary. The updated labels will reflect any additions or deletions to the project. Because EPA's approach to the protection of threatened and endangered species was in the proposal phase at the time this guide was published, any and all of the above information on threatened and endangered species is subject to change and may not be valid.

WORKER PROTECTION STANDARDS

This final rule, which was proposed in 1988 and that substantially revised standards first established in 1974, affects 3.9 million people whose jobs involve exposure to agricultural pesticides used on plants; people employed on the nation's farms; and in forests, nurseries and greenhouses. The standard reduces pesticide risks to agricultural workers and pesticide handlers. The standard is enforceable on all pesticides with the Worker Protection Standard labeling. The provisions became fully enforceable in January 1995.

Agricultural workers in Utah now have a far greater opportunity to protect themselves, their families and others. These workers will know, often for the first time, when they are working in the presence of toxic pesticides, understand the nature of the risks these chemicals present, and get basic safety instructions.

Among the provisions of the rule are requirements that employers provide handlers and workers with ample water, soap and towels for washing and decontamination and that emergency transportation be made available in the event of a pesticide poisoning or injury. The rule also establishes restricted-entry intervals -- specific time periods when worker entry is restricted following pesticide application -- and requires personal protection equipment (PPE) for all pesticides used on farms or in forests, greenhouses and nurseries. Some pesticide products already carry restricted re-entry intervals and personal protection equipment requirements; this rule raised the level of protection and requirements for all products.

Other major provisions require that employers inform workers and handlers about pesticide hazards through safety training, which handlers have easy access to pesticide-label safety information, and that a listing of pesticide treatments is centrally located at the agricultural facility. Finally, handlers are prohibited from applying a pesticide in a way that could expose workers or other people.

GROUNDWATER CONTAMINATION BY PESTICIDES

Utah has implemented a comprehensive and coordinated approach to protect groundwater from pesticide contamination.

Formulation of the Groundwater/Pesticide State Management Plan is a cooperative effort between federal, state, and private agencies and producers/user groups; it provides a basis for continuing future efforts to protect groundwater from contamination whenever possible. Furthermore, this plan provides agencies with direction for management policies, regulations, enforcement and implementation of groundwater strategies.

While it's recognized that the responsible and wise use of pesticides can have a positive economic impact, yield a higher quality of crops, enhance outdoor activities, and give relief from annoying pests, the Utah Department of Agriculture is authorized by the U.S. Environmental Protection Agency (EPA) to enforce the protection of groundwater from pesticides. Product labels will be updated as necessary.

The Utah Department of Agriculture, in concert with cooperating agencies and entities, admonishes strict compliance with all pesticide labels, handling procedures and usage to protect groundwater in the state.

Groundwater can be affected by what we do to our land. Prevention of groundwater contamination is important, because once the water is polluted, it's very hard and costly to clean up. In some instances, it's impossible, especially if it's deep underground. City and urban areas especially contribute to pollution because water runoff that contains pesticides runs into drainage tunnels, then into a river or an underground stream that drains into the river. For more complete information about what groundwater is and where it comes from, read the study manual "Applying Pesticides Correctly." Shallow aquifers or water tables are more susceptible to contamination than deeper aquifers. Sandy soils allow more pollution than clay or organic soils, because clays and organic matter absorb many of the contaminants.

The Federal Insecticide, Fungicide and Rodenticide Act (FIFRA), as amended, establishes a policy for determining the acceptability of a pesticide use or the continuation of that use, according to a risk/benefit assessment. As long as benefits outweigh adverse effects, a pesticide can be registered by the EPA. Although the intent of a pesticide application is to apply the pesticide to the target or pest, part of the pesticide will fall on the area around the target or pest. Rain or irrigation water then can pick up the part that isn't degraded or broken down and carry it to the groundwater via leaching.

The major factors that influence the amount of contamination that can get into water are the chemicals' persistence in soil, retention time or time it remains in the soil, the soil type, the time and frequency of the application(s), soil moisture, placement of the pesticide, and the ability of the chemical to persist once in the aquatic environment. Each of these factors will influence the amount of pesticide that can leave the root zone or soil surface and percolate to groundwater.

Although some pesticides may have a high absorption quality, when they are applied to sandy soil, they will still migrate to the water table because there are no fine clay particles or organic matter to hold them. The management and use of pesticides is up to the individual applicator and/or land owner as to whether safe practices are used. Water is one of our most valuable resources; we must keep it as pure as possible.

APPENDIX I

CALIBRATION FORMULAS

This appendix contains material that supplements the information found in the manual. This information isn't covered on your certification exam.

1. acres/swath run = [field length (ft.) X swath width (ft.)] ÷ 43,560
   or
   acres/swath run = [mph X swath width (ft.) X seconds traveled X 1.467] ÷ 43,560

2. acres/minute = mph X swath width (ft.) X 0.00202

3. gallons/acre = [gpm X 495] ÷ [mph X swath width (ft.)]

4. gallons/minute = [gpa X mph X swath width (ft.)] ÷ 495

5. gpm/nozzle = [gpa X mph X swath width (ft.)] ÷ [# of nozzles X 495]

6. length of swath run = mph X seconds traveled X 1.466

7. minutes/acre = 495 ÷ [mph X swath width (ft.)]

8. mph = [gpm X 495] ÷ [gpa X swath width (ft.)]
   or
   mph = [0.682 X distance traveled (ft.)] ÷ seconds

9. swath runs/load = acre load in hopper ÷ acres/swath run
   or
   swath runs/load = number of gallons in hopper ÷ [gpa X acres/swath run]

10. time (minutes)/load = [495 X number of gallons per load] ÷ [gpa X swath width (ft.) X mph]

11. time (minutes)/swath = [60 X length of run (ft.)] ÷ [mph X 5280]
    or
    time (minutes)/swath = [length of run (ft.) X 0.01136] ÷ mph

12. time (seconds)/swath = [60 X 60 X length of run (ft.)] ÷ [mph X 5280]
    or
    time (seconds)/swath = [length of run (ft.) X 0.68182] ÷ mph

CALIBRATION INFORMATION

<u>Conversion:</u>

Units

One acre = 43,560 square feet	Example: ½ acre = 21,780 square feet
One mile = 5,280 feet	Example: ¼ mile = 1320 feet
One gallon = 128 fluid ounces	Example: ½ gallon = 64 fluid ounces
One quart = 2 pints = 4 cups = 32 fluid ounces	Example: 2 quarts = 64 fluid ounces
One pint = 2 cups = 16 fluid ounces	Example: ½ pint = 1 cup = 8 fluid ounces
One tablespoon = 3 teaspoons = 0.5 fluid ounces	Example: 2 tablespoons = 1 fluid ounce
One pound = 16 ounces	Example: ¼ pound = 4 ounces
One gallon = 231 cubic inches	Example: 2 gallons = 462 cubic inches

Weight

1 ounce = 28.35 grams
16 ounces = 1 pound = 453.59 grams
1 gallon water = 8.34 pounds = 3.785 liters = 3.78 kilograms

Liquid Measure

1 fluid ounce = 2 tablespoons = 29.573 milliliters
16 fluid ounces = 1 pint = 0.473 liters
2 pints = 1 quart = 0.946 liters
8 pints = 4 quarts = 1 gallon = 3.785 liters

Length

1 foot = 30.48 centimeters
3 feet = 1 yard = 0.9144 meters
16 1/2 feet = 1 rod = 5.029 meters
5280 feet = 320 rods = 1 mile = 1.6 kilometers

Area

1 square foot = 929.03 square centimeters
9 square feet = 1 square yard = 0.836 square meters
43560 square feet = 160 square rods = 1 acre = 0.405 hectares

Speed

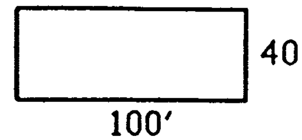
1.466 feet per second = 88 feet per minute = 1 mph = 1.6 kilometers per hour (kph)

Volume

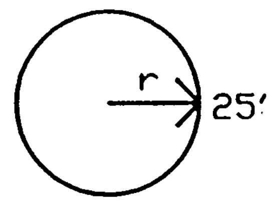
27 cubic feet = 1 cubic yard = 0.765 cubic meters
1 cubic foot = 7.5 gallons = 28.317 cubic decimeters

Area and Volume Calculations:

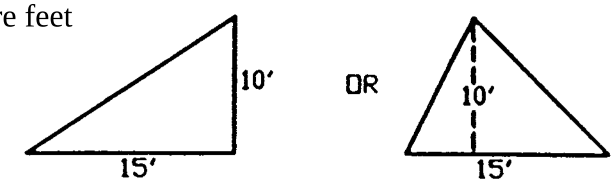
Area of Rectangular or Square Shapes
The area of a rectangle is found by multiplying the length (L) times the width (W).
(Length) x (Width) = Area
Example: (100 feet) x (40 feet) = 4000 square feet



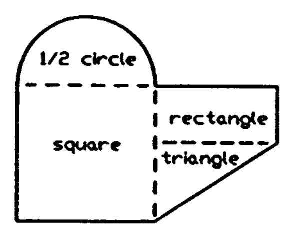
Area of Circles
The area of a circle is the radius (radius = one-half the diameter), times the radius, times 3.14.
(radius) x (radius) x (3.14) = Area
Example: (25 feet) x (25 feet) x (3.14) = 1962.5 square feet



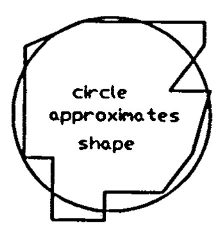
Area of Triangular Shapes
To find the area of a triangle, multiply ½ times the width of the triangle's base, times the height of the triangle.
(½) x (base width) x (height) = Area
Example: (½) x (15 feet) x (10 feet) = 75 square feet



Area of Irregular Shapes
Irregularly shaped sites can often be reduced to a combination of rectangles, circles, and triangles. Calculate the area of each shape and add the values together to obtain the total area.
Example: Calculate the area of the rectangle, triangle, square, and one-half of a circle.

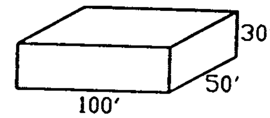


Another method is to convert the site into a circle. From a center point, measure the distance to the edge of the area in 10 or more increments. Average these measurements to find the radius, then calculate the area using the formula for a circle.
Example: Approximate the area by calculating the area of a similarly sized circle.



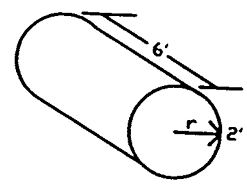
Volume of Cube and Box Shapes
The volume of a cube or box is found by multiplying the length, times the width, times the height.
(Length) x (Width) x (Height) = Volume

Example: (100 feet) x (50 feet) x (30 feet) = 150,000 cubic feet



Volume of Cylindrical Shapes
The volume of a cylinder is found by calculating the area of the round end (see formula for circle) and multiplying this area times the length or height.

Example: (radius) x (radius) x (3.14) = Area of Circle
(Area of Circle) x (Length) = Volume of Cylinder
(2 feet) x (2 feet) x (3.14) x (6 feet) = 75.36 cubic feet



Sprayer Calibration Formulas:

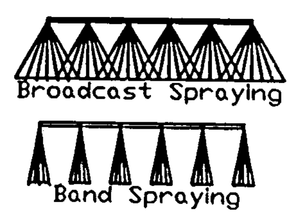
To Calculate Travel Speed in Miles Per Hour
The travel speed of a sprayer is determined by measuring the time (seconds) required to travel a know distance (such as 200 feet). Insert the values in the following formula to determine the miles per hour.

$$\frac{\text{Distance in Feet x 60}}{\text{Time in Seconds x 88}} = \text{Miles Per Hour}$$

Example: $$\frac{\text{(200 feet) x (60)}}{\text{(30 seconds) x (88)}} = \frac{12{,}000}{2640} = \text{4.55 mph}$$

To Calculate the Gallons Per Minute Applied During Broadcast Spraying
The application rate in gallons per minute (GPM) for each nozzle is calculated by multiplying the gallons per acre (GPA), times the miles per hour (MPH), times the nozzle spacing in inches (W); then dividing the answer by 5940. For small adjustments in GPM sprayed, operating pressure is changed. For large adjustments in GPM sprayed, travel speed (miles per hour) is changed or nozzle size is changed.

$$\frac{\text{GPA x MPH x W}}{5940} = \text{GPM}$$



Example: $$\frac{\text{(12 GPA) x (4.5 MPH) x (24")}}{5940} = \frac{1296}{5940} = \text{0.22 GPM}$$

To Calculate the Gallons Per Minute Applied During Band Spraying
Broadcast spraying applies chemicals to the entire area. Band spraying reduces the amount of area and chemicals sprayed per acre. To use the above formulas for band sprayer applications, use the band width (measured in inches) rather than nozzle spacing for the "W" value.

Pesticide Mixing:

Terminology

The ***active ingredients*** of a pesticide are the chemicals in a formulation that control the target pests. The ***formulation*** is the pesticide product as sold, usually a mixture of concentrated active ingredients and an inert material. Restricted use pesticides are purchased in formulations requiring ***dilution prior to application***. Formulations are diluted with inert substances such as water. The ***percentage of active ingredients*** in a pesticide formulation directly affects dilution and application rates. Given two pesticides, A = 50% active ingredients, B = 100% active ingredients; twice as much pesticide A formulation is required to equal pesticide B formulation.

To Determine the Total Amount of Pesticide Formulation Required Per Tank

To calculate the total amount of pesticide formulation needed per spray tank, multiply the recommended dilution, ounces/pints/cups/teaspoons/tablespoons/etc. of pesticide per gallon of liquid, times the total number of gallons to be mixed in the sprayer. A full or partial tank of pesticide spray may be mixed.

(Dilution Per Gallon) x (Number of Gallons Mixed) = Required Amount of Pesticide Formulation Example: (3 ounces per gallon) x (75 gallons) = 225 ounces

Note: 1 gallon = 128 ounces; through unit conversion 225 ounces = 1.76 gallons

To Calculate the Amount of Pesticide Formulation Sprayed Per Acre

The calculate the total amount of pesticide formulation sprayed per acre is determined by multiplying the quantity of formulation (ounces/pounds/pints/cups/teaspoons/tablespoons/etc.) mixed per gallon of water, times the number of gallons sprayed per acre.

(Quantity of Formulation Per Gallon) x (Gallons Sprayed Per Acre) = Formulation Sprayed Per Acre

Example: (1/2 pound per gallon) x (12 gallons per acre) = 6 pounds per acre

To Calculate the Amount of Active Ingredients Sprayed Per Acre

To calculate the total amount of active ingredients (AI) applied per acre, multiply the amount (pounds, gallons, ounces, etc) of pesticide formulation required per acre, times the percentage of active ingredients in the formulation (100%, 75%, 50%, 25%, etc.), and divide the value by 100.

$$\frac{\text{(Amount of Formulation Required Per Acre) x (Percentage of AI)}}{100} = \text{Active Ingredients Per Acre}$$

Example: $$\frac{\text{(4 pounds formulation sprayed per acre) x (75\% AI)}}{100} = \text{3 pounds of AI sprayed per acre}$$

Note: 75 % = 0.75

To Calculate the Gallons of Pesticide Mixture Sprayed Per Acre

The calculate the total amount of pesticide mixture sprayed per acre is determined by dividing the number of gallons sprayed by the number of acres sprayed.

$$\frac{\text{Gallons Sprayed}}{\text{Acres Sprayed}} = \text{Gallons Sprayed Per Acre}$$

Example: $$\frac{\text{200 Gallons Sprayed}}{\text{10 Acres Sprayed}} = \text{20 gallons of pesticide mixture sprayed per acre}$$